TRANSLOCATION MODEL FOR THE ENDANGERED STEPHENS' KANGAROO RAT

(*DIPODOMYS STEPHENSI*)

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Introduction

Stephens' kangaroo rat is one of 19 recognized species of kangaroo rats (genus *Dipodomys*) belonging to the family Heteromyidae. Trapping studies and information from captive animals suggest that they are territorial like other heteromyids (Brock and Kelt 2004a). Research on home range size reports variability in size from 0.05ha to nearly 0.2ha. Males appear to have significantly larger home ranges than females, especially during the breeding season (Kelly and Price 1992). Reproduction typically occurs late spring to early summer, but reproductive timing may depend on weather and food availability (Lackey 1967, Bleich 1977). Of the species of kangaroo rats studied, all have been shown to sandbathe both to maintain pelage condition and for communication (Eisenberg 1963b).

Stephens' kangaroo rat is native to open grasslands and sparse coastal sage scrub in Riverside and San Diego counties, California (U.S.A.). Seed predation and soil disturbance by Stephens' kangaroo rat strongly affect the vertical structure and composition of the plant community (Brown & Heske 1990; Goldingay et al. 1997). They are prey to diverse taxa, including bobcats (*Lynx rufus*), coyotes (*Canis latrans*), rattlesnakes (*Crotalus spp*.), foxes (*Vulpes spp*.), weasles (*Mustela spp*.), and owls (*Tytonidae* and *Strigidae*). Since 1970, habitat fragmentation and loss of habitat to agriculture and suburban development have been the most direct causes of the decline of Stephens' kangaroo rat. In 1971, the California Department of Fish and Wildlife (CDFW) listed Stephens' kangaroo rat as threatened under the California Endangered Species Act because a substantial amount of habitat throughout its range had been lost. In 1988, the U.S. Fish and Wildlife Service classified Stephens' kangaroo rat as endangered under the U.S. Endangered Species Act.

The Recovery plan for the species focused on habitat preservation for recovery of SKR. The SKR HCP conserved approximately 1/2 of the occupied habitat within its plan area boundary. Several additional populations are known to occur outside the plan area boundary in western Riverside and San Diego counties. Thus the HCP allowed approximately half of the occupied lands to be developed as long as the remaining half was placed in reserves and managed for SKR. However, several of the reserves have become overgrown with exotic grasses. For the smaller reserves, this may mean the loss of SKR populations. This research will aid in recovery of the species by designing effective and efficient translocation methods for SKR should the species need to be: 1) moved from areas slated for development or 2) reestablished in areas in which they have become extirpated due to overgrowth of exotic grasses. Further, this research will serve as a model from which translocations can be designed for other imperiled heteromyids in California as well as other solitary rodent species and facilitate restoration of desert, grassland and shrub ecosystems in which they play a critical role. In the broadest sense, these novel hypothesis-driven methods may be adapted for any species possessing similar social and ecological traits (i.e., most solitary mammals).

Prior to this program, translocations of kangaroo rats were ineffective. Although many translocations were conducted with several species of kangaroo rats (e.g., Williams et al. 1993; O'Farrell 1994, 1999; Montgomery 1997, 2004; Spencer 2003; Davenport 2007; Germano 2010), there were no documented cases in which a kangaroo rat translocation has successfully established a viable population that persisted over the long term. For example, a translocation of 599 Stephens' kangaroo rats in 1992 yielded no surviving animals 11 months following release (O'Farrell 1994). Survival following a translocation of the species in 2002 was estimated at 40% 4 months after release (Spencer 2003), and no individuals from the release group persisted at the release site 1 year after release.

The primary goal of this program was to use basic science to develop an efficient and reliable translocation strategy for SKR. This research began in 2008 and included 6 translocations of a total of 449 SKR.

Application of Behavioral Ecology to Improve Translocation Outcomes

Translocation is the intentional capture and transfer of wild animals or populations from one part of their historic range to another. Translocations are used to establish, re-establish or augment a wild population to increase the viability of a species or to supplement game populations. They are also used to as a control measure to remove nuisance animals from areas where they are causing damage, and thus alleviate human-animal conflict. Most translocation research has focused on mammals and birds, but translocations have also been conducted with fish, amphibians, reptiles and invertebrates. Though translocation has become an increasingly popular conservation tool, most translocations fail to produce sustainable populations and involve risks such as disease transmission. This has led to an increased interest in determining the factors that influence the success of translocations and to design methodology to minimize transmission of disease.

Post-translocation mortality is highest in the first days to weeks following release as animals make settlement decisions and modify the release-site habitat to accommodate their needs. Problems associated with this initial establishment phase include: 1) post-release dispersal (i.e. long-distance movement away from the release site), 2) predation, 3) stress response to the novel environment, 4) difficulty finding food, and/or 5) competition for resources (e.g. territories) with fellow releasees or conspecifics residents.

Among the proposed explanations for the high mortality during the establishment phase, post-release dispersal and predation are thought to be important factors. Immediate rejection of a release site indicated by post-release dispersal has been documented in many species. In some cases, translocated animals travel all the way back to their natal habitat (i.e. "homing"). Long distance movement and, for many species, the required habitat modifications (e.g. digging burrows) leave translocated animals particularly vulnerable to predators immediately after release.

Post-release dispersal may initially be high for a variety of reasons. From an ecological perspective, animals may leave release sites because the habitat at the site is unsuitable or of low quality. While from a behavioral ecological perspective translocated individuals may leave because they are site faithful, are not familiar with the physical characteristics of the release site or with the individuals with whom they were released, or because they are at a disadvantage when competing for resources with residents. Biologists studying translocations are beginning to understand these problems and modify translocation methodology to address these issues. For example, to dampen post-release dispersal and decrease stress, the IUCN recommendation is to select release sites with high quality habitat (IUCN 2012). Further, biologists have used “soft” release techniques, where the animals are provided with some form of support during the release (e.g. a period of time in an enclosure on the release site and/or supplemental food is provided after release)(Bright and Morris 1994, Biggins et al. 1999). Compared with hard-releases (e.g. direct release without an acclimation period), soft-releases are generally thought to enhance the likelihood of translocation success in small mammals, via increasing site fidelity and post-release survival. However, there are some species that exhibit distress behaviors when held in captivity or their habitat requirements are such that holding them in a soft-release cage may have a negative effect on their survival, for these species, hard releases are the best option.

Newly translocated animals may also leave the release site because there are no resident conspecifics which may indicate that the habitat is unsuitable. For example, Black rhino move less during the first 5 days after release if cues that indicate conspecific presence (i.e. dung) are broadcast at the release site (Linklater and Swaisgood 2008).

Alternatively or in addition, founder group composition may influence translocation success. Group size, age and sex class ratios, and familiarity between founder group members have all been shown to affect survival post-release. While there is a positive relationship between the size of the founder group and survival across taxa, suggested age and sex class ratios may vary by mating system. For example, Black bear (*Ursus americanus*) are polygynous. Males have large home ranges that overlap with as many as 9 females. Thus, suggested translocation schedules include a release of males prior to release of females to allow males time to establish breeding territories into which females can settle (Miller and Ballard 1982, Huber 2010).

Composing founder groups of intact social groups has been shown to have a significant influence on translocation success. For Black-tailed prairie dogs, (*Cynomys ludovicianus*) founder groups composed of intact families were more successful in terms of post-release survival, reproductive success (Shier 2006) and population viability. Maintaining family unity appears to reduce the effects of successful predation on prairie dogs and dampen post-release dispersal. Results from this research suggest that any species dependent upon social interactions for survival and reproduction may benefit substantially from the maintenance of social groups during translocations. Species for which social interactions enhance individual fitness would be especially likely to benefit from the maintenance of social groups during translocation. Those species include species with kin-selected behaviors (e.g. Belding ground squirrels, *Urocitellus beldingi*, alarm calls), those that rely on reciprocity (e.g. allogrooming, helping at a communal nest) and those that receive direct benefits from relationships with group members (e.g. coalition formation, social foraging, sexually selected cooperation, social learning, enhancement of immune function, and reduced disease transmission and stress).

Predation is a significant impediment to translocation success (Kleiman 1989, Beck et al. 1994). The effects of predation are especially prevalent during the establishment phase. Most attempts to minimize predation on newly translocated animals have involved monitoring of release sites post-release and predator removal.

In our program, we have studied the ways in which behavioral ecology can improve translocation success with Stephens' kangaroo rat. Through these efforts, we have learned how to successfully translocate this species. While additional improvements to the translocation methodology described here are possible, this report provides a synthesis of the best practices developed to date.

Release Site Selection

Climate Change and Historic Range

The first step in selecting a release site for SKR is to restrict the search to sites within the species historic range. While, this limitation may have to be reevaluated should climate change affect the ability of SKR to continue to persist in these areas, currently, there is no evidence that this is an issue.

Habitat suitability

The next step is to find habitat that matches the species habitat preferences. Ideal release sites for SKR include areas with pristine open native grassland habitat combined with sparse forbs and/or sparse coastal sage and iron-rich friable sandy loam soils (USFWS 1997). However, the type of habitat the species can survive and thrive in when they are established may be different than what the animal requires following translocation. As a prey species, two of the biggest impediments to SKR translocation success are dispersal and predation. The first days to weeks following release show the highest morality rates while animals are making settlement decisions and establishing burrows as refuges. During this period, habitat that provides shelter and promotes burrow establishment is critical (Shier 2006, Moorhouse et al. 2009).

High quality soils are likely most important for early establishment following translocation as newly released kangaroo rats are at a greater risk of predation until new burrow systems are in place. While the animals may be able to expand into less suitable (e.g. compacted) soils once established, the additional time required to dig a burrow into compacted soil may be the difference between life and death. Similarly, while established SKR can thrive in open grassland sites with no cover (pers. obs.), release sites that have a low density of forb and/or shrub cover may provide necessary shelter to facilitate early settlement. I have not studied this directly, however, newly released SKR put their burrows under shrubs if they are available on the release site onto which they are translocated (Shier, unpublished data). Finally, sites need to be selected away from raptor perching locations, for example, old fence lines, power poles, trees, site markers, etc. If these features are present on the site, they should be removed or the release location sighted at least 200m away to reduce the effects of predation by raptorial predators post release.

Sites that contain nonnative vegetation but appropriate soils can be managed to create suitable release habitat for SKR. See section below on Release Site Preparation – Habitat Manipulation

Anthropogenic Influences

It is important to consider anthropogenic influences when selecting a release site. Most obviously, humans may impact SKR during holding in acclimation cages and after release if they expand into areas where there is a potential for persecution. If releases need to be conducted into a site in which human traffic is expected, signage and/or public education may be required. Best practices dictate that translocations be planned into areas where the target species can persist without impacts in the foreseeable future (IUCN 2012).

Other factors that may influence release site selection are the presence of night lighting and roads in and around release habitat. We found that artificial night lighting significantly reduces SKR foraging up to 35 m from the light source (Shier, Bird and Wang, in prep), likely because the additional light in the night environment makes SKR more conspicuous to predators. While we have yet to study the effect of lighting on fitness, in the interim, I recommend that release sites be sighted away from sources of artificial light. Roads are a known source of direct mortality through vehicle strikes for SKR, especially if traffic moves quickly (>25mph) along roads at night (pers. obs.). In addition, gravel roads may act as movement barrier for SKR (Brock and Kelt 2004b). Another negative impact of locating a release site near a road is through indirect impacts on the species communication system. SKR footdrum to communicate with conspecifics (Shier et al. 2012). SKR footdrumming signals are masked by road noise (Shier et al. 2012). Thus, another important constraint on release site placement is to select a site away from any road constructed of gravel or paved and any dirt road on which traffic flows at >25mph at night.

Unfortunately, it is seldom the case that pristine habitat is available for establishment of a translocated population of SKR. Pristine sites are rare and often already occupied by resident SKR. Because SKR is territorial and once settled, individuals typically maintain their territories for life, if the site is already occupied by SKR residents, the releasees will have to compete with residents for resources which may negatively affect release success. Thus, I recommend that only release sites with low numbers of SKR or no SKR are used. Though to date, I have not studied the impact of releasing SKR into a release sites with a medium to high density of SKR residents, this recommendation follows the IUCN reintroduction guidelines (IUCN 2012).

Most often, management translocations of SKR are necessary as part of a mitigation measure to reduce impacts associated with a development project. Under this scenario, the source of the animals to be translocated is predetermined. However, current regulations limit where those animals can be moved and thus possible release sites. A study on SKR genetics suggested that the mitochondrial genetic variation across the species range demonstrated subpopulation structuring, indicating the presence of three geographic subregions (north, mid and south ranges; Metcalf et al. 2001). Thus to maintain the integrity of this possible subpopulation structuring, translocations are currently limited to those in which source and release sites are within the same subregion (U.S.F.W.S. 2010). Because this study was based on small sample sizes and grouping of samples from multiple locations it is considered preliminary. A more robust range-wide genetics study was recently completed which has clarified the species landscape genetics and determined the degree of connectivity that remains (Shier and Navarro 2016). This study has shown that historically, there was no geographic genetic structuring across the SKR range. However, a recent loss of connectivity across the range due to contemporary urbanization may have driven the genetic structuring that is currently present between populations. This study recommends restoring historic gene flow through translocations or the establishment of habitat corridors (Shier and Navarro 2016). Further analysis is needed to determine which extant SKR populations to target.

Release Site Preparation

Habitat Manipulations

SKR is native to sparse coastal sage scrub and open grassland habitat with vegetation covering less than 50% of the ground and its burrows are found in bare substrate with little to no cover. If the site selected for the release matches this description, no initial habitat management is required. However, non-native European grasses and/or forbs are found throughout SKR reserves and preserves and if the release site is dominated by non-native plant species, these must be managed prior to setting up the release site to receive translocated SKR. The herbaceous cover of these introduced grasses and forbs often creates an impenetrable thicket to small ground-dwelling vertebrates. To control these grasses and restore native ecosystems, managers and researchers have used controlled burns, grazing by ungulates, herbicide application, soil disturbance and/or mowing (Kenagy 1985, Kelt et al. 2005). The costs and benefits of these techniques for reserve management in general and for SKR recovery vary by situation and site. Some studies have shown that grazing is beneficial for decreasing dense cover (Germano et al. 2001), while others indicate that impacts of grazing are complex (Fehmi et al. 2005, Cox and Allen 2008) and grazing favors certain plant traits and thus may differentially affect native and nonnative species (Kimball and Schiffman 2003, Middleton et al. 2006) while reducing the nutrient content of the grasses long term. Kimball and Schiffman found that grazing negatively affected native species growth while alien species were unaffected and suggest that because European species have been exposed to grazing for centuries, these invaders may have adaptations that better enable them to recover from grazing.

Short term research indicates that SKR densities increase in sites treated with mowing and grazing (Kelt et al. 2005). Burning is favored by some small mammal experts (W. Spencer, pers. comm.) and is thought to effectively open the habitat without destroying the seed bank.

In 2010 we conducted a large-scale field experiment to determine if the type of site preparation influences SKR translocation success. We compared the effects of sheep grazing, prescribed burning, and mowing with and without subsequent restoration on the vegetation and the settlement and survival of translocated SKR. Our results indicate that translocated SKR prefer to settle in sites prepared with prescribed burning and show higher survival, reproductive success and recruitment in these sites over those in which non-native grasses and forbs were reduced via grazing or mowing (Shier 2010, 2011). Fire is a natural ecological process in California and the species that evolved here are adapted for living in areas with fire. Thus, it is not surprising that SKR thrive in areas that have been treated with fire. Our results indicate that the beneficial effects of the prescribed burns on our research plots were extended well beyond those of grazing or mowing (Shier 2010, 2011, Shier and Swartz 2012). Thus, while SKR may persist and thrive in sites managed with grazing or mowing, these sites will require more frequent management compared to fire in order to maintain the same percentage of open ground.

Release Site Boundary

In my experience, SKR release sites that have a boundary to dispersal have higher translocation success. Our translocations that had been manipulated within a boundary of nonnative grass showed higher site retention than translocations that were opened well beyond the bounds of the release area. For example, in 2008, prior to our translocation, the release site was weed whacked to remove ground cover associated with nonnatives. This left a nonnative grass barrier around the site. Post-release trapping and telemetry data revealed that translocated SKR only left the site via dirt trails that lead to the site. We had similar results from our 2009 release. In 2010, we prepared the sites with various management methods (mowing, grazing, prescribed burning) but also left the boundary of nonnative grasses intact and within 20 meters of the perimeter to our acclimation cages. The results from 2010 follow those from 2008 and 2009 in which SKR were mostly contained within release sites via vegetation boundaries and this served to restrict dispersal off of the release sites which facilitated settlement. By contrast, in 2011, we had CalFire conduct a prescribed burn on 42 acres in Bachelor Mountain. We located our 4 release sites within the footprint of the burn. Because we did not leave a grass boundary, SKR moved significantly farther from release locations before settlement and lower numbers of SKR have persisted on these sites. Another method of creating a boundary would be to install a fence around the perimeter of the release site leaving some room for expansion. Steve Montgomery has used this method with success on his release of SKR at Camp Pendleton. Thus, a boundary (either natural or artificial) to dispersal appears beneficial to prevent spread away from release locations and will likely enhance settlement on site and release success.

Methods to Dampen Predation

As a prey species, SKR is extremely vulnerable immediately following release. Thus, methods to reduce predation pressure during post-release establishment are important. Standard practices include predator removal and/or fencing to keep predators off of release sites. However, neither of these methods is consistently effective and if predators get onto release sites, many releasees will be killed. For example, in translocations with the black-tailed prairie dog, releases that incurred badger predation in the first days to weeks following release failed (Long et al. 2006); Shier, unpublished data).

Two of the primary predators of SKR that are especially problematic on release sites are coyotes (*Canis latrans*) and Barn owls (*Tyto alba*). Both of these predators are medium sized, “mesopredators” (middle of the ecological food web) that arrive on release sites immediately. Evidence from our translocations indicates that coyotes dig out acclimation cages and prey on SKR during holding and visit release sites for months. In addition, data from our 2008 and 2009 translocations show that 56% of mortalities in the first 4 weeks were depredation from Barn owls. Thus, any successful translocation program for SKR will attempt to minimize predation by these species.

Mounting evidence suggests that apex predators (i.e. predators at the top of the food web) can benefit prey populations indirectly by suppressing smaller mesopredators, failure to consider this common interaction has caused some conservation efforts to backfire (Rayner et al. 2007) and has even triggered collapses of entire ecosystems (Jones and Nowell 1974, Hurst and Beynon 2004).

Coyotes are mammals that use scent to locate and identify predator presence. Mountain lions (*Puma concolor*) are have been shown to opportunistically prey on coyotes and compete with them for forage (Hurst 1987). Thus, we proposed to systematically place mountain lion scent throughout a release site to determine if cougar scent would significantly reduce predation by coyotes and other medium sized mammalian predators. Our results indicate that survival of SKR released onto sites with cougar urine was higher than the survival of SKR that were released onto sites without cougar urine. The causal mechanism that explains this result has not yet been identified. Cougar urine did not dampen large mesopredator (i.e. bobcats, coyotes) visitation rates, yet the presence of smaller mesopredators such as skunks (*Mephitis*

mephitis), weasles (*Mustela spp.*) and foxes (*Urocyon cinereoargenteus*) and (*Vulpes vulpes*) on the release sites was reduced. Research is needed to understand the magnitude of predation pressure on SKR by smaller mesopredators to determine if they are affecting translocation success. A diet analysis of small mesopredators using stable isotopes and scat analysis may elucidate the degree to which they depredate SKR. An alternative explanation for the positive effect of cougar urine on SKR post-release survival may come from sensory ecology. It is possible that SKR may be masking their scent with cougar urine obscuring detection by mesopredators. Evidence to support this hypothesis comes from burrow establishment data. Significantly more first burrows dug by newly released SKR were placed in locations scented with cougar urine compared to those scented with water. While additional research is needed to understand the mechanism, if SKR are to be released onto sites with mesopredators, our research shows that placing cougar urine on the release sites will improve translocation outcomes.

Keeping Barn owls off our release sites has proven a more challenging goal. Barn owls are depredated by Great Horned Owls (*Bubo virginianus*) and compete with them for prey (Hurst 1989). Thus, barn owls are known to avoid areas with resident Great horned owls. Bird models or broadcast playbacks are often used to reduce the presence of nuisance birds (Kavaliers et al. 2005). In 2009, we conducted a pilot experiment to determine if playbacks of Great horned owl calls following a translocation of SKR could reduce barn owl visitation on the release site. Preliminary results were promising and indicated that barn owls may avoid areas in which Great horned owls are calling. Therefore, we conducted a large scale experiment at Bachelor Mountain during which we played back either Great horned owl calls or control calls onto 4 release sites to determine if we could reduce or eliminate Barn owl visitation from our release sites. For this experiment, we used calls from a nocturnal non-predatory bird, the Common poorwill (*Phalaenoptilus nuttallii*) for our control. Our data showed that Great-horned owl playbacks did in fact reduce Barn owl visitation, however, it did not influence post-release survival of SKR. Resident Great-horned owls were drawn into release sites on which Great horned owl calls were played. Thus, any dampening of barn owl visitation may have been countered by an increased presence of Great-horned owls. Barn owls are typically found in larger numbers than Great horned owls and because kangaroo rats likely make up a large portion of their diet, keeping them off of kangaroo rat release sites will be important for success. Results from our research have not yet determined an effective method for doing this.

Founder Group Size and Composition

In general, assuming enough available high quality habitat with little to no resident conspecifics, the larger the release group is, the higher the probability of survival. For rodents, research has shown that release groups of greater than 100 individuals fair better than those with fewer animals (e.g. prairie dogs; Robinette et al. 1995). However, prairie dogs are a highly social species and may require more social support during release. Despite being a species that lives alone in burrows, SKR, like other kangaroo rat species are is territorial and once settled, individually typically stay in the same burrow system for the duration of their life. SKR residents know their neighbors and may preferentially mate with neighbors as opposed to strangers. Because they are not social, I posited that a translocation of a minimum of 50 kangaroo rats could be successful. We have had great success with releases of 50 individuals (Shier 2009, 2010, 2011, Shier and Swartz 2012, Shier 2013), but as with social rodents, larger releases are likely to do better. I have not investigated this question directly. If a mitigation release is required and the number of kangaroo rats to be moved is below 50, success may still be achieved if more intensive post-release management is used (see below).

In our research, we have attempted to move an equal ratio of males to females. However, because translocation often requires taking whatever individuals are present at a source site, often the founder group will be composed of individuals that constitute an unequal sex ratio. Because females are the limiting sex, it follows that a male-biased release would not be as successful in terms of reproductive success as a female-biased release. I have not investigated this question directly.

We know little about how reliant species like SKR are on social interactions, but our research on the effect of familiarity on release success in SKR demonstrates that founder groups composed of known neighbor groups are wildly more successful than groups of unfamiliar kangaroo rats (Shier and Swaisgood 2012). SKR released in neighbor groups spend more time digging burrows and foraging and less time fighting when compared to SKR released without neighbors (Shier and Swaisgood 2012). Further, SKR released in neighbor groups produced 17 times more offspring compared to SKR released in without neighbors and were more likely to settle on the release site (Shier and Swaisgood 2012). These results indicate that this simple technique can be the difference in success or failure of a release and the establishment of a viable population of kangaroo rats at the release site.

Release Timing

The ideal time of year to translocation SKR is in the early fall. I arrived at this decision based on several criteria. First, one wants to avoid the height of the reproductive period (February-June), if possible. During this period, females are not in prime condition as reproduction is highly energetically expensive and they may have dependent young in the burrow. Second, it is important to avoid periods of extreme temperatures and periods of precipitation. Because kangaroo rats are held in acclimation cages for 7-10 days, they are unable to thermoregulate in a natural burrow system, thus, any extreme temperatures or rain may kill animals in holding. Throughout the range of SKR, daytime temperatures rise in the late spring and throughout the summer and can easily exceed 37.78°C (100°F). We examined the temperature range within acclimation cage burrows over 2, 24 hour periods in early September of 2008. We found when the maximum external temperatures were 40-40.6°C (104-105°F), the maximum acclimation cage temperature was 14°F lower or 32.2-32.7°C (90-91°F). While we have not examined the temperature in natural SKR burrow chambers, SKR are known to burrow 18 to 30 inches below ground and plug their burrows. This structure and use of burrows likely buffers the rats from extreme temperatures. The standard temperature range for captive kangaroo rats is 18.3-26.7°C (65-80°F), thus the temperature cutoff that we use during holding in acclimation cages is no higher than 35°C (95°F). In addition, precipitation can be problematic if SKR are being held in acclimation cages as water can travel down artificial burrows and fill the nest chamber. Thus, it is important to ensure that SKR are not being held during a period of medium to heavy rainfall. If a fall release is not an option, late spring/summer can be used. However, pregnant and lactating females should be avoided. Finally, SKR, like other kangaroo rats, are more conspicuous to predators during a full moon. Thus, if possible, I recommend, planning the release date to avoid the 3-4 days approaching, during and following a full moon.

Translocation Methods

Site Preparation

To limit dispersal and allow kangaroo rats to acclimate to the new site, we recommend a soft-release protocol. Because SKR is solitary, we prepare our sites for "soft release" by installing one acclimation cage for each animal. Acclimation cages are set 10m apart typically in a grid design but any formation which allows releasees to come into contact with each other would be suitable. Acclimation cages consist of an underground wire nest box (15.2cm x 15.2 cm x 7.6cm) set 30.5cm -38.1cm underground, two corrugated plastic tubes (5 cm diameter drainpipe with regularly spaced holes for drainage; See Appendix A for discussion of artificial burrow materials), which connect the nest box to the surface, and an above-ground retention cage (30cm x 61cm x 30 cm). This design allows movement of kangaroo rats between the nest box and the above-ground retention cage, but precludes escape during the acclimation period (Long et al. 2006; Figure 1). We place a ½ cup finch seed mix and some natural bedding material (e.g. Carefresh) into below ground nest chamber and cover the top of the chamber with a piece of cardboard prior to filling the hole in with dirt. The cardboard prevents the cage from filling with dirt. We will the above-ground acclimation cage with approximately 2-3 inches of soil for 2 reasons. First, if it rains while SKR are in the acclimation cages, water will not run down the artificial burrow if it is raised above ground level. Second, extra soil in the above-ground cage can be used by the kangaroo rat to plug the artificial burrow. If harvester ants (*Pogonomyrmex rugosus)* are in the vicinity of the acclimation cage, a landscape divider is set to surround the acclimation cage and burrow and an insect adhesive (e.g. Tanglefoot) along the seam (Figure 2). This prevents the ants from getting into the acclimation cage and collecting the seed used to supplement the kangaroo rat. When acclimation cages are set in place, we cover the top entrances to the artificial burrows with duct tape to prevent animals from moving into acclimation cages prior to translocating an SKR into them.

The site is surrounded with a battery- powered electric-tape fence to deter predation attempts by coyotes during the period in which SKR are held in acclimation cages.

Figure 1. Acclimation system

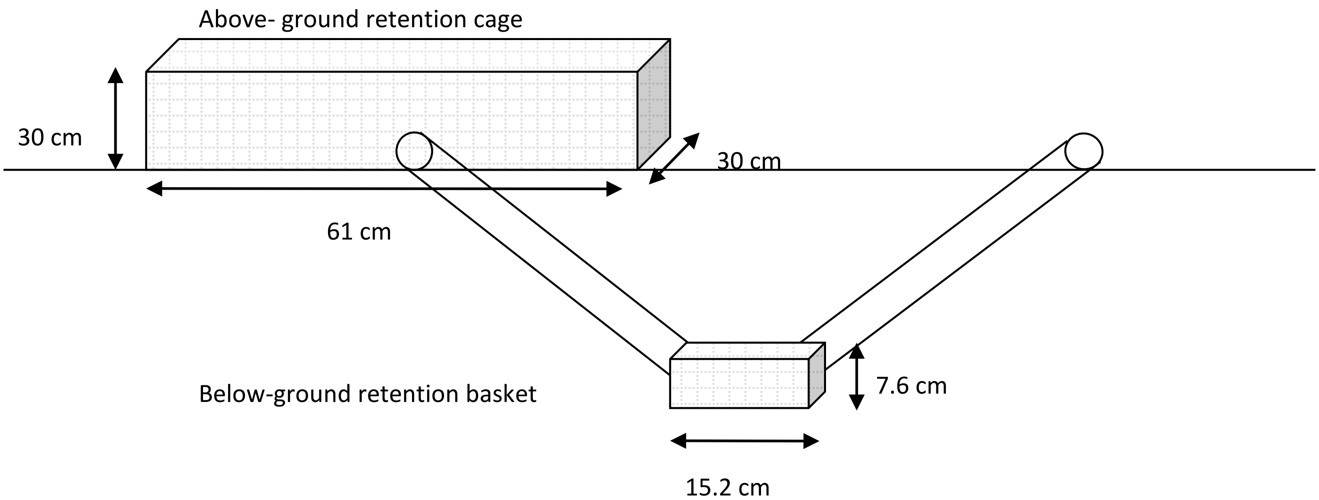


Figure 2. Acclimation cage with Landscape Divider

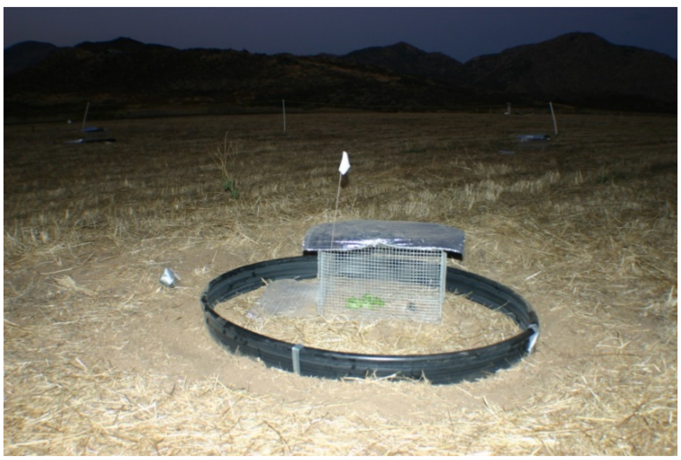
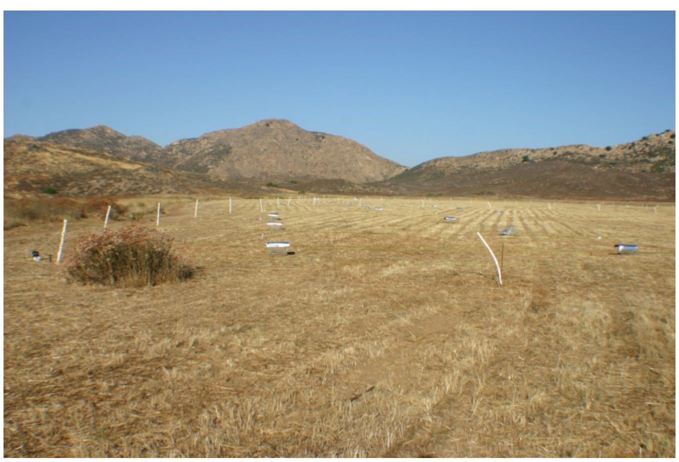


Figure 3. Release site setup



Capture and Holding Animals for Release

We assess home range and burrow ownership by trapping, sexing, aging, marking, releasing, and then observing interactions of kangaroo rats in source population(s). Just prior to translocation, all animals from neighbor groups are captured. Another less time intensive way to capture neighbor groups without conducting mark, observation, recapture is to trap heavily in a small core area keeping track of where animals are captured and the relationship of those captures on the landscape. While this method will not ensure that animals are all neighbors, it is likely that most of the animals trapped will be familiar with one another.

Upon capture, we temporarily hold animals in a quiet temperature controlled facility (60-78°F) until we capture the necessary number of animals and weather conditions are suitable for release (i.e. no precipitation and overnight temperatures are above 40°F most nights). The facility has dimed natural light or is maintained on a 12:12 light:dark cycle so SKR natural circadian rhythms are maintained. Upon capture, animals are checked for physical condition (e.g. pelage condition and ectoparasites), dusted with commercial flea power if necessary (Sikes et al. 2011) and transferred to a plastic holding cage. The plastic holding cage is similar to a large critter keeper (approximately 37 x 23 x 25 cm) with a slotted secure lid. We place 5cm of dirt/sand from the area trapped into the bottom of the holding cage. Once the dirt is in, we slide a glass nesting jar ¼ filled with bedding material (e.g. Carefresh) inside of a 15cm long PVC sleeve with a cardboard covering one end and place it into the holding cage along with a 12 cm section of the same drainpipe material used for construction of artificial burrows for the acclimation cages (see above). This both serves as a burrow entrance and familiarizes the kangaroo rats to the artificial burrows that are used in the acclimation cages. This familiarization reduces the amount of time that SKR takes to go down into the artificial burrow of the acclimation cages once they are placed inside. One-quarter cup of finch seed mix (e.g. Golden Millet, Canary Seed, Rape Seed, Flax Seed, and Oat Groats) and a small piece of romaine lettuce are provided immediately. We place holding cages on racks in the holding facility such that all cages are easily accessible and in view for observation. During holding, ¼ cup of finch seed mix (raw oats/white millet) is provided daily and a small piece of lettuce is provided every other day.

Release to New Site

Once all of the animals needed for the translocation are captured, they are transported to acclimation-cages at the release site. We place each animal in a separate acclimation-cage for 1 week. We feed animals in acclimation cages daily with ¼ cup of finch mix and a small piece of lettuce. Kangaroo rats can be checked on during this period by checking to see if seed and lettuce have been taken from the previous night and/or if there is movement of soil within the acclimation cage. At the end of the acclimation period, the above-ground portion of the acclimation-cages is removed. We attempt to minimize predation by driving by and chasing potential predators off the release site at least three times per week for the first month following release.

Post-release Monitoring

Assessments of short term survival provide a snap shot in time but without multiple data points, release population trends cannot be assessed. I recommend a post-release monitoring period of 5 years to determine release success and population viability of the release population. What fitness metrics should be used to assess release success?

The typical fitness metric used to assess release success is survival. However, for small rodents, such as SKR, lifespan is relatively short. Thus, reproductive success of translocated founders is a more informative metric as reproduction at the release site is indicative of settlement. SKR born at the release site will be less likely to disperse from the site compared to founders.

We conduct 3 different types of assessments to determine release success: behavioral observations, trapping, and radiotracking. All three assessments provide different information.

Behavioral Observations

We conduct behavioral observations on focal acclimation cages or radio tracked individuals in the 2-4 weeks immediately following release. This data provides information on how individuals interact with conspecifics, heterospecifics and the environment at the release site and whether there are any immediate threats that may cause failure of the translocation (e.g. immediate dispersal from the release site, fighting among SKR or with competitors, harvester ants, depredation by coyotes or barn owls, high density of tarantula [*Aphonopelma spp*.] etc.).

Trapping

If possible, we conduct 5 nights of trapping at 1,3,6 and 12 months post release and annually thereafter. This trapping allows for the documentation of both survival and reproductive success by generation for the first 6 months. A reduced trapping schedule of 1 month, 1 year and annual assessments will also provide trend data, but will not elucidate short term trends during the settlement/establishment phase following release.

Radiotracking

Radio telemetry can provide more detailed information about the establishment period than the other monitoring methods. VHS tracking yields data on post-release movements which guide settlement decisions. We conducted radio telemetry following 3 translocations. We learned the degree of barn owl predation in the first weeks following release and that the speed of settlement directly affects survival.

Though telemetry can provide important data following release, the question of whether placing radio transmitters on SKR during a translocation might have a negative influence on release success. We studied this during our 2010 translocation to Crown Valley and found that while SKR with radio transmitters had significantly higher stress hormones (Cortisol) while held in acclimation, there was no affect (negative or positive) of wearing transmitters on survival following release (Shier and Baker, in prep). These results indicate that in translocations of SKR where telemetry would provide necessary information, there are no negative fitness consequences of conducting telemetry studies during translocation.

With sufficient funding, newer technologies have been developed that could be used to gather similar information without the added stress to the animal. For example, a passive tracking system can be designed for release sites which would provide data on animal movements without the labor involved in tracking. Passive tracking devices smaller than a grain of rice can be injected into each kangaroo rat and readers can be placed throughout the site (e.g. at bait stations or on burrow entrances) that record when an animal moves through that reader.

Release Site maintenance Post-translocation

For SKR, translocation success and long term population viability is directly linked to post-release site maintenance. Even on reserves, SKR habitat exists in a matrix of ownerships and usages. Ongoing management of non-native grasses and forbs to maintain open ground will be required. Thus, site management must be maintained following release or the SKR that were translocated into the site and/or their progeny will be extirpated.

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Appendix A

We have primarily used plastic corrugated piping for the artificial burrows associates with acclimation cages. However, in an effort to move towards more biodegradable materials, we tested the effectiveness of artificial burrows constructed of plastic corrugated pipes compared those built from cardboard mailing tubes. Plastic corrugated drain piping is flexible and easy to attach to below ground cages. We write the plastic drain piping to the below ground cages to prevent coyotes from pulling the artificial burrows out. To use cardboard mailing tubes, we placed glue inside the tub and poured sand through the tubes to give the SKR traction inside the tube. The cardboard tube was more difficult to keep in place and attached to the below ground basket. SKR used both types of burrows regularly. However, there were 2 issues with the cardboard tubes. A substantial amount of fog and a small amount of precipitation while SKR were in the acclimation cages. This was enough to moisten the cardboard tubes and some SKR self- released from the acclimation cages. In addition, some of the cardboard tubes but none of the corrugated pipe burrows were pulled out by coyotes. Nevertheless, my preference for artificial burrows is to use cardboard mailing tubes with some modifications. First, we cut and attached a small section 4-6 inches of the plastic drain piping to each end of the cardboard tube. This allows us to wire the tube to the below ground basket and make the 30° angle that is necessary for SKR to easily enter and exit the below ground portion of the cages. The top portion is beneficial because the SKR recognize it as a burrow entrance from their time in captivity. Second, we ensure that we dig the cardboard tubes down into the soil so that the top of the cardboard is below the surface of the ground and the 4-6 section of plastic drainpipe comes up into and is wired to the above ground cage. This prevents the cardboard from getting moist and the animals from self-releasing and keeps the above ground cage secured to the artificial burrow.