RESTORATION OF TIPTON KANGAROO RATS AT KERN NATIONAL WILDLIFE REFUGE

FINAL REPORT
PREPARED FOR THE U.S. BUREAU OF RECLAMATION
SOUTH-CENTRAL CALIFORNIA AREA OFFICE
AGREEMENT NO. R11AP20501

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March 26, 2012

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EXECUTIVE SUMMARY

In August 2010, 80 endangered Tipton kangaroo rats (*Dipodomys nitratoides nitratoides*; TKR) were translocated to the Kern National Wildlife Refuge, Kern County, California, in an effort to establish a new population. Habitat conditions at the selected introduction site appeared suitable for TKR, and no TKR and only low numbers of Heermann's kangaroo rats (*D. heermanni*: HKR) were captured. Prior to translocation, 4 release areas were identified; 2 in areas with shrubs and 2 in areas without shrubs. Within the release areas, clusters of artificial burrows were created, and wire-mesh cages were installed over approximately half of these. TKR (61 males, 19 females) were moved from a site approximately 90 km southeast near the city of Lamont. Forty males were fitted with radio collars prior to release to monitor survival and movements. Translocated TKR were placed in individual burrows and provided with food and bedding material. Individuals placed in burrows without cages ("hard release") were free to leave the burrows the evening of release. Individuals in cages ("soft release") remained confined for 7-12 days to provide an acclimation period. Among collared TKR, the longest any were known to survive was 16 days, although some may have survived longer. Mortality sources included predation by snakes and raptors, interspecific competition from larger HKR, stress, and possible impacts of radio collars. Survival and predation rates were similar for caged and uncaged animals, and also for animals in areas with and without shrubs. Ten uncollared TKR were recaptured approximately 1 month after release, but no collared TKR were captured. Of the 10 recaptured TKR, 7 had been released in cages. Among the collared TKR, uncaged animals initially moved further than caged animals, but overall daily movement rates were similar for the 2 groups. Burrow use patterns also were similar, although caged animals were slightly more likely to use artificial burrows. Original plans called for translocating additional animals to the introduction site. However, 4 untagged TKR were captured during post-release live-trapping indicating that a previously undetected resident population was present at the site. To avoid further impacts to this population, no further translocations were conducted. No TKR, translocated or resident, were captured during live-trapping conducted in October 2011. Efforts to establish a new TKR population were hampered by hot temperatures during translocation, radio collar issues, rapidly increasing HKR abundance, and the unexpected presence of a resident TKR population. Recommendations for future TKR translocation efforts include conducting such efforts during a more optimal time of year (e.g., fall), investigating more effective radio transmitter attachment strategies, employing a more suitable burrow design, and possibly reducing competitor abundance prior to the translocation.

INTRODUCTION

Tipton kangaroo rat (*Dipodomys nitratoides nitratoides*; TKR) populations have been significantly reduced throughout their historic range in the San Joaquin Valley, California, primarily due to profound fragmentation, degradation, and loss of habitat. Much of the habitat within their former range was displaced by agricultural, industrial, and urban development, facilitated by the completion of the Central Valley Project and the California Water Project in the early 1970's (U.S. Fish and Wildlife Service 1998). From 1990 to 1996 alone, approximately 28,936 ha (71,500 ac) of habitat were converted to agricultural uses within the Conservation Program Focus Area of the Central Valley Project, and 41,157 ha (101,700 ac) were converted to urban uses (U.S. Fish and Wildlife Service 2007). TKR occur on only 3-4% of their former range (Williams and Germano 1992) and their numbers continue to decline (Uptain et al. 1999). As a result of this decline, TKR are federally and state listed as Endangered.

TKR currently persist in a limited number of disjunct populations in the southern San Joaquin Valley (U.S. Fish and Wildlife Service 1998). Most of these populations are on relatively small habitat fragments, and in many cases, intervening lands are not suitable for TKR dispersal and movements. This isolation results in limited or no genetic exchange between populations, higher probability of local extirpation, and low probability of natural recolonization.

Translocation is a potential strategy for reintroducing species back into vacant habitat. Relocating animals always involves considerable risk and efforts are not always successful (Fischer and Lindenmayer 2000). Translocation has been successful in re-establishing populations of some rodents, such as the Perdido Key beach mouse (*Peromyscus polionotus trissyllepsis*) in Alabama (Holler et al. 1989). The success of previous efforts to translocate TKR has been equivocal, although many of these efforts typically involved relatively small numbers (<20) of animals (Germano 2001, Germano 2010).

The Kern National Wildlife Refuge (KNWR), Kern County, California is located within the range of the TKR, and a population of TKR is present just south of KNWR on lands managed by the California Department of Fish and Game and Center for Natural Lands Management. In 2004, KNWR acquired a parcel of land with habitat suitable for TKR. Live-trapping was conducted on the parcel in 2007, but no TKR were detected (Tomlinson et al. 2008). TKR also are present at 2 adjacent sites south of KNWR in Lamont. These sites are managed by the Lamont Public Utilities District (LPUD) and the Kern County Waste Management Department (KCWMD). Planned operations at both sites would result in the deaths of TKR, and therefore, these individuals were potentially available for salvage and relocation.

Our primary objective was to relocate TKR from the Lamont sites to KNWR in an effort to establish a new population of TKR. Secondary objectives were to test the efficacy of relocation strategies. Specifically, we wanted to determine whether confining animals in protective cages for a period prior to release (i.e., "soft release") improved survival over unconfined animals (i.e., "hard release"), and whether habitat type (areas with shrubs vs. areas with no shrubs) affected survival of relocated animals.

METHODS

SOURCE AND INTRODUCTION SITES

Both of the Lamont source sites were visited in 2009. Much of the LPUD site had already been disturbed. Based on the presence of active burrows, a small number of TKR still appeared to be present around the margins of the site. The adjacent KCWMD site had a much larger number of TKR, based on abundant burrows, and had not yet been disturbed. Thus, we decided to focus on the KCWMD site as a source of animals for the relocation effort. The KCWMD site consists of a closed county landfill and adjacent buffer areas. We concentrated our efforts on a small area (~10 ha) in the northern buffer area where earthwork and fence construction was planned.

The KNWR is located approximately 32 km (20 mi) west of Delano and approximately (90 km (55 mi) northwest of the Lamont sites (Figure 1). The newly acquired parcel, Unit 15 (T25S, R22E, Section 5), is situated on the north side of KNWR and encompasses 255 ha (631 ac). The vegetation community on this parcel is classified as Valley Sink Scrub (Holland 1986) and is characterized by areas with sparse to dense shrubs (Figure 2) as well as areas with few to no shrubs (Figure 3). Common shrubs include iodine bush *(Allenrolfea occidentalis)*, bush seepweed *(Suaeda moquinii)*, and some goldenbush *(Isocoma acradenia)*. Dominant herbaceous ground cover species include red brome *(Bromus madritensis),* saltgrass *(Distichlis spicata)*, San Joaquin blue curls *(Trichostema ovatum)*, alkali heath *(Frankenia salina)*, and heliotrope *(Heliotropium curassavicum)*. Soils are classified as Nahrub and consist primarily of clay in the surface layers. They are poorly drained and moderate to strongly saline-alkaline (USFWS 2005). Under the previous owner, the Unit 15 parcel was grazed by cattle on an annual basis. As a result of this previous land use practice, soil disturbance and relatively low thatch accumulation are evident in the parcel.

RELEASE SITE SELECTION AND PREPARATION

A mosaic of habitat attributes on the release site provided an opportunity to determine whether such attributes, particularly the presence of shrubs, affected TKR translocation success. HKR potentially competitively exclude TKR (USFWS 1998, Tennant and Germano in press) and may be more abundant in areas with shrubs (Nelson et al. 2007). Thus, areas with and without shrubs were chosen as release sites for translocated TKR.

Although trapping had been conducted on Unit 15 previously in 2007 (Tomlinson et al. 2008), we decided to trap again to ensure that TKR were not present on the area. Four lines of 30 traps each were established on 7 April 2010. Two lines were in areas with shrubs and 2 lines were in areas without shrubs. Traps consisted of Sherman aluminum box traps (7.6 cm x 9.5 cm x 30.5 cm; H. B. Sherman Traps Inc., Tallahassee, FL) modified to prevent injury to kangaroo rat tails. Traps were spaced 10 m apart, opened around sunset, baited with white millet bird seed, and provisioned with a paper towel for bedding material and insulation. Traps were checked the next morning around sunrise. All captured animals were identified to species, age class and sex were determined, and individuals were belly-marked with a non-toxic felt-tipped marker to identify recaptures. Traps were checked on April 8 and 9, 2010. Four individual HKR were captured on the lines without shrubs and 7 individual HKR and one deer mouse (*Peromyscus*

maniculatus) were captured on the lines with shrubs. This indicated that TKR were not present or only at very low density, and that HKR abundance was relatively low and they appeared to be more abundant in areas with shrubs.
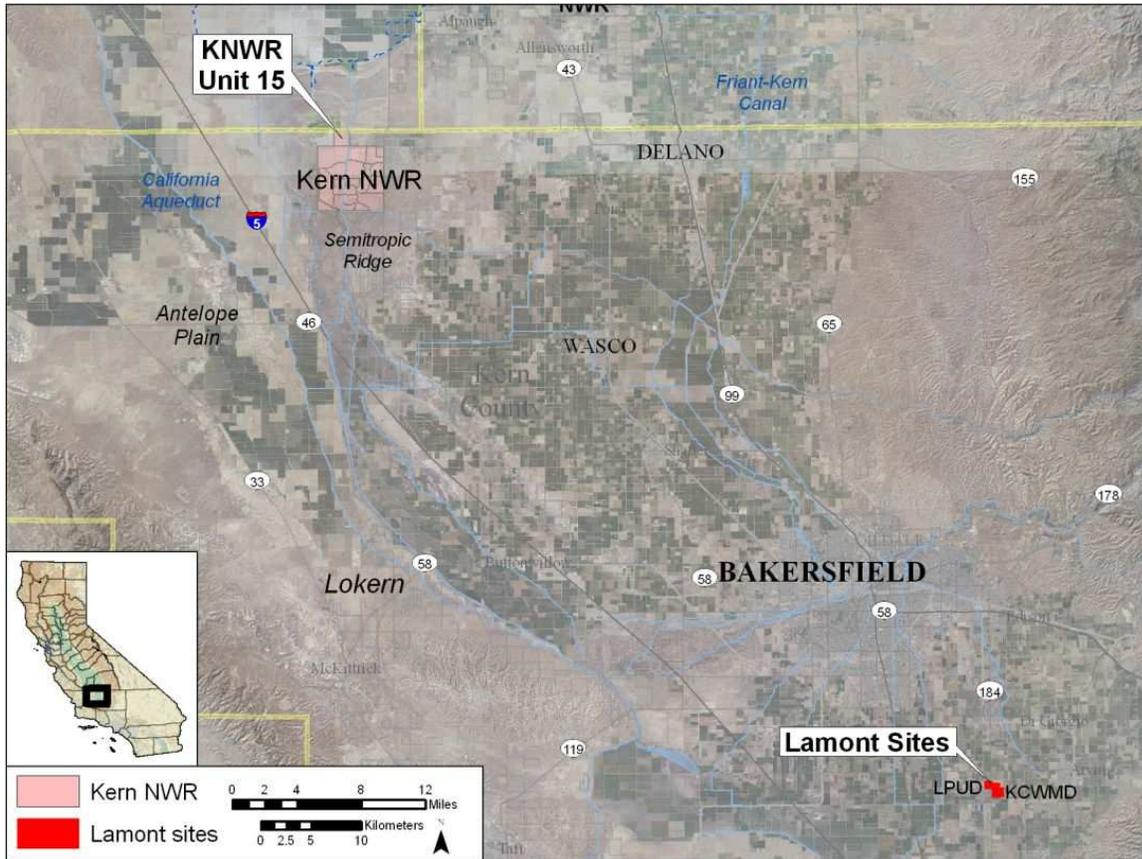
Figure 1. Locations of source sites near Lamont and the Kern National Wildlife Refuge relative to major Central Valley Project features.

We identified 4 general release areas; 2 areas were located in areas with shrubs, and 2 were located in areas without shrubs (Figure 4). Within each release area, we identified 25 specific release sites clustered into 5 groups of 5 sites each. An artificial burrow was created at each release site; one burrow was located roughly 10 m in each of the four cardinal directions from a central burrow. At each burrow site, a hole was dug approximately 40-50 cm deep. Each "burrow" consisted of a Styrofoam "faucet cover" (~12 cm x 12 cm x 15 cm; Thermwell Products Co., Sparks, NV). A hole was cut in the side of the unit and an approximately 0.5-m piece of 9-cm diameter plastic corrugated pipe (i.e., "leach line") was inserted to form an access tunnel. The other end of the flexible pipe emerged onto the ground surface. The hole was then filled in resulting in a 15-30 cm covering of soil over the burrow chamber.

Figure 2. Valley sink scrub habitat on Unit 15 at the Kern National Wildlife Refuge, Kern County, California.

Figure 3. Shrubless area dominated by annual grasses on Unit 15 at the Kern National Wildlife Refuge, Kern County, California.
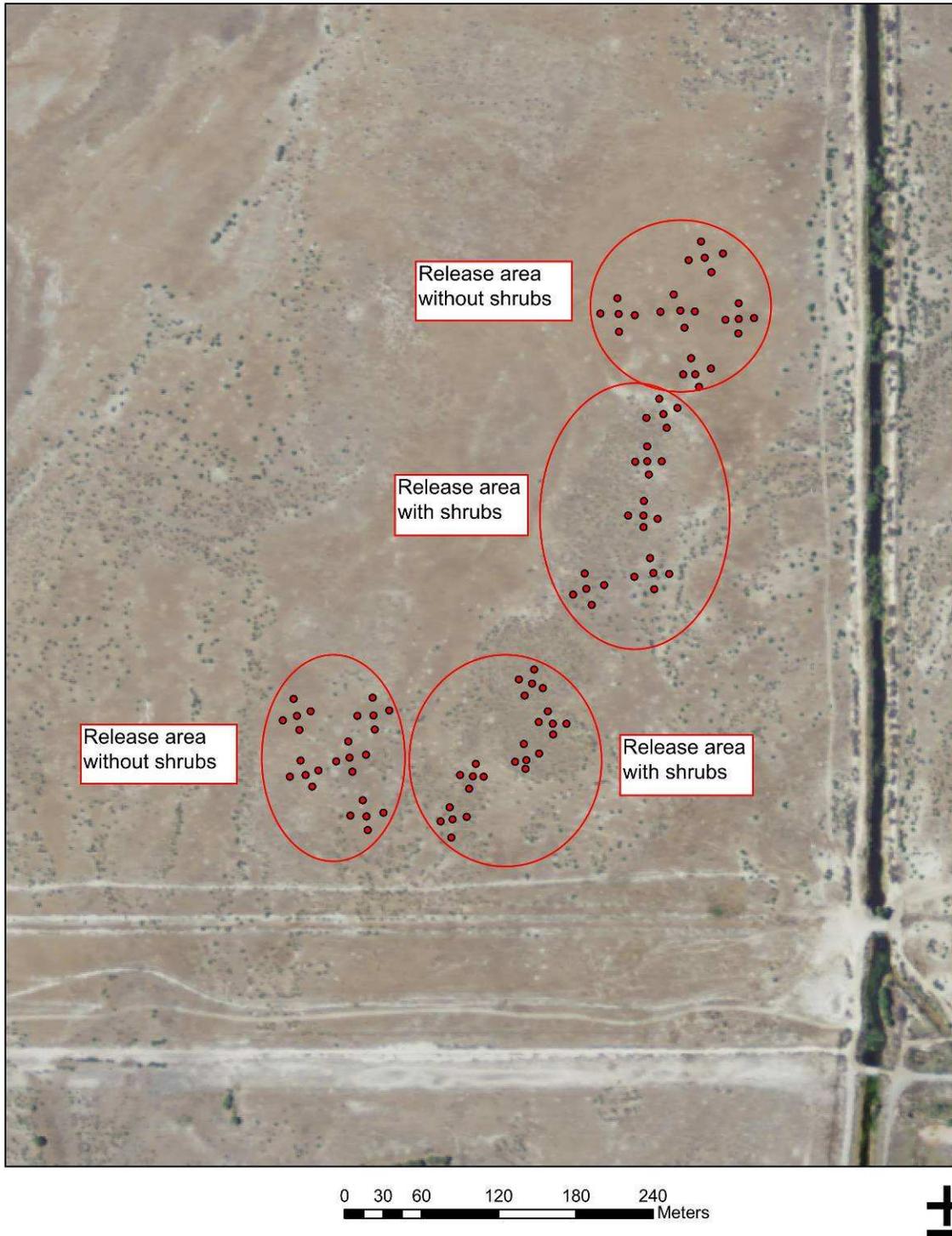
**Figure 4. Four Tipton kangaroo release areas at the Kern National Wildlife Refuge, California.**

At approximately half of the burrow clusters in each release area, a wire cage (Figure 5) was placed over the burrows. The cage was constructed of 1-cm x 1-cm hardware cloth, and the dimensions were approximately 0.5 m x 1 m x 0.75 m. The bottom edges of the cages were buried approximately 15-20 cm to discourage TKR from digging out. The top of each cage was left partially open so that a TKR could be placed inside.

Figure 5. Tipton kangaroo rat release site with wire-mesh cage at the Kern National Wildlife Refuge, California.

Finally, "escape" burrows were randomly scattered around the release site. These were constructed by using a 10-cm diameter hand-powered soil auger to create 0.5-1.0 m long burrows at 30-45 degree angles into the ground. Site preparation work was completed in late July 2010.

TRANSLOCATION, PROCESSING, AND RELEASE

Live-trapping was conducted at the source site in Lamont during early August 2010. Traps were set on 9 August and checked 10-13 August. Traps were set near active kangaroo rat burrows around sunset and checked around sunrise the next morning. Captured animals were identified, and sex, age (adult or juvenile), and reproductive status were noted. Some TKR were considered poor candidates for translocation and were released. These included TKR that appeared to be very young and potentially still dependent upon parents, female TKR that appeared to be pregnant, and female TKR that were lactating and therefore had dependent young. Otherwise, TKR were placed back in the trap to be transported for processing. A total of 80 TKR were retained for translocation consisting of 61 males and 19 females. The sex ratio of retained animals was markedly male-biased due to the number of lactating or pregnant female TKR that were captured at the source site and immediately released.

Retained TKR were transported to a laboratory for processing. All TKR received a uniquely numbered ear tag (Model 1005 size 1 monel; National Band and Tag Co., Newport, KY) in each ear. Also, a genetic sample consisting of hair with attached roots was collected from each animal and placed in a labeled coin envelope. Forty adult males were selected to receive VHF radio transmitters so that movements and survival could be monitored after release. Males were selected because they generally have higher mass and therefore easily met the requirement that the transmitters not exceed 5% of body mass. The transmitters consisted of 2 different designs; one was produced by Holohil Systems (Carp, Ontario, Canada) and the other by Wildlife Materials International (Murphysboro, IL). The Holohil Systems transmitters (model BD-2C) had a plastic-coated loop and crimp attachment system whereas the Wildlife Materials transmitters (SOM-2038 HWSC) had a cable tie attachment system. Both weighed approximately 2.0 g and had an expected battery life of approximately 60 days. Transmitters were placed on all 40 males and then they were observed for 1 or more days to ensure acclimation to the collars. In a number of instances, animals inserted front feet through the collars requiring readjustment prior to release.

Uncollared TKR were released at the KNWR on August 12 and 13 after 0-3 days in captivity. Collared animals were released August 16 and 17 after 3-5 days in captivity; one died prior to release. Collared and uncollared animals were distributed among caged and uncaged burrows in areas with and without shrubs (Table 1). Cages were closed after TKR were placed in burrows. Approximately 0.5 l of soil from the source site was placed in each burrow in an effort to provide a familiar scent. Burrows also were provisioned with approximately 0.25 l of food (bird seed) and a paper towel for bedding. A paper towel also was loosely inserted into the entrance of each burrow to discourage animals from immediately leaving the burrow. These paper towels were removed around sunset. Exit holes (2-3) were cut in cages on August 24 to allow TKR to move in and out at will. Thus, the duration that TKR remained in cages ranged from 7-12 days.

Table 1. Release locations for 38 collared and 41 uncollared Tipton kangaroo rats relocated to the Kern National Wildlife Refuge, California, in August 2010.

	Shrubs		No shrubs	
	Caged	Uncaged	Caged	Uncaged
Collared	12	11	9	6
Uncollared	11	12	8	10

MONITORING

Transmittered TKR were monitored daily for at least 30 days post-release. Animals were tracked to a burrow, or in some cases a mortality location, using a hand held antenna and receiver. GPS coordinates were collected for all locations of animals or mortalities. Animals found dead were collected for examination to determine cause of death. In a number of cases, burrows were excavated to recover dead TKR.

Live-trapping was conducted in the release area for 3 nights during 5-8 October 2010. Three parallel lines with 10 traps each (15 m between traps, 20 m between lines) were established in the 2 release areas with shrubs and the 2 without shrubs. Additionally, a number of extra traps were set off of trap lines next to burrows being used by

transmitted TKR in an effort to recapture these animals. As with other trapping efforts, traps were provisioned with bird seed and a paper towel, opened around sunset, and checked around sunrise the next morning. All captured animals were identified and weighed, and reproductive condition was noted. Each was marked ventrally with a non-toxic felt-tipped marker, and ear-tag numbers and GPS coordinates were recorded for TKR.   Live-trapping also was repeated during 19-21 October 2011 to assess relocation success.

DATA SUMMARY AND ANALYSES

Survival of relocated TKR with radio collars was measured as the minimum number of days that an animal was known to be alive, either after release for uncaged animals or after the cages were opened for caged animals. This metric was based on animals being found in new locations or direct observations of animals. Survival of TKR without radio collars was assessed through recapture during live-trapping conducted approximately 1 month after the releases. Movements of collared TKR were assessed by measuring the distance from release burrows to the first new location. Also, all straight-line movements between new locations were summed and then divided by the minimum number of days survived to produce a daily movement rate. For uncollared TKR, the distance between their release site and capture location was measured.

Two-factor analysis-of-variance was used to determine whether mean minimum number of days survived, movement distances, number of burrows used, burrows used per day, number of burrow switches, and burrow switches per day differed for collared TKR between caged and uncaged animals and between shrub and non-shrub areas. Interactive effects between caging and habitat also were examined. Contingency table analysis was used to compare the proportions of recaptured uncollared TKR between caged and uncaged animals and between shrub and non-shrub areas. P-values <0.05 were considered significant while values of 0.5-0.1 were considered marginally significant.

RESULTS

SURVIVAL AND MORTALITY SOURCES

Survival of radio-collared TKR was low and was not affected by release site (caged or uncaged, shrub or shrubless areas; $F_{3,25} = 0.51$, $p = 0.68$; Table 2). Nine TKR released in cages apparently died prior to the cages being opened to allow egress. Once the cages were opened, no animals survived more than 6 days. Among animals released into uncaged burrows, maximum survival appeared to be 16 days.

Table 2. Number of days surviving post-release for 38 collared Tipton kangaroo rats relocated to the Kern National Wildlife Refuge, California, in August 2010.

Cage	Habitat	*n*	Mean ± SE	Range
Cage	Shrub	7	3.1 ± 0.7	1 − 6
Cage	No shrub	5	3.6 ± 0.7	1 − 6
No cage	Shrub	11	5.2 ± 1.5	0 − 16
No cage	No shrub	6	3.8 ± 1.4	1 − 10

Putative mortality sources for 38 collared TKR included predation, competition from HKR, stress, and collar effects (Figure 6). In 8 cases the fate of the animals could not be determined because remains were not found, were too few, or were too decomposed. In 2 of these cases, it appeared that the animals had slipped their collars, which were found inside burrows. Predation appeared to be the cause of mortality for 13 TKR. In 3 cases, transmitter signals were tracked to Western rattlesnakes (*Crotalus oreganus*); in 2 of these cases the transmitters were regurgitated after a few weeks. Nine TKR were suspected of being killed by owls, which are a common predator on kangaroo rats. In these cases, the transmitter usually was found intact a considerable distance (>100 m) from its location the previous day, it often was found beneath a tree or large shrub, and sometimes it had blood spots on it. In one case, a collared TKR was found some distance from its previous location, and its legs and internal organs were missing. One TKR was found with wounds on its back and another was found dead in a cage and partially buried. We suspect that these 2 animals could have been killed by HKR. Seven animals may have died from stress associated with being relocated. Six of these animals were never found outside of the artificial burrow into which they were released and were recovered from inside the burrows with no signs of trauma, and one animal was found under a nearby shrub 1 day after release with no signs of trauma. Eight TKR may have died from complications related to the radio collars. These animals were found dead with one or both front legs inserted up through the collar.
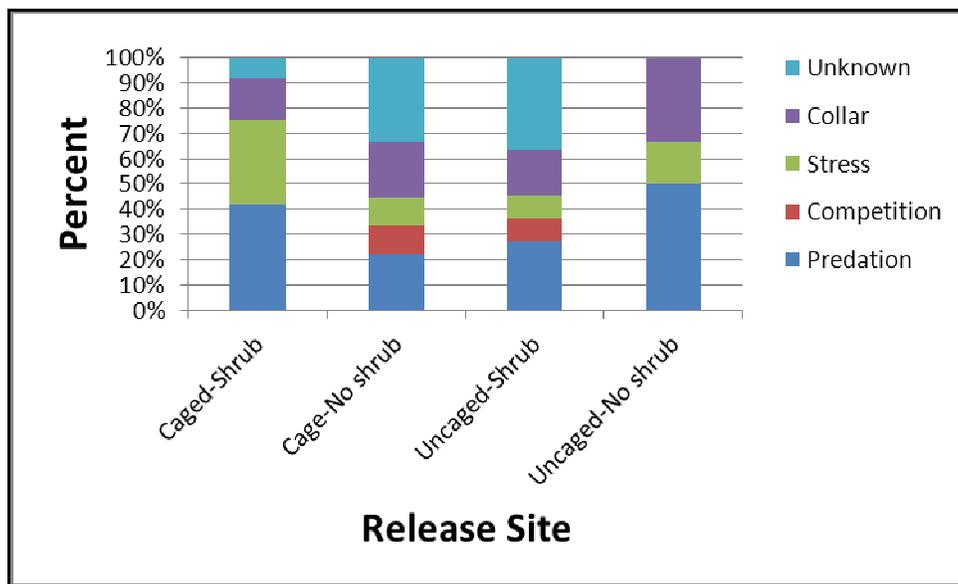

Figure 6. Putative causes of mortality for 38 Tipton kangaroo rats relocated to the Kern National Wildlife Refuge, California, in August 2010.

Caging and habitat type did not seem to affect predation rates on relocated TKR. Seven of the 21 (33.3%) TKR released in cages and 6 of the 17 (35.3%) TKR released outside of cages were predated. Likewise, 8 of the 23 (34.8%) TKR released in shrubs and 5 of the 15 (33.3%) of the TKR released in non-shrub areas were killed by predators.

Survival for uncollared TKR was more difficult to assess as the animals could not be monitored daily, nor could their final fate be determined. An index of survival was obtained during subsequent trapping approximately 1 month after animals were relocated and released. During this trapping session, 10 ear-tagged but uncollared TKR were captured consisting of 6 females and 4 males. The proportion of TKR recaptured among those released in cages was 38.9% (7/18) and the proportion recaptured that was released outside of cages was 13.7% (3/22). These proportions were marginally significantly different ($\chi^2 = 3.37$, 1 df, $p = 0.07$), but the proportions for animals released in shrub (5/22 = 22.7%) and non-shrub (5/18 = 27.8%) areas were not different ($\chi^2 = 0.08$, 1 df, $p = 0.78$).

Mass measurements were obtained for 9 of the 10 recaptured TKR and compared to mass measurements collected when the animals were initially trapped at the source site in Lamont. For 5 adult females, 2 had a lower mass (-3 g and -1 g) and 3 had higher mass (+3 g, +4 g, +5 g) at recapture. For 2 adult males, there was no difference in mass. For 2 juvenile males, both had a higher mass (+6 g, +11 g).

POST-RELEASE MOVEMENTS

The first location for a collared TKR after it left the burrow into which it was introduced was significantly farther ($F_{1,25} = 5.04$, $p = 0.03$) for uncaged animals (55.5 ± 12.8 m, $n = 17$) compared to caged animals (23.3 ± 5.6 m, $n = 12$). However, this distance did not differ between shrub and non-shrub areas ($F_{1,25} = 0.66$, $p = 0.42$), and there was no interaction ($F_{1,25} = 1.03$, $p = 0.32$) between caging and habitat (Table 3). The mean distance moved per day by collared TKR (Table 4) did not vary with caging or habitat type ($F_{1,25} = 1.17$, $p = 0.34$). Recapture locations for uncollared TKR ($n = 10$) averaged 48.6 ± 11.8 m (range = 4-128 m) from release locations.

The mean total number of burrows used by each collared TKR post-release (2.3 ± 0.2), burrows used per day survived (0.7 ± 0.1), total burrow switches (2.6 ± 0.2), and burrow switches per day survived (0.8 ± 0.1) did not vary by caging or habitat ($F_{1,25} = 0.54$, $p = 0.66$; $F_{1,25} = 0.07$, $p = 0.98$; $F_{1,25} = 0.28$, $p = 0.84$; $F_{1,25} = 0.04$, $p = 0.99$; respectively). Three TKR released in cages initially left their cage and then returned to the artificial burrow in which they were release at least once. One of these also used a different artificial burrow. One TKR released in an uncaged burrow left this burrow and eventually used another artificial burrow.

Table 3. Initial distance moved by relocated Tipton kangaroo rats with radio collars at the Kern National Wildlife Refuge, California, in August 2010.

Cage	Habitat	*n*	Mean ± SE	Range
Cage	Shrub	7	24.7 ± 9.4 m	5 – 74 m
Cage	No shrub	5	21.4 ± 5.0 m	5 – 35 m
No cage	Shrub	11	44.9 ± 12.7 m	5 – 133 m
No cage	No shrub	6	75.0 ± 27.7 m	8 – 161 m

Table 4. Mean distance per day moved by relocated Tipton kangaroo rats with radio collars at the Kern National Wildlife Refuge, California, in August 2010.

Cage	Habitat	*n*	Mean ± SE	Range
Cage	Shrub	7	19.9 ± 9.7 m	2.2 – 74.0 m
Cage	No shrub	5	22.9 ± 10.9 m	5.0 – 66.0 m
No cage	Shrub	11	24.1 ± 5.4 m	5.0 – 53.3 m
No cage	No shrub	6	45.4 ± 16.8 m	8.0 – 121.0 m

POST-RELEASE LIVE-TRAPPING

During live-trapping conducted for 3 nights in October 2010, 4 ear-tagged but uncollared translocated TKR were captured on the 4 release areas (Table 5). Also, 6 additional tagged but uncollared TKR were captured on sites outside of the release areas near burrows from which transmitter signals from collared TKR were originating. However, no collared TKR were captured during the trapping session. Unexpectedly, 4 untagged TKR were captured on the release areas with shrubs. During this trapping session, 111 HKR were captured in the release areas and another 29 HKR were captured in the additional trapping sites.

During 3 nights of live-trapping in October 2011 on the release sites, no TKR were captured (Table 6). Other species captured included 96 HKR, 10 deer mice, 1 San Joaquin pocket mouse (*Perognathus inornatus*), and 1 Western harvest mouse (*Reithrodontomys megalotis*).

Table 5. Small mammals captured at the TKR relocation area at Kern National Wildlife Refuge, California, during October 5, 6, and 8, 2010.

	Shrubs		No shrubs		
	South	**North**	**South**	**North**	**Extra trapsites**
Trapnights	**90**	**90**	**90**	**90**	**90**
Tipton kangaroo rat:					
Translocated	1	1	2		6
Untagged	1	3			
Heermann's kangaroo rat	30	32	23	26	29
Deer mouse	4	4	1	1	2

Table 6. Small mammals captured at the TKR relocation area at Kern National Wildlife Refuge, California, during October 5, 6, and 8, 2010.

	Shrubs		No shrubs	
	South	**North**	**South**	**North**
Trapnights	**90**	**90**	**90**	**90**
Heermann's kangaroo rat	27	34	16	19
Deer mouse	4	4	1	1
San Joaquin pocket mouse				1
Western harvest mouse				1

DISCUSSION

SURVIVAL AND MOVEMENTS

Survival of the TKR translocated to the KNWR was low and likely was insufficient to successfully establish a population. No collared TKR are known to have survived more than 16 days post-release. Survival estimates for collared TKR are a minimum as some transmitters may have failed prematurely, animals may have slipped their collars, animals may have dispersed from the introduction site (although we searched widely), or some animals may have survived longer but remained in the same burrow making it difficult to evaluate their status. Nevertheless, by 30 days post-release, most collared TKR either were found dead or their collars were found with signs of predation. Some uncollared TKR were still present after 1 month, but none were detected a year later. Low survival of translocated TKR also has been reported previously. In one small translocation effort, 4 TKR were released and all were dead within 5 days (Germano 2010). Other efforts have been somewhat more successful. In a larger effort, 144 TKR were translocated and introduced to the Allensworth Ecological Reserve in December 2006 (Germano et al. submitted). Survival to 30 days was 58.3% for soft-released animals and 37.5% for hard-release animals. Furthermore, TKR were still present at the site after 3 years and genetic analysis of unmarked TKR caught at the site provided evidence that the original translocated animals had successfully reproduced.

Various factors could have contributed to the low survival rates observed in this effort. Predators were abundant on the site, particularly various raptors and snakes. Predation by rattlesnakes was confirmed when tracking transmitters lead directly to snakes on 3 occasions. Predation by raptors was inferred based on relatively long, overnight distances between transmitter locations and the fact that these transmitters then commonly were found beneath probable perch sites. High predation rates are a significant challenge in translocation efforts for kangaroo rats as well as other species that commonly are consumed by other species. Germano (2010) reported that of 4 TKR released at a site, predators apparently killed all within 5 days. Predation by kit foxes (*Vulpes macrotis*) may have been responsible for a failed reintroduction attempt involving endangered giant kangaroo rats (*D. ingens*; Williams et al. 1993). In a large-scale (*n* = 325 animals) reintroduction effort for endangered riparian brush rabbits (*Sylvilagus bachmani riparius*), predation was the primary cause of mortality (26.4%) and may have been much higher considering that a definitive cause of mortality could not be determined for over 60% of animals (Hamilton et al. 2010). Likewise, high predation rates also have been reported on several reintroduction efforts for endangered pygmy rabbits (*Brachylagus idahoensis*; Becker et al. 2011).

Interspecific competition also may have affected TKR survival. One of the reasons the introduction site initially was chosen was because HKR abundance appeared to be relatively low, based on live-trapping conducted in 2007 and spring 2010. Competition by HKR is considered a potential limiting factor for TKR populations (USFWS 1998, Tennant and Germano in press). In general, larger kangaroo rat species tend to exclude or limit smaller species through both interference (e.g., spatial exclusion, aggression including mortality) and exploitative (e.g., competition for food and burrows) competition (Blaustein and Risser 1976, Frye 1983, Brown and Harney 1993, Perri and Randall 1999). Potential food (e.g., seed heads on plants) appeared to be plentiful on the

site, as did potential burrow sites. However, evidence at 2 mortality sites for TKR (e.g., wounds, partially buried carcass inside a cage) suggested potential aggression by HKR.

Stress is always a problem when translocating animals as they are taken from a familiar environment, held in captivity for some period of time and subject to "processing" (e.g., marking, collars, health screening), and then released in a completely unfamiliar location. Translocation may have been particularly stressful for the TKR that were collared as they were held in captivity for a longer period (up to 5 days). Also, the time of year that the translocation had to be conducted was not optimal due to hot, dry conditions, including reduced soil moisture that resulted in lower humidity in artificial burrows. A number of animals appeared to die within a day or two of release, particularly animals in cages, and this may have been due to stress and suboptimal conditions.

The radio collars also likely contributed to the mortality of some animals. Two different collar designs were employed in an attempt to determine whether one performed better than another. However, similar issues were experienced with both designs. Placing the collars on the animals and obtaining a proper fit proved challenging. A number of animals inserted a front leg up through the collar within the first 24 hours. This resulted in collared animals being held in captivity longer so that animals could be observed and collars adjusted as needed. Despite this extra effort, some animals were recovered dead after release with one or both front feet inserted through collars. This potentially may have impeded movements or feeding or predator avoidance. Evidence of collar effects is further provided by the fact that no collared TKR were recaptured after release. In live-trapping conducted in October 2010, 10 translocated TKR were captured and all were uncollared animals. Radio collars have been placed on kangaroo rats in other studies and some collar effects also were noted (Germano 2001, Tennant 2011), although they usually were not prevalent (e.g., Germano et al. submitted).

Finally, among the 80 translocated TKR, only 19 were females. Many of the females captured at the source site were lactating or pregnant and were released. Thus, it is possible that many of the females retained for translocation may have been younger without prior breeding experience. This inexperience and the low female:male sex ratio of translocated animals likely reduced the probability of successfully establishing a self-sustaining population. Kangaroo rats exhibit a polygynous or even promiscuous mating system (Jones 1993), and therefore a sex ratio closer to 1:1 or even one more female-biased likely is more optimal.

Ideally, additional animals would have been translocated to KNWR. Particularly for animals commonly preyed on by other species, multiple introductions commonly are necessary before a population is successfully established (e.g., riparian brush rabbits; Hamilton et al 2010). Indeed, additional translocations had been planned for KNWR. However, these plans were abandoned with the discovery of a resident TKR population in the release area during the live-trapping in October 2010. This development was unexpected given that no resident TKR had been detected in 2 previous trapping efforts. Kangaroo rat abundance seemed to be relatively low, based on HKR capture rates during live-trapping in 2007 and spring 2010. Clearly, small numbers of TKR must have been present on the parcel, but were highly localized in refugia areas missed by trapping or were outside of the release areas. Based on the marked increase in HKR captures in October 2010, kangaroo rat abundance apparently increased and resident TKR either expanded out of refugia areas or dispersed into the release areas. The survival and fitness

of residents animals can be adversely affected by the introduction of translocated animals (Chivers 1991), and therefore the decision was made to conduct no further translocations.

All collared TKR quickly moved out of the artificial burrows in which they were introduced. Some animals moved up to 161 m in their initial movement. Animals may have been seeking more optimal burrow conditions as almost all moved into natural earthen burrows. After these initial movements, a few animals were occasionally located back in their initial or even a new artificial burrow indicating that these burrows were at least somewhat suitable to the TKR. Based on the behavior of the collared animals, uncollared TKR likely quickly left their initial burrows as well. Movements by all animals may have been to explore their new environment, locate food patches, find more suitable burrows, or to find areas with lower inter- and intraspecific competition.

CAGES AND HABITAT

Confinement of animals on introduction sites for some period of time prior to release (also known as "soft release") is a common method employed in translocation efforts. Confinement potentially affords a number of benefits. It provides a protected situation where the animals have time to calm down and recover from the stress of translocation, which may help to improve physiological condition. It also allows the animal to acclimate to conditions at the release site and become familiar with its immediate surroundings, which may reduce the chances that it will panic and immediately leave the introduction site. Confinement also helps protect the animals from competitors and predators while they recover, and provides a place where they can be provided with food. Confinement in wire cages has been used in other kangaroo rat introductions and the efficacy of the cages in promoting successful survival and population establishment has been mixed. A higher survival rate was reported for TKR soft-released in cages compared to TKR that were hard-released, although the difference was not statistically significant (Germano et al. submitted). However, survival was slightly higher for hard-released HKR (Tennant and Germano in press). Survival also apparently was high for 15 San Bernardino kangaroo rats (*D. merriami parvus*) that were translocated and hard-released (O'Farrell 1999).

Likewise, the efficacy of caging TKR in this effort also was equivocal. Survival and predation rates were similar for collared TKR between caged and uncaged animals. However, 7 of the 10 uncollared TKR recaptured ca. 30 days after release had been caged. Among collared TKR, uncaged animals initially moved farther, indicating less affinity to their release location and potentially increasing their exposure to predators and competitors, although these animals did not have lower survival rates than caged animals. Movement rates per day were similar between caged and uncaged animals. Burrow use also was similar although 3 caged TKR reused artificial burrows after release versus only 1 uncaged animal. Thus, the caged animals may have become more familiar with the burrows.

Constructing and installing the wire cages added expense to the project and was labor intensive. The difficulty of installation was increased by the fact that the bottom edges of the cages needed to be buried 8-12 inches to deter translocated TKR from digging out or other kangaroo rats from digging in. The cages also had to eventually be removed and disposed of, which again involved time and labor. Thus, hard releasing animals is preferable if caging provides no clear benefit.

The relative benefits of releasing animals in different habitats also were not clear. Shrubs potentially provide more cover for animals and, indeed, TKR were observed sitting under shrubs on a few occasions after release. However, survival and predation rates as well as movements and burrow use all were similar between collared animals released in areas with and without shrubs. Furthermore, of the 10 uncollared TKR recaptured, 5 had been released in areas with shrubs and 5 had been released in areas without shrubs. Of note, release areas with and without shrubs were in sufficiently close proximity (i.e., ≤ 100 m) that animals easily could move to a different habitat if they chose to. Six of the collared TKR released in areas without shrubs moved into areas with dense ($n = 3$) or scattered ($n = 3$) shrubs. Two collared TKR released in areas with shrubs moved into areas without shrubs but then quickly moved into areas with scattered shrubs. One uncollared TKR released in an area with shrubs was recaptured in an area without shrubs. All of the "resident" TKR captured were in areas with shrubs. Thus, some evidence does suggest a preference for areas with shrubs.

CONCLUSIONS AND RECOMMENDATIONS

This TKR translocation effort did not appear to result in the establishment of a new population of TKR as desired. There were a number of factors contributing to this outcome. Despite the fact that a new population was not established, the effort provided information that could be valuable for future translocation efforts. The following recommendations are provided.

- **If possible, conduct translocations during more optimal times of year.** Extreme temperatures in summer and winter may increase animal stress resulting in mortalities. Spring and summer also may not be a good time to translocate because many females may be pregnant or already have dependent young. Fall may be the most optimal time as temperatures are more moderate, reproductive activity is lower, and soil moisture may be higher which may result in higher humidity in burrows and facilitate water conservation by animals. Furthermore, if conducted later in fall, snake activity may be reduced.

- **Investigate alternative methods for monitoring success using radio telemetry.** Monitoring survival of individual animals is desirable and informative, but radio collars obviously entail risks. Safer, easier methods would be desirable and could include different collar designs, or even alternative transmitter attachment strategies such as a harness/backpack system or even gluing transmitters directly onto animals.

- **If time and/or resources are limited, translocate animals without caging.** The benefits of caging are still equivocal. Further investigation of caging is warranted. However, if situations are such that time or resources for constructing and installing cages are insufficient, translocation should be conducted anyway, particularly if the source population is under threat of destruction.

- **Employ more suitable artificial burrow designs.** Although the design we used was intended to provide a more durable structure, it also may have had the unintended effect of retaining more heat and reducing burrow humidity.

This design may have worked fine under conditions of higher soil moisture, but under the dry conditions during this effort, a more natural style burrow may have been more suitable. A ca. 1-m long burrow created with a tool such as a soil auger is one possible design that might work better under such conditions.

- **If necessary, reduce competitor abundance.** In particular, HKR may adversely affect TKR, particularly highly vulnerable translocated individuals that are already stressed and are unfamiliar with their new environment. HKR potentially could be live-trapped and relocated outside of the introduction area. Such efforts likely would not have to be sustained, but even if conducted just once (e.g., just prior to TKR introduction), it may reduce interspecific competition sufficiently to allow TKR time to acclimate and settle into their new environment.

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