Western Wildlife 7:30–37 • 2020
Submitted: 12 May 2019; Accepted: 22 July 2020.

Strategies for Translocating Endangered Giant Kangaroo Rats (*Dipodomys ingens*)

***Larry Saslaw*[1,3] *and Brian Cypher*[2]**

[1]*14700 Orchard Crest Avenue, Bakersfield, California 93314*
[2]*Endangered Species Recovery Program, California State University-Stanislaus, Turlock, California 95382*
[3]*Corresponding author, e-mail: Larry7719@sbcglobal.net*

***Abstract*.—The Giant Kangaroo Rat (*Dipodomys ingens*: GKR) is an imperiled species in the San Joaquin Desert of California due to profound habitat loss. Occupied habitat is still being developed and translocation is becoming a common mitigation strategy. In 2012 and 2013, we translocated GKR from proposed oil-well pad sites in western Kern County, California, to a nearby conservation area. In 2012, we semi hard-released 43 animals into artificial burrows and in 2013, we soft-released 38 animals into artificial burrows within enclosures. The soft-released GKR exhibited higher apparent survival based on subsequent live-trapping. Retention time in enclosures did not affect survival, probably because GKR rapidly burrowed out of enclosures. Both hard-released and soft-released GKR exhibited rapid fidelity to their release sites. Thus, the enclosures primarily may have afforded translocated animals protection from predators while they acclimated to their new surroundings. Soft-released GKR translocated as a social group exhibited higher survival than those translocated indiscriminately. A GKR population has persisted at the release site and were still present as of April 2020. Based on our results, we recommend that GKR be translocated in social groups and soft-released in suitable habitat on conservation lands.**

Key Words.—California; hard release; soft release; survival; well pad

Introduction

The San Joaquin Desert of California is home to many species of conservation concern (U.S. Fish and Wildlife Service [USFWS] 1998; Germano et al. 2011). Urban, industrial, and agricultural development is still occurring in this region, and federally and state-listed species are sometimes present on sites planned for such development. An increasingly common mitigation strategy is to translocate rare animals and plants off of development sites, usually to designated conservation areas. Translocation has well-documented risks (e.g., Griffith et al. 1989; Dickens et al. 2010; International Union for Conservation of Nature 2013) and many efforts are not successful (Fischer and Lindenmayer 2000; Germano 2001; Armstrong and Seddon 2008). In some cases, the results of translocations are not even monitored (Tennant et al. 2013). Thus, any efforts to assess and improve translocation strategies are valuable.

Translocation efforts have been conducted for several kangaroo rat (*Dipodomys* spp.) species with limited success. These species include the Tipton Kangaroo Rat (*D. nitratoides nitratoides*; Federally listed Endangered, California listed Endangered), Stephen's Kangaroo Rat (*D. stephensi*; Federally listed Endangered, California listed Threatened), and the common and unlisted Heermann's Kangaroo Rat (*D. heermanni*). These translocation efforts have included both soft releases, in which individuals are confined to the release site for some period of time, and hard releases, in which individuals are not confined to the release site. To date, neither strategy has proven superior to the other. Previous kangaroo rat translocation attempts were thoroughly reviewed by Germano (2001, 2010), Shier and Swaisgood (2012), Tennant et al. (2013), and Tennant and Germano (2017).

The Giant Kangaroo Rat (*Dipodomys ingens*; GKR) is endemic to the San Joaquin Desert (Williams and Kilburn 1991; Germano et al. 2011). The GKR is the largest kangaroo rat (Williams et al. 1993). Each GKR inhabits an extensive burrow system referred to as a precinct. They are larder hoarders and store large quantities (up to multiple liters) of seeds, their primary food, in subterranean chambers within the precinct. GKR exhibit high fidelity to their precinct and will vigorously defend it. Thus, precincts constitute a critical aspect of GKR ecology (Williams and Kilburn 1991).

GKR are listed federally and by the state as endangered, primarily due to profound habitat loss and degradation (USFWS 1998). They primarily persist in three large and three small populations (USFWS 1998). The large population areas are considered to be core areas and are critical for the conservation and recovery of GKR. One of these core areas is in western Kern County, which also is a region of extensive hydrocarbon (crude oil and natural gas) production. New facilities and infrastructure (e.g., well pads, pipelines, roads) are sometimes constructed in habitat occupied by GKR. When this happens, an increasingly common mitigation strategy is to translocate the GKR to another area, preferably one that is conserved and not under threat of future development.

In 2012 and 2013, the lead author coordinated the translocation of 81 GKR from well-pad construction sites to conservation lands approximately 14 km away. The animals translocated in 2012 were semi hard released (i.e., released into artificial burrows provisioned with seed). The animals translocated in 2013 were soft released and we hypothesized that this strategy would result in better survival, as suggested by Germano et al.

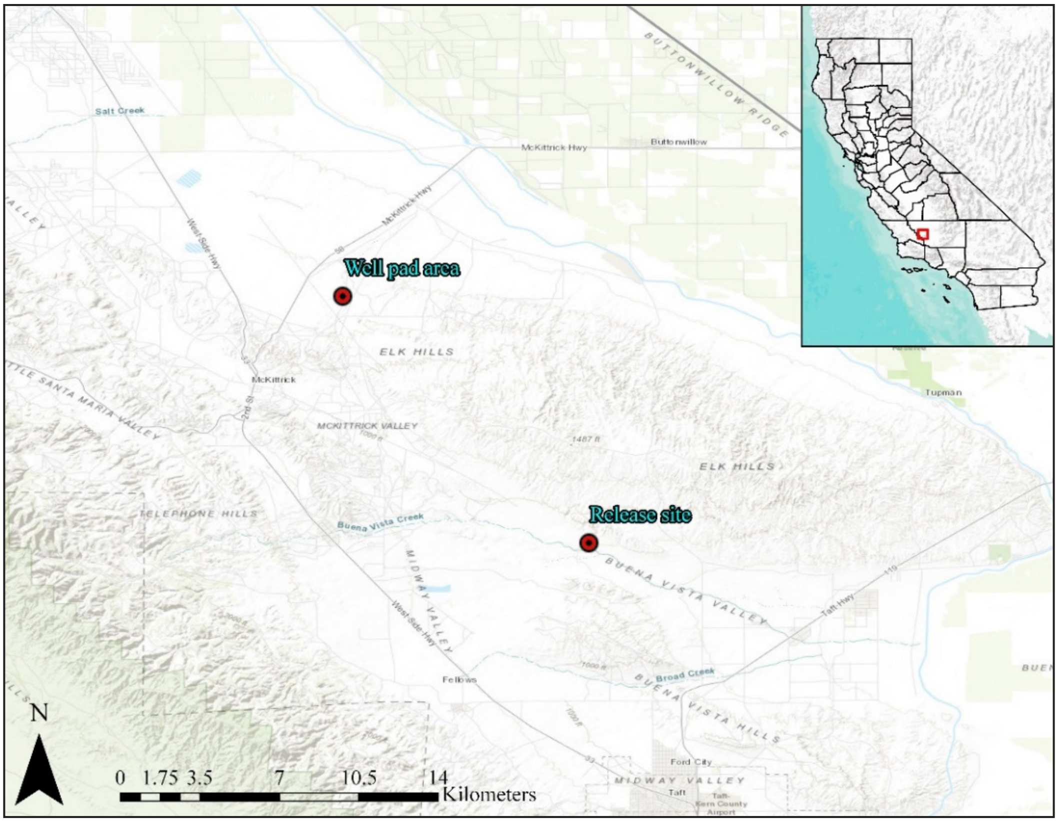

Figure 1. Locations of well pads from which Giant Kangaroo Rats (*Dipodomys ingens*) were translocated and the release site in Kern County, California.

(2013) and Tennant et al. (2013). Furthermore, in 2013 we compared survival of animals moved as a social group to those not moved as a social group as we hypothesized that this might improve survival as well. Our objective was to compare translocation strategies with an overall goal of establishing a GKR population at the release site. We predict that soft-released GKR will exhibit higher survival than hard-released individuals and that GKR moved in social groupings would have higher survival rates than those moved irrespective of trapped location.

Methods

Study areas.—The well pad sites from which we translocated GKR were in the Gunslinger Unit of the Occidental of Elk Hills (OEH) oilfield, and were located approximately 4 km northeast of McKittrick, Kern County, California (Fig. 1). The release site was located approximately 14 km southeast of the well pad sites on OEH conservation lands in the Buena Vista Valley (Fig. 1). We selected this release site because it was not occupied by GKR at the time but was within a region with suitable habitat where the specie was known to consistently occur (USFWS 1998). Habitat conditions in the well pad site and release site were similar. The terrain in both areas was flat to gently rolling and the elevation was approximately 100 m. The regional climate was Mediterranean in nature and was characterized by hot, dry summers, and cool, wet winters with frequent fog. Mean maximum and minimum temperatures were 35° C and 18° C, respectively, in summer, and 17° C and 5° C, respectively, in winter (https://wrcc.dri.edu/cgi-bin/cliMAIN.pl?ca8752). Annual precipitation averaged 137 mm and occurred primarily as rain falling between October and April (https://wrcc.dri.edu/cgi-bin/cliMAIN.pl?ca8752.). The vegetation community at both sites was characterized as Lower Sonoran Grassland (Twisselmann 1967) or Allscale Series (Sawyer and Keeler-Wolf 1995). The plant community consisted of arid shrublands dominated by Desert Saltbush (*Atriplex polycarpa*). Ground cover consisted primarily of annual grasses and forbs and was dominated by Red Brome (*Bromus rubens madritensis*) and Red-stemmed Filaree (*Erodium cicutarium*).

GKR capture, translocation, and monitoring.—We live-trapped GKR on the well pad sites by setting traps near kangaroo rat burrows that appeared active. We set traps at burrows within the enclosed (metal flashing) well pad site. We used Sherman XLK Extra-Large Kangaroo Rat Traps (30.5 × 9.5 × 7.6 cm; H.B. Sherman Traps Inc., Tallahassee, Florida). We opened the traps within 2 h of sunset and we provisioned each trap with a handful of millet seed and two sheets of crumpled, unbleached paper towels for insulation and to keep kangaroo rats from chewing on the traps. We checked and closed the traps the following morning within 2 h of sunrise. After checking that we had captured a GKR, we placed them

Figure 2. Soil auger being used to create artificial burrows for translocated Giant Kangaroo Rats (*Dipodomys ingens*) as a release site in western Kern County, California. (Photographed by Brian Berry).

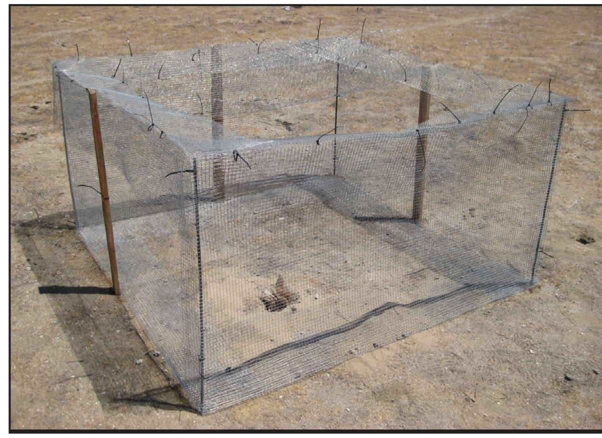

Figure 3. Soft-release enclosure for translocated Giant Kangaroo Rats (*Dipodomys ingens*) at a release site in western Kern County, California. (Photographed by Larry Saslaw).

back in the trap and then transported them via vehicle to the release site or to a home office for fitting a radio transmitter and then subsequent release at the study site.

In 2012, we used a semi hard-release approach for all captured GKR. At the release site, we created artificial burrows using an 8.5-cm soil auger angled to a depth of 60–90 cm below the surface and about 120 cm in length (Fig. 2). The artificial burrows were located at least 10 m apart and no resident GKR were present at the site. We provisioned each burrow with about 250 ml of birdseed. During trapping conducted 4–9 April 2012 at the well pad sites, we captured 43 GKR (22 females, 21 males) and transported them directly to the release site. We then released one animal into each artificial burrow and loosely plugged the entrance with paper towels to discourage animals from immediately leaving the burrows (Germano et al. 2013). The GKR could exit the artificial burrow at will by simply pushing through the paper towel, which we confirmed the next day. Prior to release, we attached a uniquely numbered No.1 Monel ear tag (American Band and Tag Co., Newport, Kentucky) in each ear of an individual. We placed animals in the burrows in a pattern that roughly approximated that of the capture locations at the well pad sites. Thus, animals captured closer together were released closer together and animals captured farther apart were released farther apart (social grouping). We did not have a control group in 2012 and so could not evaluate whether translocating with social grouping improved survival. Also, comparing the 2012 data to 2013 would be confounded by the inclusion of soft releases in 2013.

In 2012, we trapped kangaroo rats at the release site 35 d post-release (for four nights from 14–18 May). Trapping methods were similar to those used to capture animals at the well pad sites. We placed traps near the artificial burrows as well as nearby locations with active kangaroo rat sign. We recorded the ear tag number, weight, and reproductive condition for all GKR captured and we recorded the capture location using a Global Positioning System (GPS) unit. We re-trapped the site approximately 5 mo later (16–18 October 2012) to further assess GKR survival and movements.

In 2013, we used a soft-release approach for GKR we translocated. At the release site, we constructed artificial burrows as in the 2012 release; however, we also constructed over each burrow an enclosure using 1-cm hardware cloth (Fig. 3). Each enclosure was either 183 × 183 × 92 cm in length, width, and height, or 244 × 183 × 92 cm (some just happened to be built larger, but the difference in sizes was not considered sufficiently significant to affect GKR survival). The enclosure was held in place by 122-cm long pieces of 1-cm diameter rebar driven into the ground at each corner and a 122-cm long wood lath driven into the ground on each side. On all sides of the enclosure, a 30-cm flange extended inward along the surface of the ground at the bottom of the enclosure to inhibit GKR from quickly leaving the enclosure by digging underneath the side (Fig. 3). We staked this flange to the ground so that it remained flat. At each corner, we formed a 7 cm fold on one end of each side piece to seal the corner. Additionally, we folded a 60-cm wide piece of hardware cloth in half at 90° that we attached inward around the top edge of each enclosure to discourage GKR from climbing up and over the side (Fig. 3). Finally, we extended chicken wire across the top of the enclosure to exclude entry by avian predators. We attached the sides of the enclosure to the rebar supports and the chicken wire top with 30-cm nylon cable ties. Finally, a tight seal around the bottom of the enclosure was formed by staking the bottom edge to the ground with 30-cm spikes. We located enclosures avoiding any small mammal burrows and we spaced them at least 10 m apart (Fig. 4) and at least 10 m from any 2012-released GKR precincts.

During trapping we conducted 11–18 June 2013 at the two well pad sites, we captured 36 GKR (24 females,

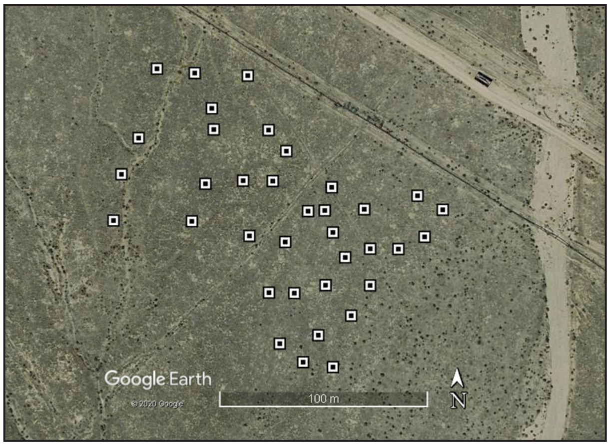

Figure 4. Aerial image of release pen locations for translocated Giant Kangaroo Rats (*Dipodomys ingens*) at a release site in western Kern County, California. (Aerial image from Google Earth).

12 males). We captured two additional male GKR at two well pad sites 28 June and 8 July 2013. We marked all GKR translocated in 2013 with a passive integrated transponder (PIT) tag inserted subcutaneously in the shoulder region of the back (Williams et al. 1997). Additionally, we fitted 19 (11 females, eight males) GKR with radio transmitters (Model BD-2, Holohil Systems, Carp, Ontario, Canada) attached to beaded chain collars to monitor survival and movements. We maintained these GKR in 19-l buckets for 5 d at a home office to ensure a proper collar fit. During 13–17 June 2013, we transported and released 36 GKR to the release site and we placed each one in an artificial burrow within the enclosures. We then secured enclosures with cable ties to prevent entrance or exit from the cage. We released all of the 19 radio-collared GKR into their respective artificial burrows and enclosures on 17 June. To determine if survival of GKR was affected by retention time in the enclosures, we removed 14 enclosures 22–24 d post-release and the remainder after 33–35 d. Also, we moved 14 GKR from one of the well pad sites as a social group, meaning that they all were released in the same part of the release site and in a pattern that approximated their relative capture locations. Thus, animals captured closer together were released closer together and animals captured farther apart were released farther apart. We did not translocate the other 24 GKR we caught as a social group, and we simply placed them in available burrows at the release site in no particular pattern.

We tracked the radio-collared GKR daily for the first 10 d and several times per week thereafter using a hand-held receiver and 3-element Yagi antenna. Tracking either led to a burrow that the animal was in or to a mortality site where typically we only found the transmitter. In either case, we recorded the location with a GPS unit. Also, using methods similar to those used in 2012, we trapped at the release site approximately four weeks, six weeks, and 10 weeks post release. During the last trapping session, we removed radio collars from collared GKR.

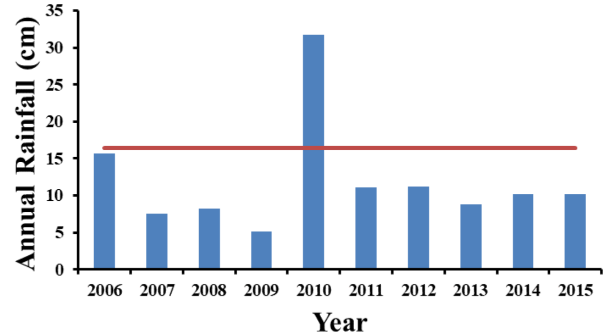

Figure 5. Annual precipitation at Bakersfield, California, from 2006 to 2015. The horizontal line is the long-term average from 1889 to 2019. (https://weather.gov/hnx/bflmain).

We trapped at the release site again in March 2014 to determine if any GKR were still present. We placed two traps at each artificial burrow with obvious GKR activity (e.g., fresh digging) and at natural burrows in the area exhibiting possible GKR activity. Due to successive years of low precipitation and concomitant plant growth in spring 2014 (Fig. 5), we distributed approximately 250-500 ml of bird seed around active burrows to enhance GKR survival during this period of low food availability. We distributed seed approximately every two weeks from March through the end of 2014. We trapped on the release site again in April 2015 to assess the status of GKR.

***Statistical analyses.*—**We used Contingency Table Analysis and a Chi-square Test to compare the proportion of translocated GKR detected after 40 d in 2012 to the proportions of GKR detected after 30 d and after 60 d in 2013. We used the same analysis to compare the proportions of animals detected after 60 d in 2013 between animals whose enclosures had been removed at 22–24 d to those whose enclosures had been removed at 33–35 d. All of the Chi-square Tests entailed 2 × 2 Contingency Tables and so we used a Yates correction for all tests (Zar 1984). We used a Fisher exact text (due to small cell sample sizes) to compare the proportion of GKR that were known to be alive after 60 d in 2013 between animals moved as a social group and those not moved as a social group. For all statistical analyses, we considered significance at $\alpha = 0.10$. We chose a more relaxed alpha value in an effort to reduce the risk of committing a Type II error and not detecting a potentially useful conservation strategy (Taylor and Gerrodette 1993; di Stefano 2003; Scherer and Tracey 2011).

Results

In 2012, 40 d post-release, we caught 14 of the 43 (32.5%) GKR that we translocated. Of these 14, we captured nine within 20 m of the artificial burrow into which we released them. After approximately 6 mo post-release, we caught five of the 43 (11.6%) translocated

GKR. In 2013, 30 d post-release, we caught 24 of 38 (63.2%) translocated GKR, and approximately 60 d post-release, we caught 20 of the 38 (52.6%). Of these 20, we captured 14 within 5 m of the artificial burrow into which we released them.

The difference in the proportion of translocated GKR detected after 40 d in 2012 (32.5%) and detected after 30 d in 2013 (63.2%) was significant ($\chi^2 = 6.41$, df = 1, $P = 0.011$), although some number of animals still were in the enclosures (the exact number is not known because some GKR apparently dug out before we removed the enclosures). The difference in the proportion of translocated GKR detected after 40 d in 2012 (32.5%) and those detected after 60 d in 2013 (52.6%) was not significant ($\chi^2 = 2.56$, df = 1, $P = 0.110$). The proportion of animals detected after 60 d in 2013 did not differ significantly ($\chi^2 = 0.08$, df = 1, $P = 0.777$) whether their enclosures had been removed at 22–24 d (10/13 = 76.0%) or 33–35 d (10/18 = 55.5%). Also, the proportion of GKR that were moved as a social group that were known to be alive after 60 d (10/14 = 71.4%) was significantly higher (Fisher exact text; $P = 0.075$) than the proportion that was not moved as a social group (10/24 = 41.7%).

The ultimate fate of the GKR translocated in 2012 is not known. Of the 38 GKR we followed in 2013, four were never detected post-release, 25 were still alive after 30 d and 20 of those were still alive after 60 d. For the remaining nine animals we moved in 2013, one was killed by a predator while in a trap, we found one dead on the ground outside of its enclosure, two dead in burrows, and just the radio collar of the last five GKR lying on the ground 22 m, 109 m, 115 m, 120 m, and 142 m from their release locations. We think these last five were killed by a predator, probably an owl.

In 2014, we captured 14 GKR in two nights of trapping, none of which were from the 2012 release but nine of which were marked animals from the 2013 translocation. Thus, 23.7% (9/38) of the translocated GKR in 2013 had survived for 9 mo post-release. Based on weight (< 100 g) and pelage characteristics (Williams and Kilburn 1991), three of the six new GKR were young-of-the-year. Approximately 22 mo after the 2013 releases, we caught 17 GKR in 2015. We captured one ear-tagged GKR from the 2012 translocation and one PIT tagged GKR from the 2013 translocation and three of the unmarked animals were young-of-the-year.

Discussion

Although our monitoring methods were not identical between years, survival of translocated GKR apparently was higher in 2013 when we used a soft-release strategy compared to 2012 when we used a semi hard-release strategy. This was consistent with our prediction that soft-released animals would exhibit higher survival. Prior to our study, GKR had been translocated in other locations, but either soft-release or hard-release were used exclusively. In July 1989, GKR were translocated and hard released into artificial burrows at two sites on the Carrizo Plain in San Luis Obispo County (Williams et al. 1993). At one site, 15 of 30 (50%) translocated animals were recaptured approximately 1-mo post-release. At the other site, 12 of 30 (40.0%) animals were recaptured 11 mo post-release and at least one translocated GKR was captured each month thereafter through November 1991 (28 mo post-release). These values are generally similar to those observed in our study.

From September 2011 to August 2013, 221 GKR also were translocated at the California Valley Solar Ranch in San Luis Obispo County, California, as part of a solar farm project (H.T. Harvey, unpubl. report). The animals were soft-released into artificial burrows within large enclosures (6 × 3 × 1.2 m length, width, height) constructed with 1.3-cm mesh hardware cloth and covered with shade cloth to exclude aerial predators. The enclosures were left in place until no activity was observed for at least 48 d or until it was clear that the GKR inside had expanded its burrow to outside of the enclosure. Survival was not specifically assessed, but using a passive PIT-tag reader system, 63 of the 221 (28.5%) of the translocated GKR were still present at their release sites 47 d post-release and one was still present after 721 d. In comparison, in our study 32.5% of translocated GKR were still present after 40 d in 2012 and 52.6% were still present after 60 d in 2013.

In two translocation efforts conducted with other kangaroo rat species from the San Joaquin Desert, soft-release and hard-release strategies were compared directly, but the results were equivocal. In 2006, 144 endangered Tipton Kangaroo Rats (*D. nitratoides nitratoides*) were translocated and 86 were soft released while 36 were hard released. Based on animals with radio collars, survival to 30 d was 58.3% for soft-released animals and 37.5% for hard-released animals, although these values were not significantly different (at 0.05 α; Germano et al. 2013). In 2009, 43 Heermann's Kangaroo Rats (*D. heermanni*) were translocated and 32 were soft-released while 10 were hard-released (one escaped prior to release). Based on radio-collared individuals, survival actually trended higher among the hard-released individuals although the values were not significantly different (Tennant and Germano 2017).

In southern California, translocations of the endangered Stephen's Kangaroo Rats (*D. stephensi*), efforts employing soft release were more successful than those employing hard release, although the efforts differed in a number of regards. Stephen's Kangaroo Rats were translocated and hard released in two efforts in 1992 and 2002 (O'Farrell 1984; Spencer 2003 cited in Shier and Swaisgood 2012). In the first effort, none of the 599 translocated animals could be found after 11 mo. In the second, 40% were still present after 4 mo, but none could be found after one year. In another attempt with this species, 54 animals were translocated in 2008 and another 45 in 2009. All were soft released into enclosures that were removed after one week. Early survival estimates were not given, but a thriving, expanding population was reported to be present on the release site 3 y post-release (Shier and Swaisgood 2012). Success was attributed to soft release along with social group translocation. Finally, in a translocation of endangered San Bernardino Kangaroo Rats (*D. merriami parvus*) in southern California, the animals were hard released and no artificial burrows were provided. Four months post-release, 40% of the 15 translocated animals were still present and most were reproductively active (O'Farrell 1999).

In our study, retention time in the enclosures did not affect the survival of translocated GKR contrary with our prediction that a longer retention time would result in higher survival. This may have been due to the relatively small difference between the two retention times (22–24 d versus 33–35 d). The intent of the different retention times was to determine whether GKR would be more likely to exhibit burrow fidelity if they were confined to the release site for a longer period; however, GKR have such a strong affinity for where they are that confinement may not be necessary. As is common among the larger kangaroo rat species (e.g., Bannertail Kangaroo Rat, *D. spectabilis*; Reichman et al. 1985), individuals construct elaborate burrow systems, store huge quantities of food in these systems (i.e., larder-hoard), and limit their activity to just one system. Thus, this system is integral to their survival and fitness, and consequently, translocated GKR seem to rapidly adopt a burrow and begin modifying and expanding it.

We observed modification and expansion of the artificial burrows at most of the release sites, including those of the semi hard-released animals. At some of the release sites, these modifications were evident within 24 h of release. Rapid, and in many cases immediate, modifications also were observed among the soft-released GKR at the California Valley Solar Ranch (H.T. Harvey, unpubl. report). In the 1989 Carrizo Plain translocations where all of the GKR were semi hard released, observations on the first night after release indicated that GKR exited artificial burrows, explored the immediate area up to 50 m, and then quickly returned to the burrow (Williams et al. 1993). By the next day, the GKR had clearly begun to modify many of the artificial burrows. We captured 64.3% of the semi hard released GKR within 20 m of their release site 30 d post-release and 70.0% of the soft-released GKR within 20 m of their release site 60 d post-release. Thus, confinement may not be necessary for GKR to rapidly develop fidelity to the release site. Results regarding soft versus hard releases of smaller kangaroo rat species may be equivocal in part because they have less fidelity to a particular burrow system and instead, consistent with their scatter-hoarding behavior, commonly use multiple burrows distributed over a larger area than that used by GKR (Reichman 1983; Tennant and Germano 2013).

Enclosures may be beneficial in reducing predation on newly translocated kangaroo rats. GKR, and indeed all kangaroo rats, are prey for a multitude of predators. Thus, they naturally will have relatively high mortality rates just from natural predation. Translocated animals are particularly vulnerable, especially in the early days following release, because they are unfamiliar with their new environment and also may be somewhat disoriented due to the stress of being trapped and transported (Banks et al. 2002; Hamilton 2010). High predation rates were strongly suspected of contributing to the failure of a GKR translocation at one site on Carrizo Plain in 1989 because the release site was unintentionally placed within the home range of a pair of San Joaquin Kit Foxes (*Vulpes macrotis mutica*; Williams et al. 1993). High predation rates also were reported for semi hard released (no cages) Tipton and Heermann's Kangaroo Rats within the first few days following release (Germano 2010; Germano et al. 2013). Enclosures may enhance survival of translocated animals by affording them protection from predators while they are acclimating to their new environs and creating a suitable burrow system. Even GKR that dug out of enclosures were found to continue returning to and using the burrows within the enclosures in this study as well as at the translocation at the California Valley Solar Ranch (H.T. Harvey, unpubl. report). The protection from predators afforded by the enclosures likely explains the higher apparent short-term survival of soft-released GKR compared to hard released or semi hard released GKR in our study.

Maintaining social grouping of GKR during this translocation resulted in higher post-release survival, which was consistent with our prediction. Shier and Swaisgood (2012) compared groups of Stephen's Kangaroo Rats translocated with and without neighbors. Those translocated with neighbors exhibited significantly higher survival, site fidelity, and reproductive success. Individuals translocated with neighbors spent less time fighting with neighbors and more time foraging and creating new burrows. Similar positive results were found for Black-tailed Prairie Dogs (*Cynomys ludovicianus*) translocated in family groups in New Mexico (Shier 2006). Although GKR are essentially solitary, neighbor recognition and familiarity apparently enhance fitness (Randall et al. 2002).

We seem to have established a population of GKR at our release site, which was a primary goal of the translocation effort. Based on the trapping conducted at the site 9 mo and 22 mo after the 2013 releases, GKR were still present, including some of the translocated animals. The number may have been higher at 9 mo, but trapping was terminated after two nights due to trap disturbance by San Joaquin Kit Foxes or Coyotes (*Canis latrans*). The presence of unmarked animals, and particularly the capture of juveniles, indicated that reproduction was occurring at the site. GKR sign (e.g., large burrow entrances, vertical burrow entrances, large scat) was abundant at the release site and surrounding area during site visits in July 2017 and April 2020. This was particularly encouraging given the region-wide low annual precipitation in 2012–2015 (Fig. 5) and concomitant marked declines in GKR abundance recorded on the Carrizo Plain (Prugh et al. 2018) and the Lokern Natural Area (Germano and Saslaw 2017; Greg Warrick, unpubl. data). Six-month survival of GKR at the Lokern study site located 23 km to the north was 29.7% from April to October in 2012 and 12.7% from April to October in 2013 (Germano and Saslaw 2017). In our study, 9-mo survival from June 2013 to March 2014 was 23.7%. Overwinter survival between summer 2013 to spring 2014 on the Carrizo Plains was between 10% and 20% (Prugh et al. 2018). Thus, we considered our translocation effort to be a success.

Our enclosure design appeared to be effective because it prevented GKR from immediately vacating the release site while also affording them protection from predators while they acclimated to their new environment. The design we used was relatively simple, easy to construct as well as remove, and relatively inexpensive (approximately $142 per enclosure for materials). Thus, enclosure designs need not be complex or expensive to be effective. Also, the bottom edge of our enclosures had a flange of hardware cloth and was not buried. This precluded the need for trenching or digging. Not only did this reduce the labor needed to install the enclosures but it also significantly reduced the potential for impacts to endangered Blunt-nosed Leopard Lizards (*Gambelia sila*). This species occurs almost everywhere that GKR occur and also use burrows, including kangaroo rat burrows (USFWS 1998). Ground-disturbing activities can result in injury or death of Blunt-nosed Leopard Lizards.

Our comparison of hard-release and soft-release strategies was not ideal in that the efforts were conducted in different years and differences in annual environmental conditions (e.g., precipitation, seed production, predator abundance) could have influenced results. Despite these potential weaknesses, ours is the only effort to date that provides a quantitative comparison between the release strategies as applied to GKR. Clearly, further research would be informative as the need for future translocations is likely given the continuing development activities in GKR habitat.

Acknowledgments.—This project was funded by California Resources Corporation (formally Occidental Elk Hills) and conducted under the Bureau of Land Management 2001 Oil and Gas Programmatic Biological Opinion (1-1-01-F-0063), the 1995 Elk Hills Maximum Production Biological Opinion (1-1-95-F-103), California Department of Fish and Wildlife Incidental Take Permit 2081-2011-026-04, and U.S. Fish and Wildlife Service Recovery permit TE019489-1. Bill Van Herweg assisted in trapping at the donor site, and Brian Berry and Matt Perry helped build the release pens. Todd Becky, Bailey Christenson, Colton Parrish, Maria Myers, Monte Myers, and Travis Toliver assisted in trapping, pen construction, and post release monitoring. Animal handling procedures adhered to guidelines established by the American Society of Mammalogists (Sikes et al. 2016).

Literature Cited

Armstrong, D.P., and P.J. Seddon. 2008. Directions in reintroduction biology. Trends in Ecology and Evolution 23:20–25.

Banks, P.B., K. Norrdahl, and E. Korpimäki. 2002. Mobility decisions and the predation risks of reintroduction. Biological Conservation 103:133–138.

di Stefano, J. 2003. How much power is enough? Against the development of an arbitrary convention for statistical power calculations. Functional Ecology 17:707–709.

Dickens, M.J., D.J. Delehanty, and L.M. Romero. 2010. Stress: an inevitable component of animal translocation. Biological Conservation 143:1329–1341.

Fischer, J., and D. Lindenmayer. 2000. An assessment of the published results of animal relocations. Biological Conservation 96:1–11.

Germano, D.J. 2001. Assessing translocation and reintroduction as mitigation tools for Tipton kangaroo rats (*Dipodomys nitratoides nitratoides*). Transactions of the Western Section of The Wildlife Society 37:71–76.

Germano, D.J. 2010. Survivorship of translocated kangaroo rats in the San Joaquin Valley, California. California Fish and Game 96:82–89.

Germano, D.J. and L.R. Saslaw. 2017. Rodent community dynamics as mediated by environment and competition at a site in the San Joaquin Desert. Journal of Mammalogy 98:1615–1626.

Germano, D.J., G.B. Rathbun, L.R. Saslaw, B.L. Cypher, E.A. Cypher, and L. Vredenberg. 2011. The San Joaquin Desert of California: ecologically misunderstood and overlooked. Natural Areas Journal 31:138–147.

Germano, D.J., L.R. Saslaw, P.T. Smith and B.L. Cypher. 2013. Survivorship and reproduction of translocated Tipton kangaroo rats in the San Joaquin Valley, California. Endangered Species Research 19:265–276

Griffith, B., J.M. Scott, J.W. Carpenter, and C. Reed. 1989. Translocation as a species conservation tool: status and strategy. Science 245:477–480.

Hamilton, L.P., P.A. Kelly, D.F. Williams, D.A. Kelt, and H.U. Wittmer. 2010. Factors associated with survival of reintroduced Riparian Brush Rabbits in California. Biological Conservation 143:999–1007.

International Union for the Conservation of Nature (IUCN). 2013. Guidelines for reintroductions and other conservation translocations. Version 1.0. IUCN Species Survival Commission, Gland, Switzerland. 35 p.

O'Farrell, M.J. 1999. Translocation of the endangered

San Bernardino Kangaroo Rat. Transactions of the Western Section of The Wildlife Society 35:10–14.

Prugh, L.R., N. Deguines, J.B. Grinath, K.N. Suding, W.T. Bean, R. Stafford, and J.S. Brashares. 2018. Ecological winners and losers of extreme drought in California. Nature Climate Change 8:819–824.

Randall, J.A., E.R. Hekkala, L.D. Cooper, and J. Barfield. 2002. Familiarity and flexible mating strategies of a solitary rodent, *Dipodomys ingens*. Animal Behaviour 64:11–21.

Reichman, O.J. 1983. Behavior of desert Heteromyids. Great Basin Naturalist Memoirs 7:77–90.

Reichman, O.J., D.T. Wicklow, and C. Rebar. 1985. Ecological and mycological characteristics of caches in the mounds of *Dipodomys spectabilis*. Journal of Mammalogy 66:643–651.

Sawyer, J.O., T. Keeler-Wolf, and J.M. Evens. 2009. A manual of California vegetation. 2nd Edition. California Native Plant Society, Sacramento, California. 471 p.

Scherer, R.D., and J.A. Tracey. 2011. A power analysis for the use of counts of egg masses to monitor Wood Frog (*Lithobates sylvaticus*) populations. Herpetological Conservation and Biology 6:81–90.

Shier, D.M. 2006. Effect of family support on the success of translocated Black-tailed Prairie Dogs. Conservation Biology 20:1780–1790.

Shier, D.M., and R.R. Swaisgood. 2012. Fitness costs of neighborhood disruption in translocations of a solitary mammal. Conservation Biology 26:116–123.

Sikes, R.S., and the Animal Care and Use Committee of the American Society of Mammalogists. 2016. 2016 guidelines of the American Society of Mammalogists for the use of wild mammals in research and education. Journal of Mammalogy 97:663–688.

Taylor, B.L., and T. Gerrodette. 1993. The uses of statistical power in conservation biology: the Vaquita and Northern Spotted Owl. Conservation Biology 7:489–500.

Tennant, E.N., and D.J. Germano. 2013. Competitive interactions between Tipton and Heermann's kangaroo rats in the San Joaquin Valley, California. Southwestern Naturalist 58:258–264.

Tennant, E.N., and D.J. Germano. 2017. Survival of translocated Heermann's Kangaroo Rats (*Dipodomys heermanni*) in the San Joaquin Valley of California using hard and soft release methods. Western Wildlife 4:1–11.

Tennant, E.N., D.J. Germano, and B.L. Cypher. 2013. Translocating endangered kangaroo rats in the San Joaquin Valley of California: recommendations for future efforts. California Fish and Game 99:90–103.

Twisselmann, E.C. 1967. A flora of Kern County, California. Wasmann Journal of Biology 25:1–395.

U.S. Fish and Wildlife Service (USFWS). 1998. Recovery plan for upland species of the San Joaquin Valley, California. U.S. Fish and Wildlife Service, Portland, Oregon. 319 p.

Williams, D.F., H.H. Genoways, and J.K. Braun. 1993. Taxonomy. Pp. 38–196 *in* Biology of the Heteromyidae. Genoways, H.H., and J.H. Brown (Eds). Special Publication No. 10, American Society of Mammalogists, Provo, Utah.

Williams, D.F., D.J. Germano, and W. Tordoff, III. 1993. Population studies of endangered kangaroo rats and Blunt-nosed Leopard Lizards in the Carrizo Plain Natural Area, California. Report 93-01, Nongame Bird and Mammal Section, California Department of Fish and Game, Sacramento, California.

Williams, D.F., and K.S. Kilburn. 1991. *Dipodomys ingens*. Mammalian Species 377:1–7.

Williams, D.F., W. Tordoff, III, and D.J. Germano. 1997. Evaluation of methods for permanently marking kangaroo rats (*Dipodomys*: Heteromyidae). Pp. 259–271 *in* Life Among the Muses: Papers in Honor of James S. Findley. Yates, T.L., W.L. Gannon, and D.E. Wilson (Eds.). Special Publication of the Museum of Southwestern Biology, Number 3, Albuquerque, New Mexico.

Zar, J.H. 1984. Biostatistical Analysis. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Larry Saslaw is a Research Technician with the Endangered Species Recovery Program, Bakersfield, California. Larry worked as a Wildlife Biologist for the Bureau of Land Management, Bakersfield Field Office, California, from 1985 to his retirement in 2011. He continues his interest in the conservation and recovery of San Joaquin Desert listed species through the various studies conducted by ESRP and others. (Photograph by Dan Hack).

Brian Cypher is the Director of and a Research Ecologist with the Endangered Species Recovery Program of California State University, Stanislaus. His primary research interest is the ecology and conservation of wild canids. Since 1990, he has been involved in research and conservation efforts for endangered San Joaquin Kit Foxes (*Vulpes macrotis mutica*) and other sensitive species in the San Joaquin Valley of California. (Photograph by Larry Saslaw).