Conservation of Endangered Tipton Kangaroo Rats (*Dipodomys nitratoides nitratoides*): Status Surveys, Habitat Suitability, and Conservation Strategies

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EXECUTIVE SUMMARY

Tipton kangaroo rats (*Dipodomys nitratoides nitratoides*: TKR) are endemic to the southern San Joaquin Valley in central California. TKR once were widely distributed in arid scrub habitats on the valley floor but much of this habitat has been converted to agricultural, urban, and industrial uses. Habitat loss within the range of TKR is still occurring and this continuing loss threatens to extirpate existing populations and could even preclude recovery. A critical need is to identify remaining populations and also attributes of suitable habitat so that conservation efforts can be optimized by focusing on areas that will provide the greatest benefit to conservation and recovery efforts. Objectives of this project were to (1) conduct surveys throughout the range to identify sites where TKR were extant, (2) assess habitat attributes on all survey sites, (3) use the attribute data from sites with and without TKR to generate a GIS-based model of TKR habitat suitability in the southern San Joaquin Valley, (4) extend the model across the TKR range to determine the quantity and quality of remaining habitat, and (5) use the results from the above tasks to develop conservation recommendations.

Using sites known to be occupied by TKR, we used GIS analysis to develop an initial habitat suitability map that was applied across the range of TKR. Using this map, we then identified potential sites to survey for TKR. On 44 sites where access was granted, we surveyed for TKR by live-trapping. TKR were detected on 15 of the sites.

On each of the 44 sites surveyed, we also collected habitat attribute data including information on topography, shrubs, ground cover, and past and current disturbances. Sites with TKR tended to have larger alkali scalds and no obvious sign of past tilling compared to sites without TKR. Also, sites with TKR usually had relatively sparse ground cover and seepweed was present. Finally, a larger competitor, Heermann's kangaroo rat (*Dipodomys heermanni*), was either absent or present in relatively low numbers at sites with TKR, and when present its abundance was inversely related with that of TKR.

Habitat attributes from sites with and without TKR were used to further refine the habitat suitability model. The final model was applied across the range of TKR and revealed that an estimated 30,000 ha of moderately-high or high quality habitat and 60,000 ha of lower quality habitat remain. However, habitat is still being lost and conversion of at least one survey site with TKR occurred during this project.

Recommendations resulting from this project are to (1) conduct additional TKR surveys on additional sites as opportunities present themselves, (2) conserve habitat on unprotected lands where TKR have been detected as well as lands with highly suitable habitat, (3) manage vegetation on lands if necessary to reduce ground cover and enhance suitability for TKR, (4) conduct further research into translocation strategies, (5) conduct translocations of TKR to unoccupied sites with suitable habitat, and (6) develop and test strategies for restoring disturbed lands to make them suitable for occupation by TKR.

INTRODUCTION

Tipton kangaroo rats (*Dipodomys nitratoides nitratoides*: TKR) are endemic to the southern San Joaquin Valley in central California (U.S. Fish and Wildlife Service 1998). TKR are one of three subspecies of the San Joaquin kangaroo rat. TKR once were widely distributed on the Valley floor from about the Kings River in Kings County down to the southern end of the Valley in Kern County (Figure 1). They occur in arid scrub habitats on the valley floor but much of this habitat has been converted to agricultural, urban, and industrial uses (U.S. Fish and Wildlife Service 1998). By 1985, only an estimated 3.7% of historical habitat remained, and many of these lands consisted of small, isolated fragments of varying quality (Germano and Williams 1992). Due to this profound habitat loss, fragmentation, and degradation, TKR were listed as Federally Endangered in 1988 and California Endangered in 1989.

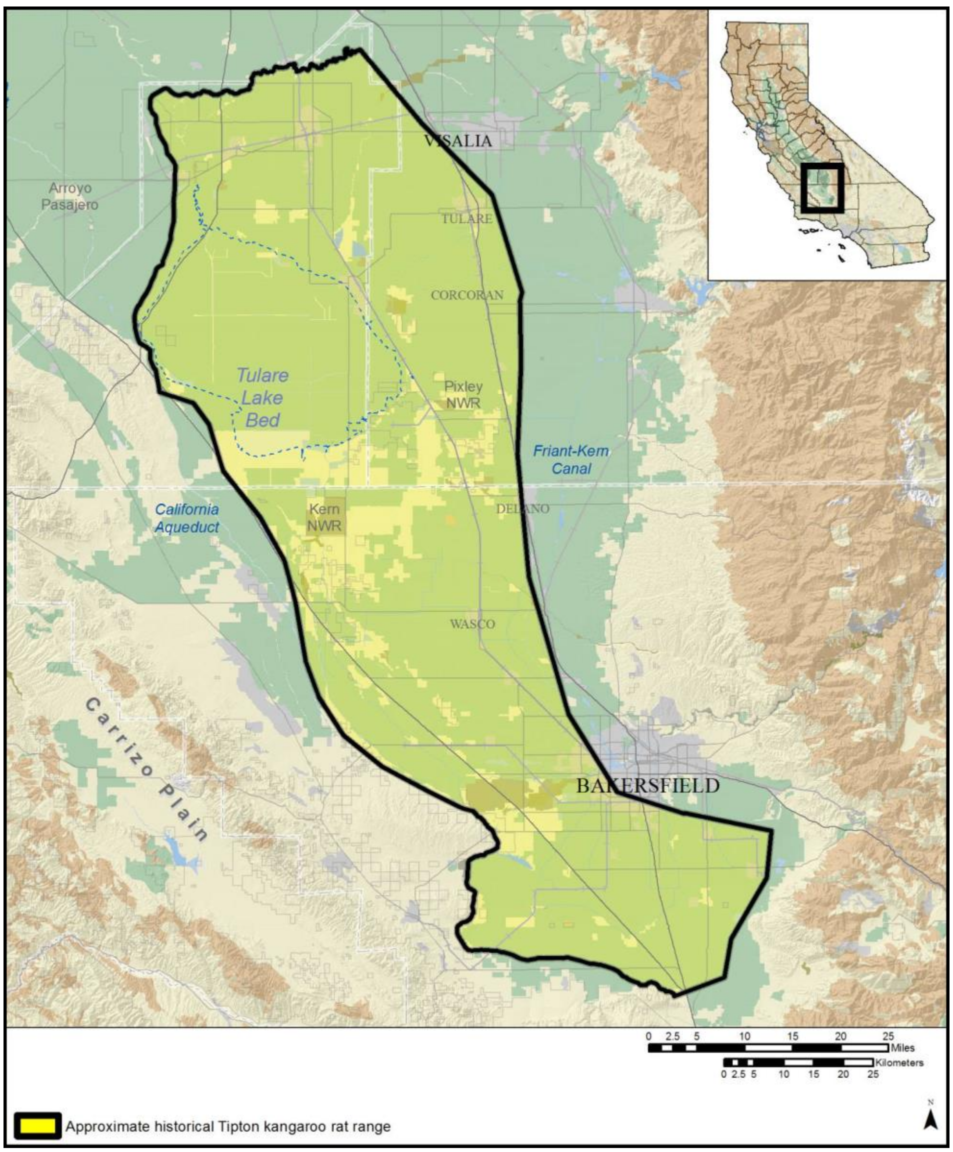

Figure 1. Range map for Tipton kangaroo rat in the San Joaquin Valley, California.

Based on recent survey and monitoring efforts, TKR are known to persist in some locations (U.S. Fish and Wildlife Service 2010). However, habitat loss within the range of TKR is still occurring and this continuing loss threatens to extirpate existing populations and could even preclude recovery. A critical need is to identify remaining populations and also attributes of suitable habitat so that conservation efforts can be optimized by focusing on areas that will provide the greatest benefit to conservation and recovery efforts.

The goal of this project was to generate information and tools that will significantly enhance conservation and recovery efforts for endangered TKR. Specific objectives were to (1) conduct surveys throughout the range to identify sites where TKR were extant, (2) assess habitat attributes on all survey sites, (3) use the attribute data from sites with and without TKR to generate a GIS-based model of TKR habitat suitability in the southern San Joaquin Valley, (4) extend the model across the TKR range to determine the quantity and quality of remaining habitat, and (5) use the results from the above tasks to develop conservation recommendations.

METHODS

STUDY AREA

The study area for this project was the southern San Joaquin Valley within the range of TKR (Figure 1). This area is within the region known as the San Joaquin Desert (Germano et al. 2011). The regional climate is Mediterranean in nature, and is characterized by hot, dry summers, and cool, wet winters with frequent fog. Mean maximum and minimum temperatures are 35°C and 18°C in summer, and 17°C and 5°C in winter. Annual precipitation averages ca. 15 cm and occurs primarily as rain falling between October and April (National Oceanic and Atmospheric Administration 2002).

Most of the region within the range of TKR is largely flat valley bottom land with elevations generally around 100 m. Vegetation is characterized by desert scrub habitat on the upland sites and alkali sink habitats on the valley floor. Historically, there were riparian corridors along rivers and creeks that carried runoff water from the Sierra Nevada into the valley. This water collected in shallow lakes that were surrounded by seasonal wetlands (Griggs et al. 1992). Most of the riparian and wetland habitats are now gone and large proportions of the desert scrub and alkali sink habitats also have disappeared due to conversion of natural lands to agricultural, industrial, and urban uses (U.S. Fish and Wildlife Service 1998, Kelly et al. 2005).

INITIAL HABITAT SUITABILITY MODELING

To identify locations to target for TKR surveys, we initially conducted a habitat suitability analysis using existing information. We consulted with colleagues who had conducted small mammal surveys in the southern San Joaquin Valley to identify sites where TKR had been detected. Some of these sites were long-term monitoring plots; these sites were particularly valuable because in addition to TKR presence they also provided information on persistence over time. We qualitatively categorized sites based on TKR abundance and persistence (Table 1).

Table 1. Qualitative Tipton kangaroo rat habitat quality categories based on abundance and presence.

Site quality category	TKR abundance and persistence
High	Multiple TKR captured during a given trapping effort and TKR are consistently present based on annual monitoring or repeated surveys
Medium	Only 1 or 2 TKR captured during a given trapping effort or TKR are only intermittently detected based on annual monitoring or repeated surveys
Low	Site surveyed or monitored but TKR not detected

Based on this screening, we identified 8 high quality sites, 8 medium quality sites, and 8 low quality sites. Remotely sensed attributes from these sites were used to construct the initial habitat suitability model. Habitat variables used to construct the model were land use/land cover, and the amount of bare ground. We included the amount of bare ground because at the time, a detailed vegetation map defining areas of desert scrub and alkali sink habitats on the valley floor was not available.

We started by creating a model boundary to include TKR range on the east side of the San Joaquin Valley floor (east of Tulare Lake and the California Aqueduct) floor, south of the Kings River. Within that boundary, we used both current land use GIS layers (DWR 2012, FMMP 2012) and historical (early 1980's) land use GIS layers (USGS 2007) to identify lands that are both undeveloped now and in the past. Within areas of undeveloped rangeland with a minimum area of 10 acres (4 ha), we estimated the amount of peak growing season bare ground cover using the Web-Enabled Landsat Data (WELD), *Peak growing season Bare Ground cover per 30m pixel* dataset (USGS 2013).

Using our initial 24 sites around the TKR range that were of low, medium or high quality habitat, we compared the amount of ground cover at the 24 sites to classify the percentage of bare ground into four habitat quality categories of *Low*, *Medium*, *High*, and *Likely Disturbed*. Low quality was defined as having less than 29% bare ground, medium between 29% and 42% bare ground, and high quality between 42% and 60% bare ground. Areas with greater than 60% bare ground appeared to be highly disturbed by oil development or disking.

The model results were applied across the landscape within the TKR range to produce an initial map of habitat suitability (Figure 2). Using this map, we selected sites within high and medium suitability areas to survey for TKR. The specific sites we chose to survey were those for which access was granted by the landowner and for which no long-term monitoring was being conducted.

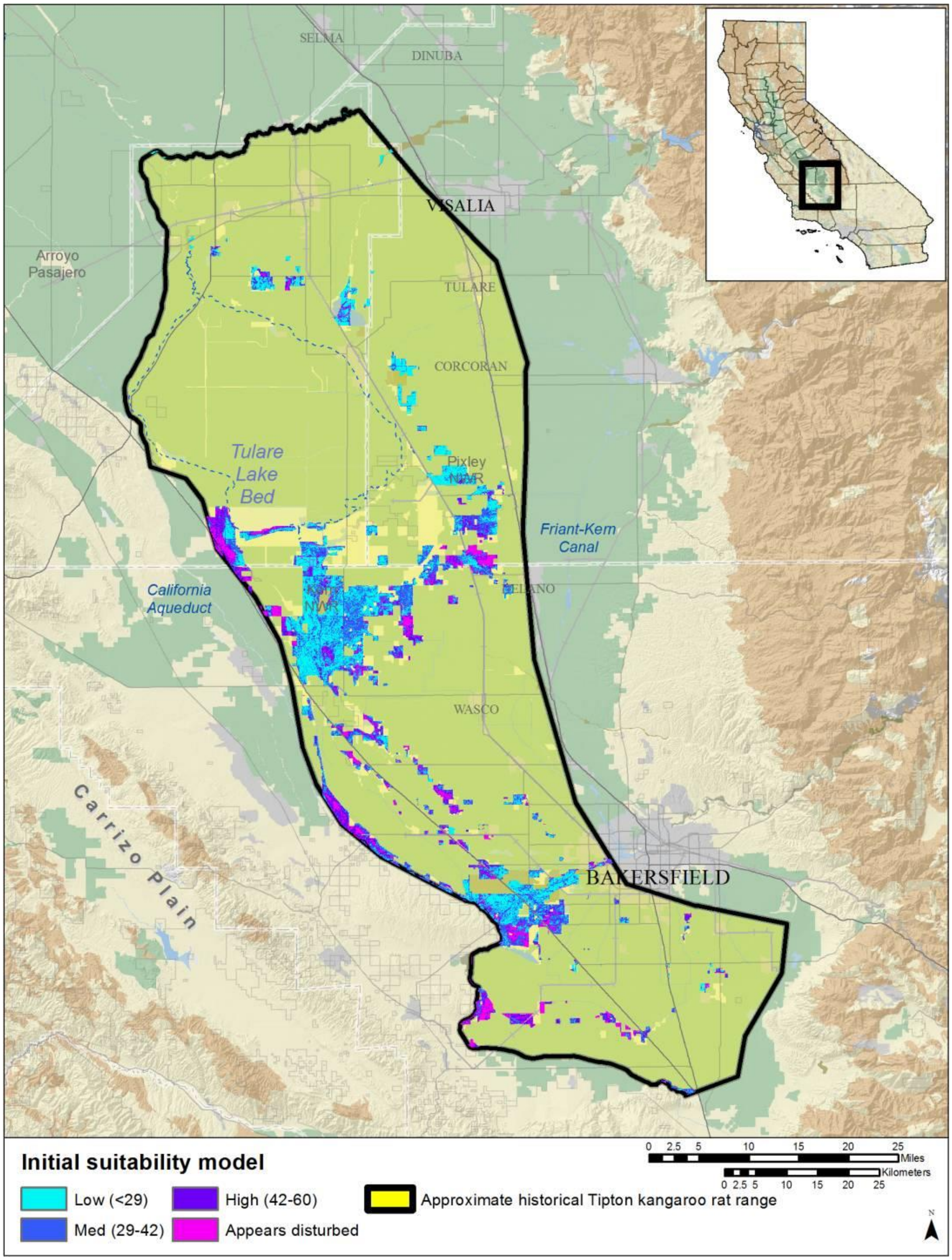

Figure 2. Initial map of habitat suitability for the Tipton kangaroo rat in the southern San Joaquin Valley, CA.

SURVEYS

On sites with potential habitat for TKR and for which access was granted, we surveyed for TKR by live-trapping. We used 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 the long tails of kangaroo rats. Traps were spaced 10-15 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 and sex were recorded, and then animals were marked on their ventral side with a non-toxic felt-tipped marker to identify recaptures.

Trapping methods varied on a few sites. On most sites, 2 lines of 15 or 20 traps were set (the number of traps depended upon the amount of potential habitat on a given site). The lines generally meandered so that traps could be set in close proximity to areas with kangaroo rat activity (e.g., active burrows, fresh scats, dust baths). However, a few sites were surveyed opportunistically as part of other efforts, such as trapping to determine the presence and distribution of TKR on development project sites. On these sites, more traps were generally deployed and trapping was conducted for more nights.

Due to funding limitations, we trapped on most sites for just 2 nights. Prior experience suggested that on sites with high quality habitat, TKR usually were detected during the first night of trapping. To further assess detection rates, we examined data provided by colleagues who were conducting annual TKR monitoring on multiple monitoring plots. We asked them to rate habitat quality on each of the plots and then compared that to number of nights to first TKR capture on each plot.

HABITAT ATTRIBUTES

At each site surveyed for TKR, habitat attributes were characterized and recorded (Appendix A). This information was primarily qualitative so that a relatively large area (several hectares) could be characterized quickly (ca.15 minutes). Information recorded (see Appendix B for more detailed descriptions of attributes) included:

- Presence of alkali scalds (playas)
- Size of scalds – large, medium, or small
- Presence of shrubs
- Density of shrubs – sparse, medium, or dense
- Common shrub species
- Ground cover density – sparse, medium, or dense
- Common herbaceous species
- Presence of anthropogenic disturbances
- Presence of microtopography – flat, gentle undulations, or larger mounds
- Distance to active agriculture – as measured on Google Earth

For shrubs, iodine bush (*Allenrolfea occidentalis*) and seepweed (*Suaeda moquinii*) are commonly associated with TKR habitat (U.S. Fish and Wildlife Service 1998) and so the presence of these species was of particular interest. For categorical variables, frequencies were compared between sites with and without TKR using contingency table analyses with a Yate's correction for continuity applied on 2x2 analyses.

To further explore variables that might affect TKR presence and abundance, we compared the frequency of the presence of Heermann's kangaroo rats (*D. heermanni*; HKR) between sites with and without TKR using contingency table analyses with a Yate's correction for continuity. We also compared the mean number of HKR captured per 100 trapnights between sites with and without TKR using a paired *t*-test. Finally, for sites where TKR were present, we used regression analysis to examine the relationship between TKR and HKR abundance (number per 100 trapnights). Because of the presence of a number of zero values for HKR abundance, a square root transformation was applied to the data to correct normality prior to conducting the regression analysis.

FINAL HABITAT SUITABILITY MODELING

A final habitat suitability model was produced using information on habitat attributes from the sites surveyed for TKR. In particular, any attributes that differed significantly between sites with and without TKR were used to modify the model. Furthermore, information on vegetation communities also was incorporated into the model. Vegetation communities have been recently mapped in the San Joaquin Valley (CSUC-GIC 2016) and the distribution of communities that TKR are known to use were incorporated into the model.

We ranked map units from the newly-mapped vegetation communities from highest quality habitat (Rank 1) to low-quality habitat (Rank 4; Table 3). We used the newly-mapped vegetation communities to identify areas of rangelands (grassland and scrub communities, Table 2) to include as potential habitat with a rank of 4 (*low* quality) or better (Figure 3, Table 3). Within these rangelands, we used both current land use GIS layers (DWR 2012, FMMP 2012) and historical (early 1980's) land use GIS layers (USGS 2007) to identify lands that are both undeveloped now and in the past (i.e., we assumed them to be undisturbed or untilled; Figure 4, Table 3). We assigned undisturbed rangelands with a minimum area of 10 acres (4 ha) a rank of 3 (*medium* quality) or better. Within these undisturbed rangelands, we identified map units with a mean percentage of bare ground (USGS 2013) greater than 29% (Figure 5, Table 3). This corresponds to the categories of *medium* or *high* quality in our initial habitat suitability model. We assigned undisturbed rangelands with a mean percentage of bare ground >29% a rank of 2 (*moderately-high* quality) or better. Within undisturbed rangelands with greater than 29% mean bare ground, we ranked alkali sink communities (Table 2) as the highest-quality (rank 1; Figure 6, Table 3).

Table 2. Vegetation classes from CSUC-GIC (2016) used in our analysis of Tipton kangaroo rat habitat suitability.

Vegetation Class	NVCSNAME	NVCSLEVEL
Alkali sink	Allenrolfea occidentalis	Alliance
	Suaeda moquinii	Alliance
	Southwestern North American salt basin and high marsh	Group
	Frankenia salina	Alliance
	Atriplex lentiformis	Alliance
	Atriplex spinifera	Alliance
	Isocoma acradenia	Provisional Association
Desert scrub	Atriplex polycarpa	Alliance
	Ambrosia salsola	Alliance
	Prosopis glandulosa	Alliance
	Atriplex canescens	Alliance
	Lepidospartum squamatum	Alliance
Grassland	California annual forb/grass vegetation	Group
	Centaurea (virgata)	Provisional Semi-Natural Alliance
	California Annual and Perennial Grassland	Macrogroup
	Mediterranean California naturalized annual and perennial grassland	Group
Saline wetland	Distichlis spicata	Alliance
	Western North American disturbed alkaline marsh and meadow	Group
	Bolboschoenus maritimus	Alliance
	Sesuvium verrucosum	Alliance
Barren	Barren	-

Table 3. Habitat ranking criteria used in the habitat suitability analysis for the Tipton kangaroo rat.

Land use	Disturbance	% Barren	Vegetation	Habitat rank
Rangeland	Undisturbed	> 29%	Alkali sink	1
			Other rangeland	2
		=< 29%		3
	Disturbed	-	-	4

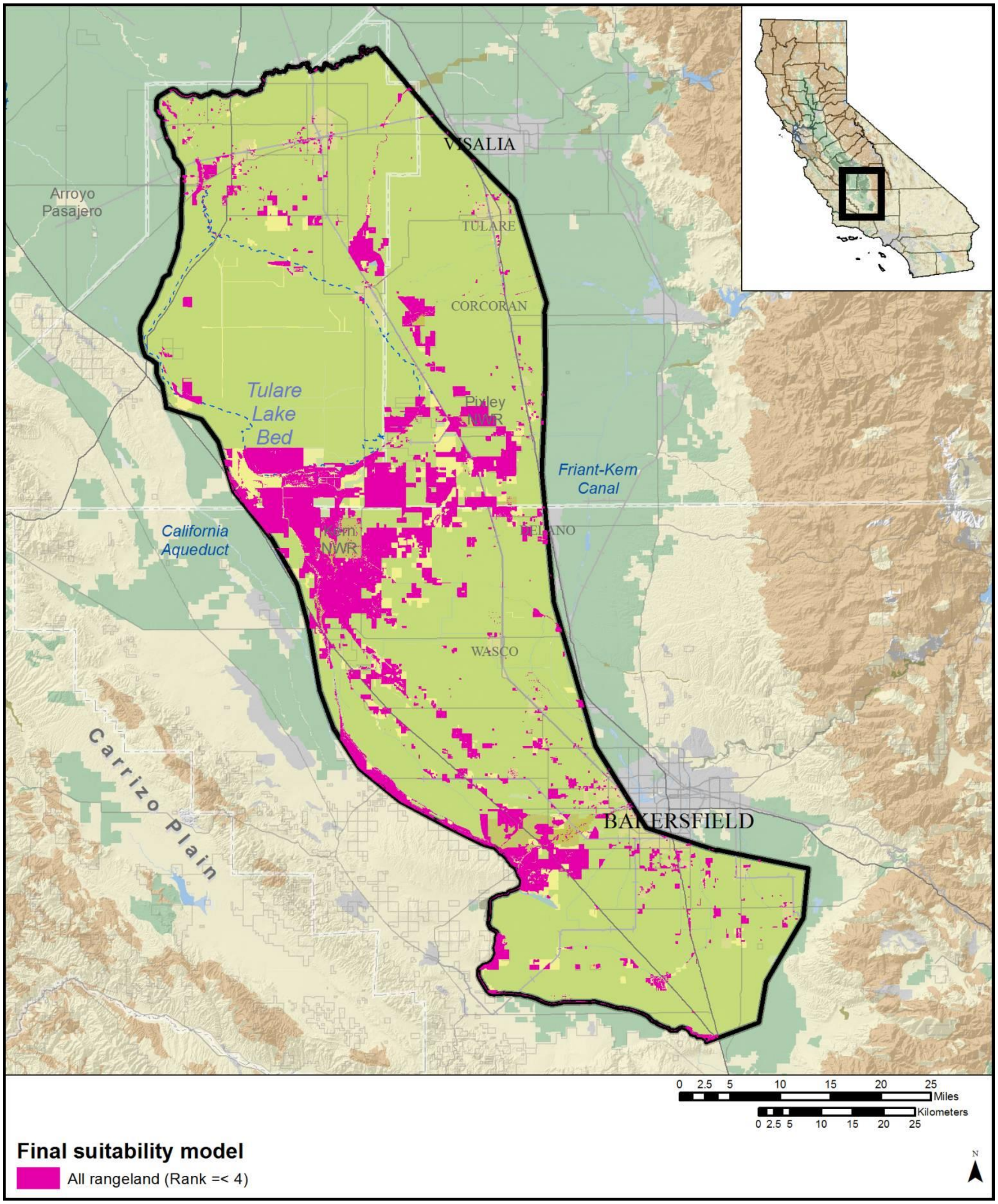

Figure 3. Rangelands within the range of the Tipton kangaroo rat.

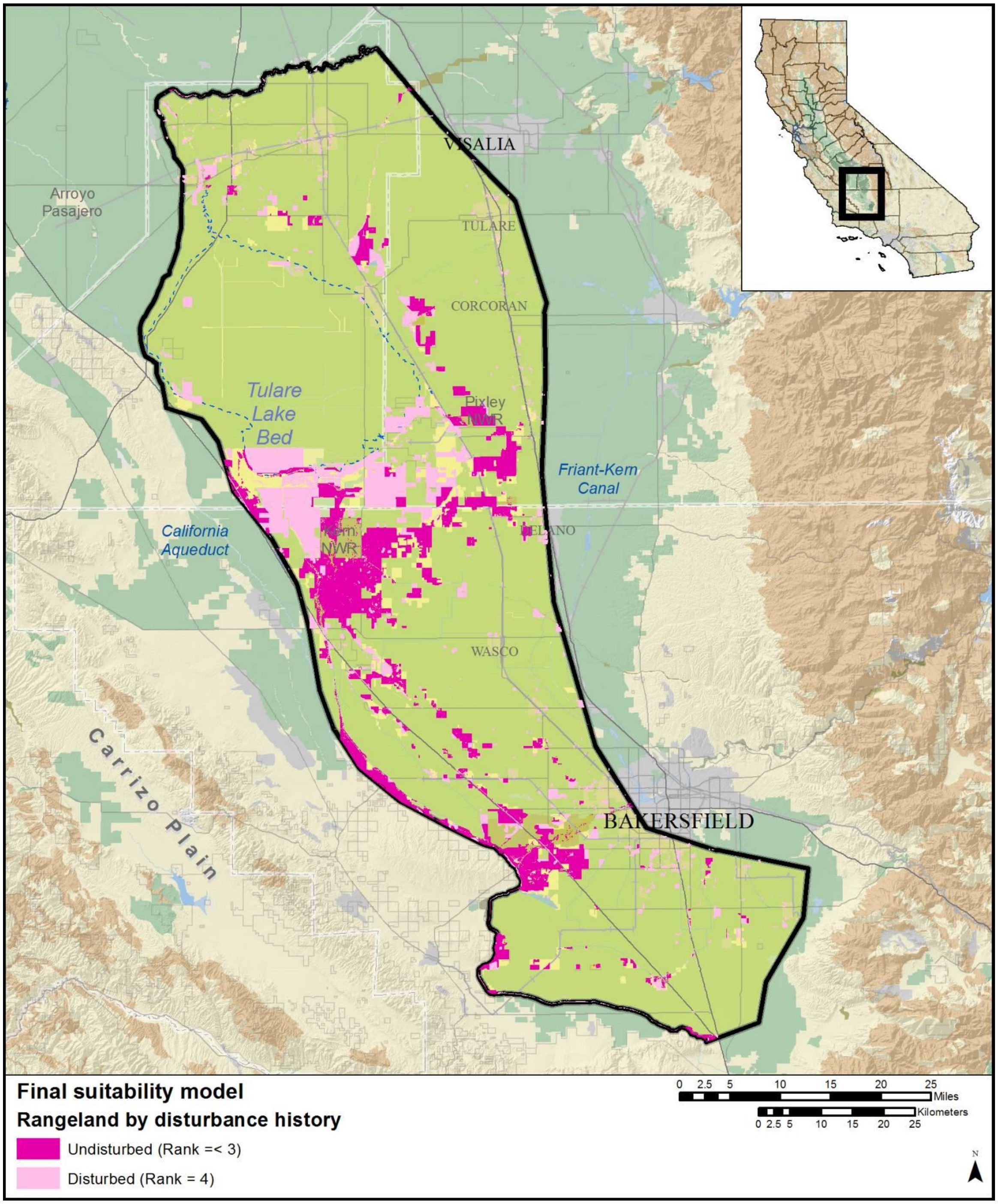

Figure 4. Rangeland by disturbance history within the range of the Tipton kangaroo rat.

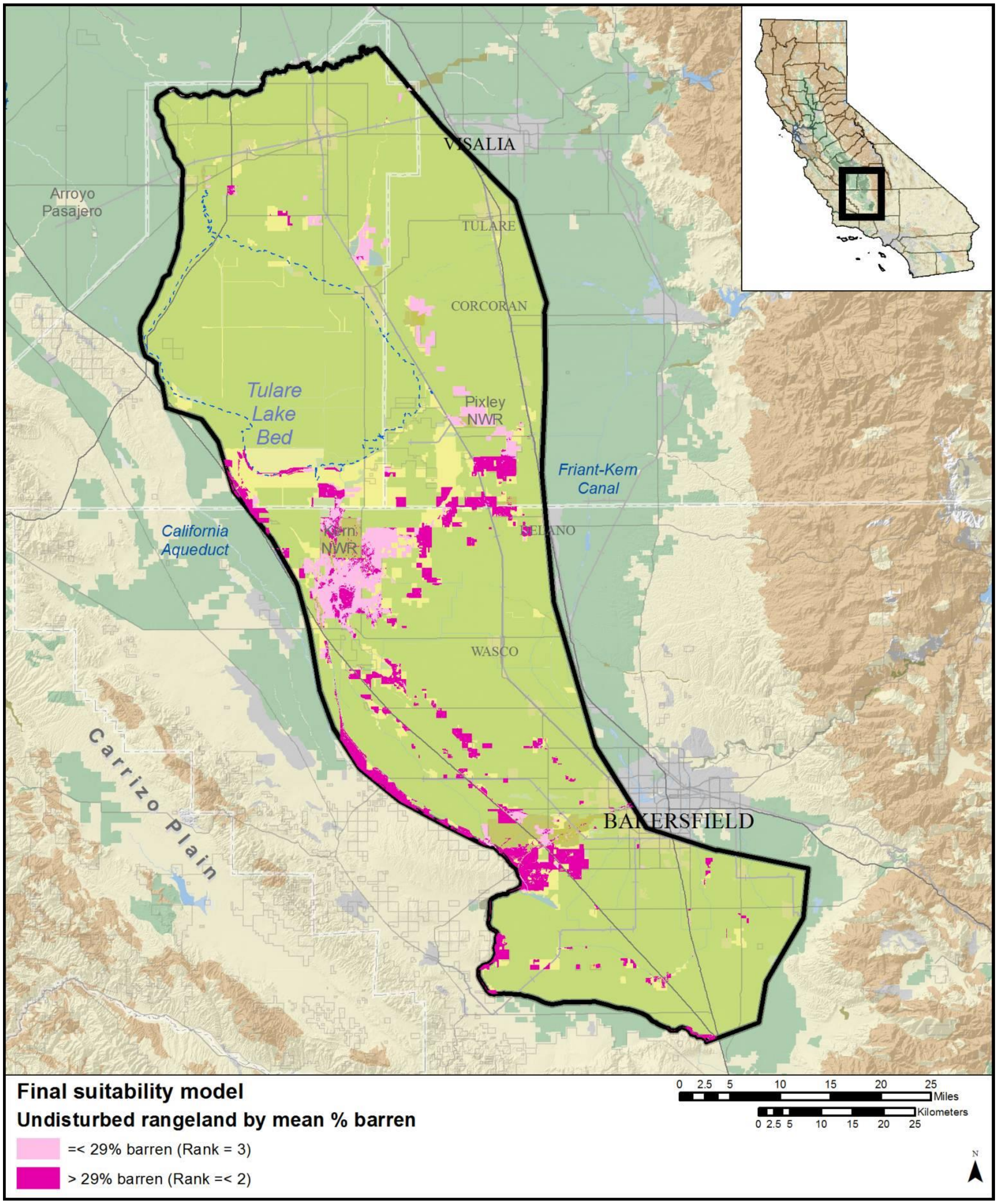

Figure 5. Undisturbed rangeland by mean percent barren within the range of the Tipton kangaroo rat.

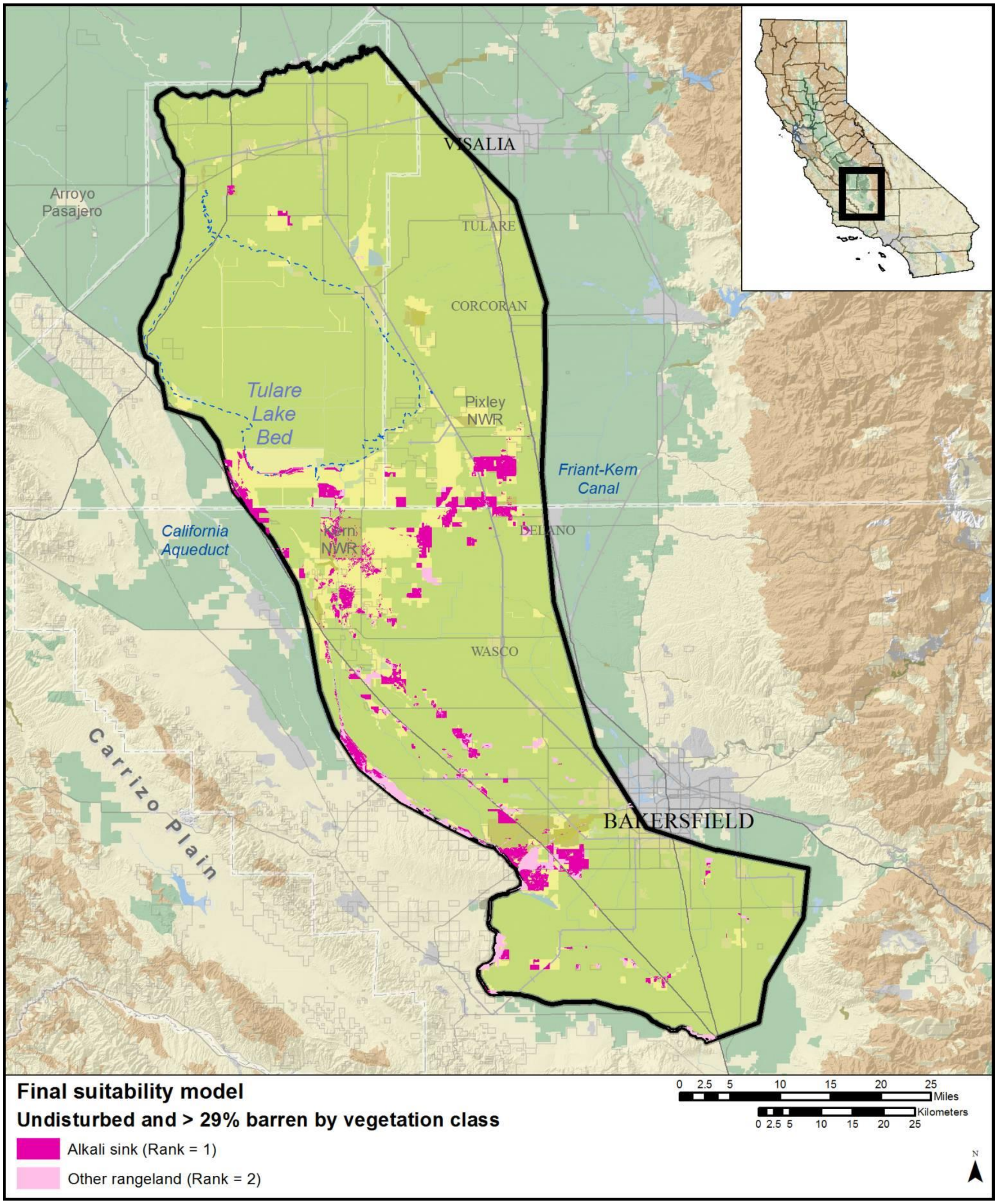

Figure 6. Undisturbed rangeland with greater than 29% bare ground by vegetation class within the range of the Tipton kangaroo rat.

ANALYSES

Statistical tests were conducted using Excel (Microsoft Excel v. 2010) or Social Science Statistics (http://www.socscistatistics.com/tests/Default.aspx). *P*-values ≤ 0.05 were considered significant.

RESULTS

SURVEYS

We conducted surveys on 44 sites (see Appendices B and C). Most of the surveys were conducted during October 2013-May 2014. Information from 4 additional survey efforts conducted in November 2012, October 2014, and March 2015 also were included in our analyses. Of these 44 surveys, 32 were on CDFW lands, 5 were on private lands, and 7 were on federal conservation lands (Pixley National Wildlife Refuge, Bureau of Land Management). TKR were captured on 15 sites, and were not detected on 29 sites (Figure 7).

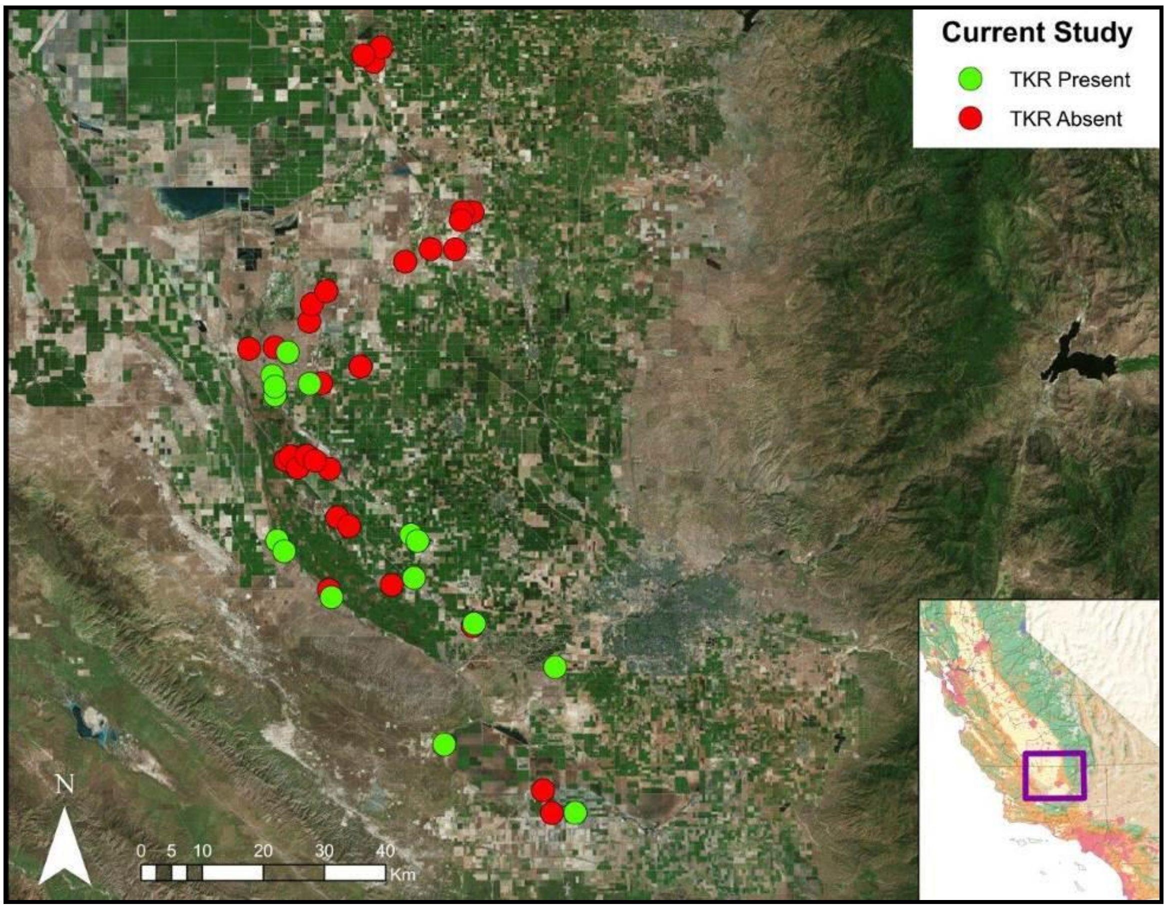

Figure 7. Sites (n = 44) surveyed for Tipton kangaroo rats in the southern San Joaquin Valley, California.

TKR capture information was provided by the Center for Natural Lands Management for 6 long-term monitoring grids in the Semitropic Ridge area in northern Kern County. Five of the grids are considered to have high quality habitat and 1 grid is considered to have lower quality habitat. Annual 5-night trapping sessions have been conducted on the grids since 2001, although some grids were not trapped in some years. For the 79 sessions completed on the 5 grids with high quality habitat, TKR were detected on the first night of trapping in all 79 sessions. For the 12 sessions completed on the grid with lower quality habitat, TKR were first detected on the first night in 9 sessions, second night in 2 sessions, and fifth night in 1 session.

TKR capture information also was provided by South Valley Biology Consulting for 9 long-term monitoring grids within the Coles Levee Ecosystem Preserve in western Kern County. No TKR have been captured on 4 of the grids. On the remaining 5 grids, 4 are considered to have high quality habitat and 1 grid is considered to have low quality habitat for TKR. Annual 5-night trapping sessions have been conducted on the grids since 2009. For the 32 sessions completed on the 4 grids with high quality habitat, TKR were first detected on the first night of trapping in 27 sessions, the second night in 4 sessions, and the third night in 1 session. For the 8 sessions completed on the grid with low quality habitat, TKR were not detected in 5 nights of trapping during 7 of the sessions, but were detected on the first night for 1 session.

HABITAT ATTRIBUTES

Habitat attribute data were collected for all sites surveyed for TKR (Table 4). Significant differences were not detected for most attributes. However, sites with TKR tended to have larger sized scalds (Table 4). Obvious signs of past tilling were present on a greater proportion of sites without TKR (75.9%) compared to sites with TKR (7.7%; Table 4).

Table 4. Habitat attributes on sites with and without Tipton kangaroo rat detections during surveys conducted in the southern San Joaquin Valley, CA.

Attribute	Sites w/ TKR (n = 15)	Sites w/o TKR (n = 29)	Statistical tests
Scalds present	Yes: 12 (80.0%) No: 3 (20.0%)	Yes: 25 (86.2%) No: 4 (13.8%)	$\chi^2 = 0.28$, 1 df $p = 0.59$
Scald size	Large: 9 (75.0%) Medium: 1 (8.3%) Small: 2 (16.7%)	Large: 8 (32.0%) Medium: 13 (52.0%) Small: 6 (24.0%)	$\chi^2 = 7.72$, 1 df $p = 0.02$
Shrubs present	Yes: 15 (100%) No: 0 (0.0%)	Yes: 29 (100%) No: 0 (0.0%)	-
Shrub density	Dense: 1 (6.7%) Medium: 10 (66.6%) Sparse: 4 (26.7%)	Dense: 3 (10.3%) Medium: 15 (51.7%) Sparse: 11 (38.0%)	$\chi^2 = 0.90$, 2 df $p = 0.64$
Iodine bush present	Yes: 6 (40.0%) No: 9 (60.0%)	Yes: 8 (27.6%) No: 21 (72.4%)	$\chi^2 = 0.70$, 1 df $p = 0.40$
Sinkweed present	Yes: 11 (73.3%) No: 4 (26.7%)	Yes: 21 (72.4%) No: 8 (27.6%)	$\chi^2 < 0.01$, 1 df $p = 0.95$
Ground cover density	Dense: 1 (6.7%) Medium: 2 (13.3%) Sparse: 12 (80.0%)	Dense: 3 (10.3%) Medium: 11 (38.0%) Sparse: 15 (51.7%)	$\chi^2 = 3.46$, 2 df $p = 0.18$
Presently grazed	Yes: 8 (53.3%) No: 7 (46.7%)	Yes: 22 (75.9%) No: 7 (24.1%)	$\chi^2 = 2.31$, 1 df $p = 0.13$
Previous tilling	Yes: 1 (7.7%) No: 14 (92.3%)	Yes: 22 (75.9%) No: 7 (24.1%)	$\chi^2 = 18.97$, 1 df $p < 0.01$
Microtopography	Flat: 5 (33.4%) ≤30 cm: 8 (53.4%) >30 cm: 2 (13.3%)	Flat: 3 (10.3%) ≤30 cm: 18 (62.1%) >30 cm: 8 (27.6%)	$\chi^2 = 3.88$, 2 df $p = 0.14$
Mean distance to agriculture	0.77 ± 0.07 km	0.61 ± 0.07 km	$t = -0.88$, 31 df $p = 0.19$

HKR were present on a lower proportion (χ^2 = 4.32, 1 df, p = 0.04) of sites with TKR (53.3%) compared to sites without TKR (82.8%). The mean number of HKR captured per 100 trapnights was lower (t = -2.73, 40 df, p = < 0.01) on sites with TKR (1.8 ± 0.6) compared to sites without TKR (4.2 ± 0.7). On sites with TKR, the number of TKR captured per 100 trapnights was negatively related ($F_{1,13}$ = 6.10, p = 0.03, r^2 = 0.32) to the number of HKR captured per 100 trapnights.

HABITAT SUITABILITY MODELING

We identified around 30,000 ha that we consider high quality (rank 1) or moderately high quality habitat (Table 5, Figure 8). We identified an additional 20,000 ha of medium-quality and 40,000 ha of low-quality habitat (Table 5, Figure 8).

Table 5. Amount of remaining habitat by suitability rank for the Tipton kangaroo rat in the southern San Joaquin Valley, CA.

Land use	Disturbance	% Barren	Vegetation	Habitat rank	Area (ha)
Rangeland	Undisturbed	> 29%	Alkali sink	1	21,267 (24%)
			Other rangeland	2	8,446 (9%)
		=< 29%		3	20,592 (23%)
	Disturbed	-	-	4	39,621 (44%)
Total					**89,926**

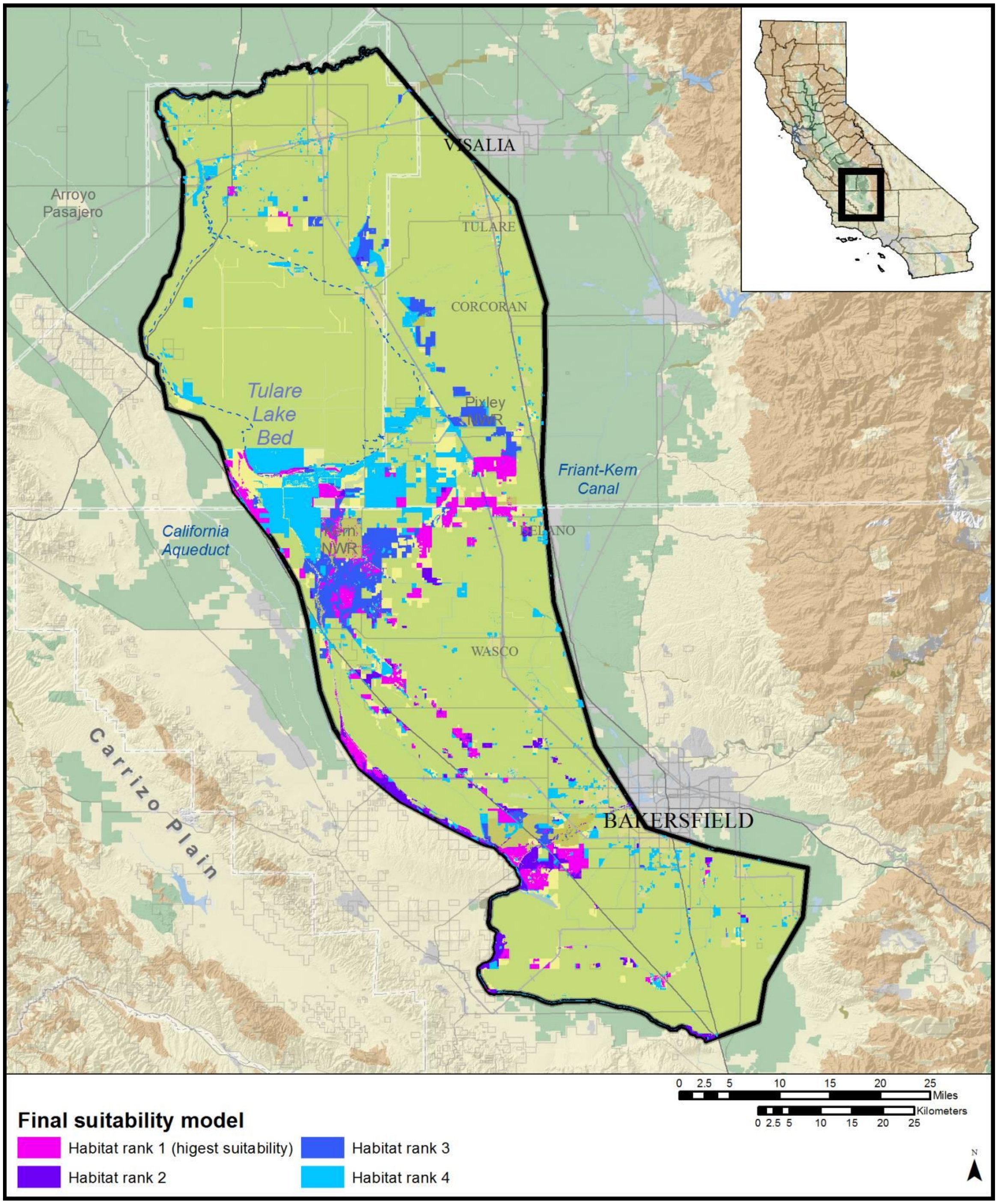

Figure 8. Results of habitat suitability modeling analysis for Tipton kangaroo rats.

DISCUSSION

TKR OCCURRENCE AND DISTRIBUTION

The TKR surveys we conducted have some inherent limitations. Most of the surveys (93%) were only conducted for a maximum of two nights. Consequently, TKR potentially may have been present but not detected on some sites. However, the rate of missed detections likely was low, based on the results from the long-term monitoring grids at the Coles Levee Ecosystem Preserve and Semitropic Ridge area. On the grids with high quality habitat at the Coles Levee Ecosystem Preserve, TKR were detected in 84% of the sessions after one night of trapping and in 97% of the sessions after two nights. TKR were only detected during one session on the grid with poor quality habitat, but that detection came on the first night of trapping. Similarly, on the grids with high quality habitat in the Semitropic Ridge area, TKR were detected in 100% of the sessions after just one night of trapping. On the grids with lower quality habitat, TKR were detected in 75% of the sessions after one night of trapping and in 92% of the sessions after two nights. Thus, when present, detection rates for TKR tend to be high in just one or two nights of trapping, even in lower quality habitat where TKR density may be lower.

In addition to a limited number of trap nights at each site, we also were only able to survey relatively small portions of most sites. A number of the sites were quite large (several hundred hectares) and we typically selected areas to trap where the habitat seemed to be in good condition and particularly where any sign of kangaroo rat activity was present. However, TKR potentially could have been present on some of sites in portions that we did not trap.

Finally, our survey results should not be considered definitive. First, as discussed above, our methodology had some inherent limitations that potentially resulted in TKR not being detected on some sites. Second, most of our surveys were conducted in 2013 and 2014. Precipitation was below average in both years and kangaroo rat populations generally were considered to be declining. Thus, TKR may have been present on some sites we surveyed, but in low density or patchy distributions, both of which would inhibit detection. Also, some sites, particularly those with lower quality habitat, may experience source-sink dynamics with regard to TKR presence whereby the animals become extirpated in years with poor conditions and then recolonize the site in years with more favorable conditions. For example, at the Coles Levee Ecosystem Preserve, TKR were not detected on the grid with low quality habitat in most years, but were detected in 2016 when conditions were favorable and kangaroo rat abundance was high regionally. Third and finally, on a regional scale, we were not able to survey in many locations with potential TKR habitat because the sites were on private lands where access was not granted. Thus, TKR likely occur on additional sites and more surveys are warranted.

Even with the caveats above, our survey results provide an informative assessment of the current distribution of TKR populations, particularly when combined with the results from other efforts. We detected TKR at 15 specific sites (see Figure 7). We also examined results of TKR trapping survey and monitoring efforts conducted during the past 20 years. These results were provided by colleagues and also by the U.S. Fish and Wildlife Service permit office in Sacramento, CA. These results yielded additional sites where TKR have been detected. At some sites, natural habitat is no longer present based on Google Earth imagery. Disregarding these sites, another 51 sites were identified where TKR were detected and presumably still occur (Figure 9, Appendix D). Combining these detections with those from our study (Figure 10) provide a current evaluation of the distribution of sites occupied by TKR. However, most of the additional sites consist of monitoring plots on conservation lands, or surveys related to proposed development projects. Thus, as previously stated, there likely are other sites occupied by TKR that have not been surveyed.

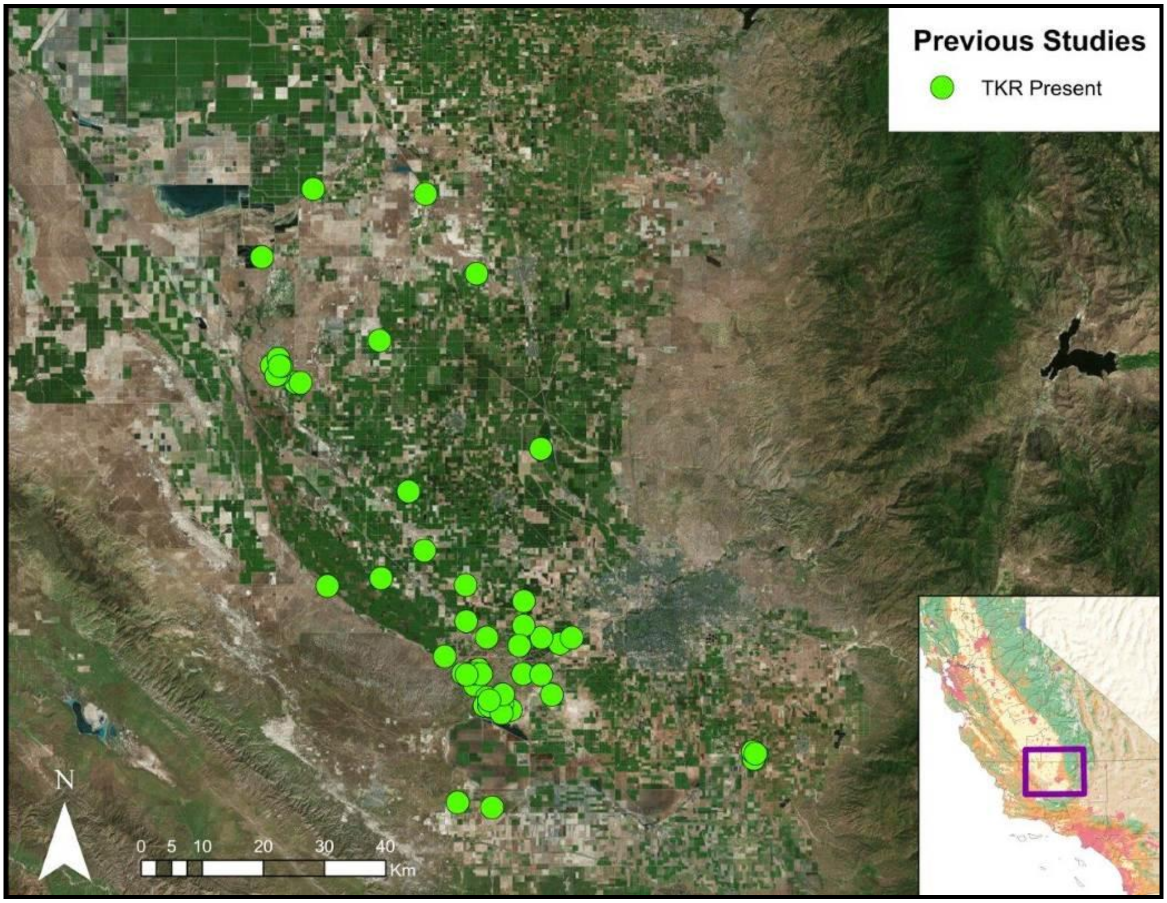

Figure 9. Sites (n = 51) at which Tipton kangaroo rats have been detected in previous survey and monitoring efforts conducted in the southern San Joaquin Valley, California.

Regarding the distribution of the sites with TKR, a number of these are in close proximity. In many cases, different portions of the same site may have been surveyed. In other cases, multiple monitoring grids may be present within a population area, such as occurs in the Coles Levee Ecosystem Preserve (9 grids) and Semitropic Ridge area (8 grids). Consequently, even though 66 sites with TKR are identified in this report (Figure 10), not all of the sites represent different populations, and the number of actual populations is much less than 66.

Sites with TKR present are distributed throughout the historic range of TKR. More sites are extant on the western side of the San Joaquin Valley because a larger proportion of the habitat on the eastern and central portions of Valley has been converted to agricultural and other incompatible uses. Furthermore, TKR habitat is still being converted. As mentioned previously, several sites surveyed by others in the past 20 years no longer have natural habitat, and one of our survey sites in this study was disked in preparation for development within months after we completed our survey. Consequently, the number of extant TKR populations continues to decline.

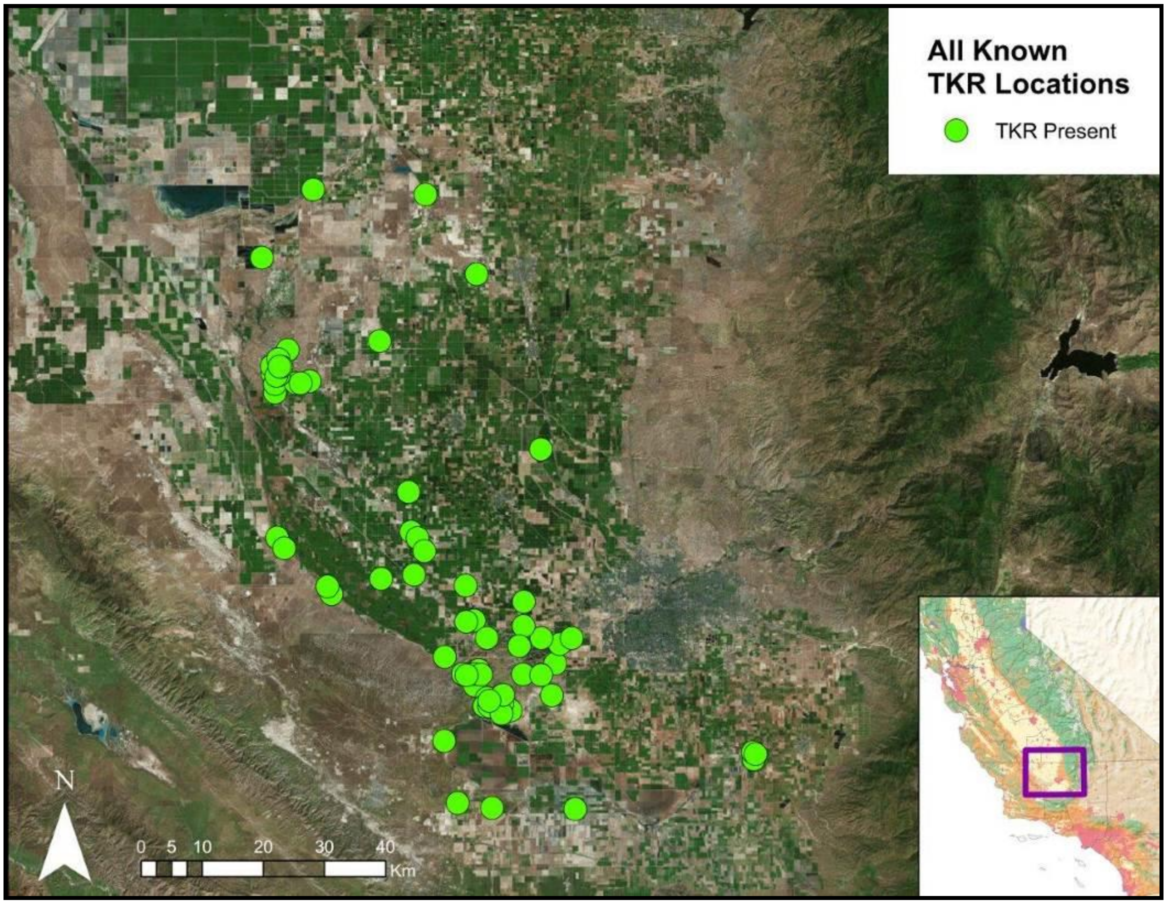

Figure 10. Total sites (n = 66) from previous efforts and from this study where Tipton kangaroo rats were detected and are assumed to be extant in the southern San Joaquin Valley, California.

HABITAT ATTRIBUTES

Specific habitat attribute preferences for TKR have not been well quantified. According to the species account in the recovery plan for TKR (U.S. Fish and Wildlife Service 1998), they are limited to arid-land communities with level or nearly level terrain. Shrubs typically present include spiny saltbush (*Atriplex spinifera*), desert saltbush (*Atriplex polycarpa*), arrowscale (*Atriplex phyllostegia*), quailbush (*Atriplex lentiformis*), iodine bush, pale-leaf goldenbush (*Isocoma acradenia*), and honey mesquite *(Prosopis glandulosa*). Seepweed is described as a "conspicuous semiwoody species" in areas with TKR. Shrub cover typically is sparse to moderate in areas with high TKR density. Because flat terrain on the valley floor is subject to flooding, some microtopography is considered important as it provides refugia during flood events. Finally, higher densities of TKR tend to occur on soils with higher salinity.

Based on the habitat description above and our previous survey experiences as well as that of other researchers, we targeted sites with alkali sink habitat (e.g., alkaline playas and seepweed or iodine bush present). Generally, sites with TKR usually had good quality alkali sink habitat and were consistent with the habitat description above.

Of interest was the finding that TKR rarely were found on sites with evidence of past tilling. Tilling and associated crop production likely result in the collapse of burrows and possibly direct mortality of animals, as well as the removal of native vegetation, compaction of soil, and possibly a reduction in microtopography. Thus, when land is being actively farmed, it may be unsuitable for TKR. However, once tilling and farming are discontinued, then a reasonable expectation is that TKR could eventually recolonize the site, particularly if there was adjacent occupied habitat. Recolonization of former agricultural lands has been observed among other kangaroo rat species (e.g., giant kangaroo rats [*D. ingens*]); U.S. Bureau of Land Management 2010) and at least one of our surveyed sites with TKR had evidence of past tilling. None of the sites we surveyed appeared to have been tilled within the past 10 years or so, but possibly more time is needed before the sites again become suitable for TKR. Restoration strategies might help to speed up this process.

During our surveys, we noted that some survey sites, particularly in the northern portion of the range, had relatively dense ground cover largely consisting of non-native grasses (e.g., red brome [*Bromus madritensis*], ripgut brome [*Bromus diandrus*]). TKR have been documented in the past on some of these sites but were not detected during our surveys. Most of the sites where TKR were present had sparse ground cover. Dense ground cover renders habitat less suitable for TKR as among other impacts, it may inhibit movements and increase predation risk (Williams and Germano 1992, Germano et al. 2001). Vegetation management may be necessary to enhance suitability on sites with dense ground cover. Such management is more likely to be necessary in the northern portion of TKR range where precipitation tends to be higher due to a north-south precipitation gradient in the San Joaquin Valley (Germano et al. 2011). Livestock grazing would likely be the most practical and effective strategy to reduce ground cover to more suitable levels for TKR (Williams and Germano 1992, Germano et al. 2001).

One final note is that our assessment of habitat attributes was essentially coarse-scale. The assessments were rapid and qualitative and characterized entire sites. Thus, if suitable TKR habitat is defined by more subtle differences among attributes, we were less likely to detect them. Also, other factors that we did not assess (e.g., soil characteristics, flooding frequency, predator abundance, etc.) might influence the presence of TKR. Finally, past events also might determine whether TKR are present at a given site. Many of the remaining parcels of habitat on the San Joaquin Valley floor are relatively small and also isolated due to habitat fragmentation. It is possible that some past event, such as flooding or rodenticide use, could have extirpated TKR from a site. For example, closely related Fresno kangaroo rats (*D. n. exilis*) apparently were extirpated from the Alkali Sink Ecological Reserve when a break in a San Joaquin River levee flooded this site (Williams and Germano 1992). Lack of connectivity to other occupied habitat would preclude recolonization of sites. Thus, sites with suitable habitat may not be occupied by TKR. Several of the sites we surveyed appeared to have suitable habitat but TKR were not detected. Such sites may be good candidates for reintroductions of TKR.

Another important habitat attribute is the presence of competitors. Competition between species of kangaroo rats is well documented, and larger species generally are dominant over smaller species in competitive interactions (Blaustein and Risser 1976, Frye 1983, Brown and Munger 1985, Reichman and Price 1993, Perri and Randall 1999).

Competition between HKR and TKR has long been suspected (Williams and Germano 1992, U.S. Fish and Wildlife Service 1998) but quantitative evidence for competitive interactions as a limiting factor for TKR populations has been limited. Tennant and Germano (2013) did document a 500% increase in TKR on a plot from which HKR had been removed whereas no increase in TKR was observed on an associated control plot from which HKR were not removed.

Data collected during this project provided strong evidence for competitive interactions between HKR and TKR. At sites with TKR, HKR were more likely to be absent or at least in sufficiently low numbers to evade detection. HKR abundance was lower on average on sites with TKR, and HKR and TKR abundance were inversely related. These results suggest that HKR may engage in interference competition with TKR and competitively exclude them resulting in lower TKR abundance. However, we also cannot dismiss an alternative hypothesis that habitat preferences of the two species are sufficiently dissimilar such that attributes more optimal for TKR are less optimal for HKR, and that this might be the reason at least in part for the inversely related abundance. Regardless of whether it is competition or habitat attributes, sites where HKR are abundant seem to be less suitable for TKR.

SUITABILITY MODELING

We attempted to use the best available information on TKR occurrence and preferred habitat attributes in developing our habitat suitability model. However, we caution that as with any suitability model, the results do not guarantee that TKR are present on any specific parcel of land. Instead, modeling results should be viewed as an estimate of the potential for TKR to occur on given lands; higher suitability rankings indicate a higher probability of TKR occurrence. Surveys for TKR should be conducted on any given parcel of land prior to implementing conservation or management strategies for TKR.

Habitat attributes from sites with TKR were used to model habitat suitability. This model indicated that a maximum of 90,000 ha of suitable (ranging from *low-high* quality, rank 1-4) habitat might remain. Within that 90,000 ha, around 40,000 ha are highly degraded (former farmland) and/or fragmented and considered *low*-quality (rank 4). Around 20,000 ha are relatively densely-vegetated or lack scalds and are considered medium-quality habitat (rank 3). The remaining 30,000 ha are what we consider *moderately-high* to *high* quality habitats that are less-disturbed, less fragmented, and less-densely vegetated.

Some of the remaining good quality habitat (ranks 1 and 2) occurs in relatively large patches (Figure 8). Such areas include the Coles Levee Ecosystem Preserve region, Semitropic Ridge region, and Lokern region (east of the California Aqueduct). Other large blocks of habitat are present near the Kern-Tulare County line and in southern Tulare County. Most of these lands are owned by either CDFW (e.g., Allensworth Ecological Reserve) or USFWS (e.g., Pixley National Wildlife Refuge). However, TKR were detected on almost none of these lands during recent surveys. As alluded to previously, many of these more northern sites have dense ground cover, consisting largely of non-native grasses. These sites likely will require active vegetation management to maintain suitability.

Fortunately, many of the remaining lands with highly suitable habitat are conserved and owned/managed by conservation organizations (e.g., CDFW, USFWS, CNLM). Areas with relatively large blocks of highly suitable habitat on private lands include the Goose

Lake region and an area just south of the Tulare Lake bed on the Tulare-Kern County boundary (Figure 8). These areas should be targeted in habitat conservation efforts. Additionally, lands with lower quality habitat that link patches with higher quality habitat also should be targeted for conservation. Due to their small size, TKR have limited capacity to cross large stretches of unsuitable habitat (e.g., active agricultural lands, industrial developments, urban areas).

CONCLUSIONS

TKR are still present at a number of locations throughout their historic range. Some of these locations contain relatively large blocks of habitat whereas other locations contain relatively small parcels without connections to other occupied habitat. Continuing loss of natural habitat, some of which was observed during this study, is reducing the number of sites occupied by TKR as well as further isolating populations through habitat fragmentation. Small, isolated populations are more vulnerable to extirpation via stochastic demographic, environmental, or catastrophic processes.

TKR were most likely to be present on sites with high quality, intact alkali sink habitat. In general, these sites commonly had large alkali scalds (i.e., playas), sparse ground cover, and seepweed present. The sites also usually had no obvious sign of past tilling. Previously tilled lands might benefit from restoration actions to increase suitability for TKR. Finally, HKR were either absent or only present in relatively low numbers on sites with TKR. Some sites appeared to have highly suitable habitat conditions, but TKR were not detected. Past events could have caused TKR extirpation and these sites may be good candidates for TKR reintroductions.

Habitat suitability modeling identified areas with varying levels of habitat suitability for TKR within the historic range. Some large patches of habitat persist while many patches are relatively small and isolated. Essentially, TKR currently persist in a metapopulation structure consisting of subpopulations of varying size and connectivity. The probability of long-term population persistence (i.e., population viability) is higher on larger patches and increases with connectivity between patches. Thus, goals for TKR conservation should include conserving as much of the remaining higher quality habitat as possible, expanding buffers around occupied habitat, and increasing connectivity between habitat patches to facilitate genetic and demographic flow, all of which will help maintain more optimal metapopulation dynamics. This is particular important due to the marked environmental fluctuation in this region, which increases the potential for local extirpation of TKR from patches thus necessitating recolonization via linkages between patches.

RECOMMENDATIONS

Based on the results of this project, the following recommendations are offered for Tipton kangaroo rat conservation.

1. ADDITIONAL SURVEYS ON UNSURVEYED LANDS WHEN POSSIBLE

Many parcels with potential TKR habitat have not been surveyed because they comprise private land where access has not been granted. In the event that such parcels become accessible in the future, then TKR surveys should be conducted.

2. *Habitat Protection*

Sites where the presence of TKR has been confirmed but that are not permanently protected should be high priority for habitat conservation. Sites where TKR have not been confirmed (usually due to lack of access) but that have high quality habitat based on the suitability model also should be a priority for conservation. Sites with lower quality habitat also may be valuable if they provide connectivity between patches with high quality habitat.

3. *Habitat Management*

Particularly due to invasion by non-native grasses, vegetation on some sites may need to be managed to maintain or improve suitability for TKR. Grazing with livestock likely would be the most efficient and cost-effective management strategy.

4. *Further Translocation Research*

Past TKR translocations have had a low success rate (Germano 2001, Germano 2010, Germano et al. 2013, Tennant et al. 2013). Given the potential availability of unoccupied but suitable sites for TKR, additional research should be conducted on translocation strategies to increase success rates and establish new populations of TKR.

5. *Translocations to Suitable, Unoccupied Habitat*

TKR habitat is still being lost and the number of sites occupied by TKR is declining. TKR salvaged from sites prior to habitat destruction should be translocated to unoccupied sites with suitable habitat. Furthermore, TKR from sites with robust populations could be translocated to unoccupied sites with suitable habitat to increase the number of TKR populations and reduce extinction risk.

6. *Habitat Restoration*

Given that TKR habitat is still being lost, previously disturbed lands could play a role in TKR conservation. However, these lands may require active habitat restoration to make them suitable for TKR. Restoration strategies should be developed and tested, and this may help at least partially offset the on-going habitat loss.

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Appendix A. Form used to assess habitat attributes on sites surveyed for Tipton kangaroo rats.

Tipton Kangaroo Rat Habitat Suitability Project
Site Assessment

Site number: ____________________________ **Pictures:** Y N

Date: __________________________________

Alkali scalds

Present: Yes No

Size (check all that apply):

_______ Large (mostly larger than a 2-car garage - like at office)

_______ Medium (smaller than garage but larger than a car)

_______ Small (smaller than a car)

Shrubs

Present: Yes No

Density:
(if present)

________ Sparse (generally couldn't hit the next one with a rock)

________ Medium (generally could easily hit the next one with a rock)

________ Dense (commonly have to alter course to get around shrubs)

Species (check if more than just 1 or 2 are present on site; put a "D" by the dominants):

______ Suaeda (sinkweed, seepweed)
______ Allenrolfea (iodine bush)
______ small-leaved Atriplex (desert or spiny saltbush)
______ large-leaved Atriplex (valley saltbush, quailbush)
______ Isocoma (alkali goldenbush)
______ Salsola (tumbleweed, Russian thistle)
______ Bassia (4-hook bassia)
______ tamarisk
______ Other ____________________________(***or collect a sample***)

Ground cover

Density:

________ Sparse (>30% bare ground)
________ Medium (10-30% bare ground)
________ Dense (<10% bare ground)

Species (check all that appear abundant on the site):

_______ red brome
_______ salt grass
_______ Arabian grass
_______ wild oats (Avena)
_______ wild barley (Hordeum)
_______ other grass

_______ Amsinkia
_______ filaree
_______ alkali heath
_______ other
_______ other
_______ other

_______ tarweed
_______ doveweed
_______ mustard

Disturbances

Anthropogenic (check all that apply):

_______ grazing (circle one: cow, sheep, horse, goat, other)
_______ off-road vehicles
_______ trash dumping
_______ shooting
_______ previous tilling
_______ bee hives
_______ other ____

Rodent activity:

_______ Low (from any given point, can see on average 0-2 burrows)
_______ Medium (from a given point, can see on average 3-5 burrows)
_______ High (from a given point, can see on average 6+ burrows)

Microtopography:

_______ Generally flat
_______ Undulations generally less than 12”
_______ Mounds or ridges >12”

GPS coordinates

Line	GPS point	Northing	Easting
_________	Start_________	______________________________	________________________________
	End _________	______________________________	________________________________
_________	Start_________	______________________________	________________________________
	End _________	______________________________	________________________________
_________	Start_________	______________________________	________________________________
	End _________	______________________________	________________________________
_________	Start_________	______________________________	________________________________
	End _________	______________________________	________________________________

Notes:

APPENDIX B. LIVE-TRAPPING RESULTS AND HABITAT ATTRIBUTES FOR SITES SURVEYED FOR TIPTON KANGAROO RATS.

Site:	ESRP site number
Dates trapped:	Dates live-trapping was conducted.
No. traps:	Number of traps deployed per site for live-trapping.
No. TN:	Number of traps times the number of nights trapping was conducted.
TKR present:	Were Tipton kangaroo rats (TKR) captured during live-trapping.
No. TKR:	Number of TKR capture during live-trapping.
No. HKR:	Number of Heermann's kangaroo rats captured during live-trapping.
Dist. to Ag:	Distance from the center of the trapping area to the nearest active agriculture in kilometers.
Scalds present:	Were alkaline scalds (i.e., playas) present.
Scald size:	Size of scalds on average (see data form for more details).
Shrubs present:	Were any shrubs present on site.
Shrub density:	Qualitative assessment of shrub density (see data form for more details).
Iodine bush present:	Was iodine bush (Allenrolphea occidentalis) present.
Seepweed present:	Was seepweed (Suaeda spp.) present.
Dominant shrub species:	What were the dominant shrub species.
GC density:	Qualitative assessment of ground cover density (see data form for more details).
Grazing:	Was there evidence of grazing by livestock on the site.
Tilling:	Was there evidence of past tilling (i.e., disking resulting in furrows) on the site.
Microtopography:	Qualitative characterization of microtopography on the site.

Site	Dates trapped	No. traps	No. TN	TKR present	No. TKR	No. HKR	Dist. to Ag (km)	Scalds present	Scald size	Shrubs present	Shrub density	Iodine bush present	Seepweed present	Dominant shrub species	GC density	Grazing	Tilling	Micro-topography
1	10/30-10/31/13	40	80	yes	2	6	0.37	no	n/a	yes	medium	no	yes	small-leaved Atriplex	sparse	no	no	undulations < 12''
2	10/30-10/31/13	30	60	no	0	5	0.24	no	n/a	yes	medium	no	yes	Isocoma	dense	no	yes	generally flat
4	10/30-10/31/13	30	60	no	0	3	0.24	no	n/a	yes	n/a	yes	no	Allenrolfea	sparse	no	yes	undulations < 12''
5	11/26-11/27/13	40	80	yes	7	1	0.45	yes	large	yes	medium	no	yes	Suaeda	sparse	no	no	undulations <12'' and mounds or ridges >12''
6	11/26-11/27/13	40	80	yes	1	1	0.6	yes	large	yes	medium	no	yes	Suaeda and Isocoma	medium and dense	no	no	undulations <12'' and mounds or ridges >12''
7	11/6-11/7/13	40	80	no	0	3	0.28	yes	large, medium, and small	yes	medium	yes	yes	small-leaved Atriplex	medium	no	no	mounds or ridges >12''
8	11/6-11/7/13	40	80	no	0	8	0.27	yes	large and medium	yes	dense	no	yes	small-leaved Atriplex	medium	no	yes	undulations < 12''

Site	Dates trapped	No. traps	No. TN	TKR present	No. TKR	No. HKR	Dist. to Ag (km)	Scalds present	Scald size	Shrubs present	Shrub density	Iodine bush present	Seepweed present	Dominant shrub species	GC density	Grazing	Tilling	Micro-topography
9	11/14-11/15/13	39	78	no	0	3	0.7	yes	large and medium	yes	medium	yes	yes	Allenrolfea and small-leaved Atriplex	sparse	no	no	undulations < 12''
10	11/14-11/15/13	40	80	no	0	0	0.38	yes	large	yes	medium	yes	no	Allenrolfea and small-leaved Atriplex	sparse	yes	no	mounds or ridges >12''
11	11/14-11/15/13	40	80	no	0	1	0.21	yes	medium and small	yes	medium	no	no	small-leaved Atriplex	sparse	yes	no	generally flat
12	11/19-11/20/13	40	80	no	0	5	0.16	yes	medium	yes	medium	yes	yes	Suaeda	sparse	yes	no	undulations < 12'' and mounds or ridges > 12''
13	11/19-11/20/13	40	80	no	0	3	0.63	yes	large	yes	sparse to medium	no	yes	Suaeda	sparse	yes	no	mounds or ridges >12''
14	11/19-11/20/13	40	80	no	0	6	0.39	no	n/a	yes	medium	yes	yes	Suaeda	medium	no	no	undulations < 12'' and mounds or ridges > 12''
15	02/13-02/14/14	40	80	no	0	2	0.19	yes	medium	yes	medium	no	yes	small-leaved Atriplex	sparse	yes	no	undulations <12''
16	02/13-02/14/14	40	80	no	0	3	0.4	yes	medium	yes	sparse	no	yes	small-leaved Atriplex	medium to sparse	yes	no	mounds or ridges >12''
17	02/13-02/14/14	40	80	yes	3	0	1.19	yes	large	yes	sparse	no	no	small-leaved Atriplex	sparse	yes	no	undulations <12''
18	02/18-02/19/14	45	90	yes	1	2	0.5	yes	small to medium	yes	medium	yes	yes	Sinkweed	sparse	yes	no	generally flat
19	02/18-02/19/14	40	80	yes	9	0	0.96	yes	small to medium	yes	medium	yes	yes	Sinkweed	sparse	yes	no	generally flat
21	02/20-02/21/14	40	80	no	0	1	2.49	yes	large	yes	dense	no	yes	Suaeda and Isocoma	medium	yes	no	undulations generally <12''
22	02/20-02/21/14	40	80	no	0	0		yes	medium	yes	sparse	no	yes	Sinkweed	sparse	yes	yes	undulations generally <12''
23	02/20-02/21/14	40	80	yes	1	2		no	n/a	yes	sparse	yes	no	Iodine bush	sparse	yes	no	undulations generally <12''
24	02/25-02/26/14	40	80	no	0	3	1.24	yes	medium to small	yes	sparse	yes	no	Allenrolfea	sparse	yes	no	undulations generally <12''
25	02/25-02/26/14	40	80	no	0	2	2.18	yes	medium to small	yes	sparse	yes	yes	Suaeda and Allenrolfea	sparse	yes	no	undulations generally <12''
26	02/25-02/26/14	40	80	no	0	1	1.12	no	n/a	yes	sparse	no	yes	Suaeda	sparse	yes	no	undulations generally <12''
27	02/18-02/19/14	40	80	yes	4	0	1.92	yes	large and small	yes	sparse to medium	no	no	small-leaved Atriplex	sparse	yes	no	mounds or ridges >12''
28	03/06-03/07/14	40	80	no	0	7	1.17	yes	small, medium, and large	yes	medium	no	no	Small-leaved Atriplex	medium to sparse	yes	no	undulations generally <12''
29	03/06-03/07/14	40	80	no	0	0	0.37	yes	large	yes	medium	no	yes	Suaeda	medium	yes	no	undulations generally <12''
30	03/06-03/07/14	40	80	no	0	0	0.36	yes	small	yes	sparse	no	yes	Suaeda and Isocoma	dense	yes	yes	undulations generally <12'' and a few mounds or ridges >12''.
36	05/01-05/02/14	39	78	no	0	3	0.23	yes	medium	yes	sparse to medium	no	yes	Suaeda	medium	yes	no	undulations generally <12''
37	05/01-05/02/14	40	80	no	0	2	0.32	yes	small	yes	sparse	no	yes	Suaeda, small-leaved Atriplex, and Bassia	medium	yes	no	undulations generally less than <12''

Site	Dates trapped	No. traps	No. TN	TKR present	No. TKR	No. HKR	Dist. to Ag (km)	Scalds present	Scald size	Shrubs present	Shrub density	Iodine bush present	Seepweed present	Dominant shrub species	GC density	Grazing	Tilling	Micro-topography
38	05/01-05/02/14	40	80	no	0	5	0.43	yes	medium to small	yes	sparse	no	no	large-leaved atriplex, salsola, and bassia	dense	yes	no	generally flat, undulations generally <12'', and mounds or ridges > 12''
41	11/5-11/6/13	30	30	yes	1	0	0.36	no	n/a	yes	dense	no	yes	Suaeda	medium	no	no	undulations < 12''
45	04/30-05/01/14	30	90	no	0	3	1.27	yes	large	yes	medium	no	yes	Suaeda and Isocoma	sparse	yes	no	undulations < 12''
46	04/30-05/01/14	30	60	no	0	3	0.73	yes	small	yes	sparse	no	yes	Suaeda and Isocoma	sparse	yes	no	mounds or ridges >12''
47	04/30-05/01/14	30	90	no	0	8	0.17	yes	medium	yes	medium	no	yes	Suaeda and Isocoma	sparse	yes	no	mounds or ridges >12''
50	12/17-12/18/13	40	80	no	0	0	0.42	yes	medium	yes	medium	no	yes	Suaeda	sparse	yes	no	undulations <12''
51	12/17-12/18/13	40	80	yes	2	0	0.57	yes	large	yes	sparse to medium	yes	yes	Suaeda and small-leaved Atriplex	sparse	yes	no	undulations <12'' and mounds or ridges >12''
52	02/11-02/12/14	40	80	yes	2	0	0.71	yes	large	yes	medium	yes	yes	small-leaved Atriplex	sparse	no	no	generally flat
53	02/11-02/12/14	40	80	yes	5	0	0.9	yes	large	yes	medium to sparse	yes	yes	small-leaved Atriplex	sparse	no	no	generally flat
54	12/1-12/2/13	40	80	no	0	12	0.11	yes	small	yes	medium	no	no	small-leaved Atriplex	medium	no	yes	mounds or ridges >12''
55	10/16-10/20/14	187	935	yes	7	34	0.51	yes	large	yes	medium	no	no	small-leaved Atriplex, Isocoma, Tamarisk	sparse	yes	no	mounds or ridges > 12''
56	3/10-3/13/15	86	332	no	0	9	0.45	yes	medium	yes	dense	no	no	small-leaved Atriplex	medium	yes	yes	mounds or ridges >12''
57	3/17-3/18/15	80	160	yes	2	7	0.13	yes	large, medium, and small	yes	medium to dense	no	yes	small-leaved Atriplex	dense	yes	yes	undulations generally <12'', and mounds or ridges >12''
58	11/13-24/12	180	720	yes	1	27	1.55	yes	small	yes	medium	no	yes	Suaeda and small-leaved Atriplex	sparse	no	no	generally flat

APPENDIX C. LOCATION COORDINATES FOR THE APPROXIMATE CENTER OF SITES SURVEYED FOR TIPTON KANGAROO RATS IN THIS STUDY.

Site	Longitude*	Latitude*
1	-119.167	35.127
2	-119.202	35.126
4	-119.214	35.154
5	-119.399	35.453
6	-119.408	35.460
7	-119.499	35.471
8	-119.517	35.481
9	-119.592	35.549
10	-119.585	35.554
11	-119.575	35.540
12	-119.562	35.555
13	-119.549	35.549
14	-119.528	35.539
15	-119.483	35.661
16	-119.540	35.641
17	-119.557	35.641
18	-119.608	35.627
19	-119.608	35.637
21	-119.646	35.682
22	-119.609	35.684
23	-119.589	35.678
24	-119.558	35.715
25	-119.554	35.735
26	-119.533	35.751
27	-119.612	35.650
28	-119.417	35.786
29	-119.379	35.801
30	-119.344	35.801
36	-119.463	36.024
37	-119.452	36.041
38	-119.478	36.032
41	-119.360	35.209
45	-119.318	35.845
46	-119.333	35.845
47	-119.335	35.835
50	-119.529	35.394
51	-119.525	35.385
52	-119.605	35.453
53	-119.595	35.440
54	-119.437	35.400
55	-119.404	35.409
56	-119.318	35.351
57	-119.316	35.354
58	-119.197	35.302

* North American datum of 1983

APPENDIX D. LOCATION COORDINATES FOR SITES SURVEYED PRIOR TO THIS STUDY ON WHICH TIPTON KANGAROO RATS WERE DETECTED. ALL OF THE SITES WERE EXTANT AS OF 2016.

Year	County	Longitude/Latitude*	Source
1990	Kern	-119.217, 35.289	D. Germano, CSU-Bakersfield
1990	Kern	-119.327, 35.352	D. Germano, CSU-Bakersfield
1990	Tulare	-119.387, 35.864	D. Germano, CSU-Bakersfield
1992	Kern	-119.359, 35.310	D. Germano, CSU-Bakersfield
1992	Kern	-119.190, 35.325	D. Germano, CSU-Bakersfield
1992	Kern	-119.412, 35.508	D. Germano, CSU-Bakersfield
1992	Kern	-118.905, 35.187	D. Germano, CSU-Bakersfield
1992	Kern	-119.309, 35.294	D. Germano, CSU-Bakersfield
1992	Kern	-119.243, 35.376	D. Germano, CSU-Bakersfield
1992	Kern	-119.332, 35.289	D. Germano, CSU-Bakersfield
1992	Kern	-119.217, 35.333	D. Germano, CSU-Bakersfield
1993	Kern	-119.297, 35.333	D. Germano, CSU-Bakersfield
1993	Kern	-119.315, 35.276	D. Germano, CSU-Bakersfield
1993	Kern	-119.297, 35.260	D. Germano, CSU-Bakersfield
1993	Kern	-119.243, 35.347	D. Germano, CSU-Bakersfield
1993	Kern	-119.297, 35.260	D. Germano, CSU-Bakersfield
1993	Kern	-119.244, 35.289	D. Germano, CSU-Bakersfield
1993	Kern	-119.315, 35.289	D. Germano, CSU-Bakersfield
1993	Kern	-119.306, 35.289	D. Germano, CSU-Bakersfield
1994	Kern	-119.262, 35.246	D. Germano, CSU-Bakersfield
1994	Kern	-119.312, 35.769	D. Germano, CSU-Bakersfield
1994	Kern	-119.172, 35.333	D. Germano, CSU-Bakersfield
1994	Kern	-119.218, 35.559	D. Germano, CSU-Bakersfield
1995	Kern	-119.454, 35.689	D. Germano, CSU-Bakersfield
2001	Kern	-119.452, 35.404	D. Germano, CSU-Bakersfield
2005	Kern	-119.328, 35.396	D. Germano, CSU-Bakersfield
2008	Kern	-119.249, 35.323	D. Germano, CSU-Bakersfield
2011	Kern	-119.249, 35.323	D. Germano, CSU-Bakersfield
2011	Kern	-119.531, 35.394	D. Germano, CSU-Bakersfield
2012	Kern	-119.275, 35.254	D. Germano, CSU-Bakersfield
2012	Kern	-119.301, 35.251	D. Germano, CSU-Bakersfield
2016	Kern	-119.275, 35.242	J. Jones, South Valley Biology
2016	Kern	-119.293, 35.250	J. Jones, South Valley Biology
2016	Kern	-119.293, 35.257	J. Jones, South Valley Biology
2016	Kern	-119.273, 35.265	J. Jones, South Valley Biology
2016	Kern	-119.327, 35.288	J. Jones, South Valley Biology
2016	Kern	-119.578, 35.639	G. Warrick, Center for Natural Lands Management
2016	Kern	-119.571, 35.638	G. Warrick, Center for Natural Lands Management
2016	Kern	-119.603, 35.648	G. Warrick, Center for Natural Lands Management
2016	Kern	-119.606, 35.647	G. Warrick, Center for Natural Lands Management
2016	Kern	-119.599, 35.658	G. Warrick, Center for Natural Lands Management
2016	Kern	-119.601, 35.658	G. Warrick, Center for Natural Lands Management
2016	Kern	-119.613, 35.659	CA Dept. Fish and Wildlife
2016	Kern	-119.603, 35.667	CA Dept. Fish and Wildlife
2012	Tulare	-119.552, 35.870	U.S. Bureau of Land Management
2016	Kern	-119.389, 35.437	D. Germano, CSU-Bakersfield
2011	Kern	-118.902, 35.193	CSU-Stanislaus, Endangered Species Recovery Program
2010	Kern	-118.911, 35.194	CSU-Stanislaus, Endangered Species Recovery Program
2011	Kern	-119.340, 35.134	C. Uptain, QUADKnopf
2011	Kern	-119.289, 35.128	C. Uptain, QUADKnopf
2016	Kern	-119.627, 35.788	CSU-Stanislaus, Endangered Species Recovery Program

* North American datum of 1983