Reviewer Name	Chapter	Page	Comment
D. Germano	Exec Summary	ii	1st paragraph: GKR also occur on the Carrizo and Elkhorn Plains and the Cuyama Valley, which are not the western slope of the San Joaquin Valley.
D. Germano	2	5	Life History - Distribution: "Kangaroo rats belong to the family Heteromyidae, and are native to arid deserts and grasslands of North, South and Central America" Kangaroo rats (Dipodomys) only occur in North America. I have no idea why you listed pages 489-617 of Genoways and Brown (1993). These pages have nothing to do with distribtuion of Dipodomys. See page 337 and succesive range maps of Dipodomys.
D. Germano	2	5	Life History - Distribution: "There are more than twenty species kangaroo rats in the genus Dipodomys, of which the giant kangaroo rat is the largest (Merriam 1904, p. 139; Williams and Kilburn 1991, p. 1; table 1)." These are out of date references. Use Williams et al. from Genoways and Brown (1993).
D. Germano	2	6	Habitat: "Giant kangaroo rats are found only on the arid uplands on the western side of the San Joaquin valley, where gently sloping hills and grasslands meet the coastal range of low mountains." Same comment as for the Executive Summary.
D. Germano	2	6	Habitat: "Due to limited annual rainfall and high summer temperatures, the southwestern portion of the San Joaquin Valley characterized as a climatic desert (Germano et al. 2011 p. 139-145)" You have misstated the location of the SJ desert. It occupies the western and southern part of the SJ Valley (not the southwestern part - there is a big difference). It also occupies the Carrizo and Elkhorn Plains and the Cuymama Valley.
D. Germano	2	6	Habitat: "Mostly likely, giant kangaroo rat abundance was highest in areas where the driest month received a mean of 0 mm of precipitation (Bean et al. 2014, p. 6)." What does this mean? You must have misinterpreted the citation. There are usually 6-8 months in Mediterranean climates that experience no or virtually no precipitation. This seems to be a meaningless statement.
D. Germano	2	6	Habitat: "Researchers attempting to relocate giant kangaroo rats on unoccupied habitat saw initial population growth for several years, until the population crashed when the climate became wet (Germano, 2010, p. 86)." But see Germano and Sasalaw (2017).
D. Germano	2	6	Habitat: "Optimal habitat for giant kangaroo rats are usually annual grassland communities with few or no shrubs ….." This is too generalized a statement. I have worked at a number of sites where GKR are abundant and there are medium densities of shrubs. The Elkhorn Plain site, where I captured GKR from 1989-1992 with Dan Williams has many Mormon Tea bushes. Also, the site in the Germano and Saslaw (2017) paper was invaded by Atriplex early on but GKR numbers were often abundant there periodically, as with any site. Soils are likely the driving component of good GKR habitat because they need well drained soils so food larders don't spoil. By the time Grinnel and Shaw were working on GKR, overgrazing and fires had probably eliminated much of the shrubs in many areas of their range. Unless shrubs are really dense, I don't think shrubs make GKR habitat suboptimal.

D. Germano	2	9	Feeding habits: "These colonies of burrows are called precincts (Shaw 1934, p. 276)." This is incorrect (or you have misstated what you intended). Each burrow system (usually home to one adult GKR) is a precinct. Many precincts are found together in areas often separated by unoccupied habitat from other groups (colonies?) of precincts. Why is this information in Feeding Habits?
D. Germano	2	10	Life Cycle and Reproduction: "The average longevity of the giant kangaroo rat is unknown. " See Germano and Saslaw (2017). GKR can live to at least 4-5 y, although not many live this long. Although we didn't give an average, many lived to 1.5 y (Table 7)
D. Germano	2	11, 12	Genetic Diversity: You did not include Balckhawk et al. (2016). This study indicates that the southern San Joaquin population may be a distinct metapopulation from the Carrizo Plain metapopulation. The Temblor Mtns. likely are an effective barrier to significant dispersal. The Stantham et al. work only included one individual from the southern San Joaquin Valley (unless their data is more complete than when I reviewed this work). I think you should at least mention the possibility that there are three metapopulations of GKR, not two.
D. Germano	2	13	"It is clear that giant kangaroo rats have the ability to alter the plant and animal communities surrounding them, making them a central, possibly essential, part of a healthy, native ecosystem." I dispute this claim. Although you can state they are keystone species, I know of no vertebrate species that exist only where GKR exist. This is especially true of listed veretbrates. The distribution of these other species in the S.J. Desert extend far beyond the range of GKR. How does that make GKR a central, possibly essential, part of a healthy ecosytem? Does that mean the ranges of all these other species are not healthy? How did these species survive outside the range of GKR for thousands of years? I really think this whole discussion of keystone species should be dropped. It is an overused and abused ecological idea.
D. Germano	2	14	GKR Needs "Giant kangaroo rats are restricted to grasslands-dominated landscapes on sandy-loam soils" GKR are not RESTRICTED to grasslands as I have stated above
D. Germano	2	15	Population needs: "The San Joaquin Valley floor has largely been converted to agriculture, fragmenting much the historical range for the giant kangaroo rat" GKR have never been known to occur on the valley floor. You have already stated they occur on the wetsern slopes of the valley.
D. Germano	2	15	Precipitation paragraph: You have ignored Germano and Saslaw (2017) in the discussion. We have the only published long-term data set (24 y) that directly addresses effects of dry and wet years. Its complicated.
D. Germano	2	15	Species Needs: "The giant kangaroo rat is limited to a narrow band of habitat in the western San Joaquin Valley. " Incorrect. See above.
D. Germano	3		Descriptions of GKR range correct in this chapter. Modify statements made in Chpt 2.

D. Germano	3	37	Urban and Residential Development: Although GKR are in the Bakersfield HCP, this was always in error, as GKR have never been known in the area covered by the HCP. The species is restricted to the western bajada of the valley and there are only a few old records of GKR on the flat valley floor adjecent to the sloping bajada, well away from the area of the HCP. I suggested changing this paragraph to reflect what I have written. USFWS needs to show they know what they are talking about for GKR.
D. Germano	3	40	What is this citation? O'Farrell, T. P., N. E. Mathews, P. M. McCue, and M. S. Kelly. 2016. Distribution of the endangered giant kangaroo rat, Dipodomys ingens, on the Naval Petroleum Reserves, California. bioRxiv. 1-22. This is odd. Are you sure this isn't a paper from 1980s? You should really cite the orginal EG&G report. This is the original report: O'Farrell, T. P., N. E. Mathews, T. T. Kato, P. M. McCue, J. S. McManus, and M. L. Sauls. 1987. Distribution of the endangered kangaroo rat, Dipodomys ingens, on the Naval Petroleum Reserves, Kern County, California. Unpublished report of EG&G Energy Measurments to the U.S. Deprtment of Energy, Naval Petroleum Reserves in California, and Chevron U.S.A. Inc., under contract No. DE-AC08-83NV10282. 29 pp.
D. Germano	3	43	"moisture can increase the likelihood of mold and other fungi to cause seeds to spoil harming individual giant kangaroo rats through toxins or spores which when ingested, appear to be lethal (Germano et al. 2001, p. 553; Germano and Saslaw 2017, p. 1624). " This was conjecture on our part. We did not have data to support this statement. As written, it seems as though we know this for sure. Add qualifying wording.
D. Germano	3	46	"In fact, some evidence suggests that kangaroo rat abundance increases as grasses and forb cover decreases (Germano et al. 2001 553)." Please review and incorporate what was found in Germano and Saslaw (2017). The information in this paper has much to add to this topic. Also review Germano et al. (2012) for information on this topic dealing with other k-rat species. Germano, D. J., G. B. Rathbun, and L. R. Saslaw. 2012. Effects of grazing and invasive grasses on desert vertebrates in California. Journal of Wildlife Management 76:670-682.
D. Germano	3	47	"Results of studies which sought to quantify the effects of grazing on giant kangaroo rats have been mixed (Williams 1989; Williams and Germano 1994; Germano et al 2001 Kelly et al. 2004; Germano et al 2005)" Remove Germano et al. 2005 citation. It is not in Lit. Cited and has nothing to do with GKR.
D. Germano	3	49	Abundance. Again, this discussion should include information from Germano and Saslaw (2017).
D. Germano	3	50	Table 8. I ask you to rethink your analysis. Invasive plants and grazing may be the number two stressors (combined) affecting GKR, only after habitat loss. High levels of non-native herbaceous cover has been found to greatly affect all kangaroo rats in the SJ Desert. If not controlled by grazing, areas experiencing several years of above average precipitation could build up enough herbaceous cover to cause local extinctions. If a source population that perists is not able to recolonize areas affected by high plant cover, those areas will likely be lost forever.
D. Germano	3	52	Precipitation effects: "Consecutive years with less than 15cm of precipitation were considered as lower categories." Well, a few dry years after average to above average rainfall can actually be good (See Germano and Saslaw 2017). It may be hard to model, but this seems to be reality.

D. Germano	3	56	Table 10. I think the Frequency of Occupation should be changed from moderate to high for Western Kern Co. GKR are consistently found as various sites in the area, although that can be a shifting mosaic, which is not much different that other areas rated high.
D. Germano	3	58	"Giant kangaroo rat survival is expected to decrease in extremely wet years, and during prolonged periods of drought (droughts lasting longer than two years) (Swan et al. 2018, p. 427-433)." First, it is Swain, not Swan. Also, the way the sentence is structured, the citation seems to indicate it discusses GKR survival, which it does not. Thirdly, as stated above, several dry years after a wet year or two can be good for GKR.

Reviewer Name	Chapter	Page	Comment
Bean	exec summary	ii	"have not had documents occurrences…"
Bean	exec summary	ii	"The rates at which future stressor might…"
Bean	1	1	Throughout the document, the description of the GKR's historical range changes. On this page, it's described as "only on the southwestern plains in California's central valley" (should be Central Valley); you need to identify a consistent description of their historical range
Bean	1	1	"…framework to conduct and in-depth review…"
Bean	1	1	"…to downlist it from endangered to threaten or…"
Bean	1	1	"Decisions for the changing the status…"
Bean	1	2	"…and to recovery from periodic or random…"
Bean	1	2	"…measured using metric like vital rates…"
Bean	1	2	"Redundancy is the ability of a species is the ability of a species to withstand…"
Bean	1	2	"Representation is the ability of a species at adapt to…"
Bean	1	3	"…stressors (and conservation measure)…"
Bean	1	3	I'm going to stop commenting on the typos, but that's 10 in the first five pages; I will only make comments if I think you might not catch the typo in future revisions
Bean	2	5	Two things: Heteromyids are found in South America, but Dipodomys are not; the way the sentence is written, it seems to be saying that kangaroo rats are found in South America. Second, the pages refered for Genoways and Brown are for portions of a chapter on Ontongeny, proximal colon, physiological ecology, foraging, social systems, and tropical heteromyids. The biogeography chapter is p. 319-356
Bean	2	6	another example where distribution of GKR is inconsistent: "only on the arid uplands on the western side of the San Joaquin valley" (should be Valley)
Bean	2	6	The other key finding of Bean et al. 2014 was that, while they were restricted to the driest portions of central California, within those areas they were often found in the most productive parts (i.e. the "wettest parts of the driest areas")
Bean	2	9	Defines precincts as "colonies of burrows." I don't think I've ever seen precincts used in that way (and Shaw 1934 doesn't use the term at all). A precinct is, to my understanding, synonymous with a burrow mound - a (somewhat) clearly defined collection of burrow openings / tunnels that are occupied by a single rat (with exception of mothers w/ babies). I think most people say colony of precincts of colony of burrow mounds, but the colony isn't referred to as the precinct

Bean	2	9	Alexander et al. 2019 found a pair of siblings 5.5 km apart - meaning the maximum dispersal distance we can assume is 2.25. It's possible one didn't disperse and the other went the full 5.5km, but we don't know. Maximum we can assume is 2.25km. For Loew et al. 2005, they reported "occasional" dispersal of 700m, but I wouldn't call that "common." They give an average of 122m for males and 99 for females.
Bean	2	10	The AP article cited (Cone) kind of jumped the gun on our research. I did try to estimate abundance using satellite imagery to identify active/inactive burrow mounds, but active burrow counts are not an accurate indicator of abundance, whether counted on the ground or from space (see Bean et al. 2011)
Bean	2	10	evidence of breeding into July and August in some years
Bean	2	10	we have evidence of some individuals living up to 6 years on the study plots in Carrizo; longevity is really important for a species that has to try to withstand droughts >2 years. Mean lifespan might be short (from predation), but I suspect it's longer than 2 years.
Bean	2	13	again, evidence of breeding into summer in good years
Bean	2	13	this is a better summary of dispersal than given on page 10
Bean	2	15	re: "high levels of fecundity and juvenile survival" - any citations for this? I suspect that adult survival / longevity may be just as important to withstand annual variation in primary productivity
Bean	2	15-16	there's not high genetic diversity across all pops; there's high genetic diversity in Ciervo-Panoche and Carrizo. We don't know about the other pops
Bean	2	16	Not sure which paper is being cited here - Bean 2012 is my dissertation, Bean et al. 2014 is the paper published from my dissertation, and they have slightly different conclusions about which environmental factors are important in the distribution model
Bean	2	16	"have a relatively short dispersal distances (less than a kilometer)" see comments above - most have much shorter dispersal distances, but some have potentially longer
Bean	3	18	"western the San Joaquin Valley and inner-coastal ranges" this seems like closer to an accurate description of their distribution (but, again, different from previous ones)
Bean	3	19	Rutrough et al. (2019) provide an updated estimate of the historical range; the polygon in Figure 5 is similar, but there are a number of errors. The most noticeable is the "finger" extending south from the Ciervo-Panoche region - the polygon was extended to encompass a point from a museum record that was clearly recorded in the wrong geography. The historical distribution in Rutrough et al (2019) suggests the range once extended further south and north than acknowledged in the former estimate
Bean	3	23	"…which represent two genetic lineages…" - that we know of. We only really have data from Ciervo-Panoche and Carrizo/western Kern

Bean	3	23	"giant kangaroo rats in Tumey Hills contribute a disproportional amount of genetic material to other areas…" This was true for the timeframe of the study, but Statham et al. (2019) had different results about gene flow than Loew et al. 2005. Both concluded that there was movement between the subpopulations w/in Ciervo-Panoche, and that the movement would change depending on conditions (e.g. in wetter time periods, flow would be from Panoche Valley east to Silver Creek; in drier times, vice versa). So ALL areas are probably equally important for overall RRR of the Ciervo-Panoche pop
Bean	3	24	Statham et al. (2019) didn't present any information about Kettleman Hills, and there's no page 16 in that paper
Bean	3	25	I don't think we know anything about the genetic status of San Juan Creek or Kettleman Hills pops, nor the Cuyama Valley. Equally plausible that, if Cuyama is part of the southern lineage, San Juan Creek is, too
Bean	3	32	I'm not sure why rodenticide, for example, would be considered as having negative effects on populations, but solar energy development wouldn't?
Bean	3	37	"we do not know of any studies which address the potential effects of solar plants on the presence of giant kangaroo rats" - surely HT Harvey is reporting something from their surveys?
Bean	3	38	"To date, two solar installations have been completed within the range of the giant kangaroo rat" Panoche Valley Solar Farm?
Bean	3	42	"similar declines were seen in the Carrizo national monument" [sic] survival was lower than average 2018-2019, but the primary productivity was not near what was seen in the extreme declines of the mid-90s, and impacts were far more negative then
Bean	3	43	"five years from 2012-2017", but on previous page you said drought was "2013-2016"
Bean	3	44	"Garbriel et al. 2012" is Gabriel
Bean	3	45	"these corridors remain unprotected" wasn't a substantial portion of the Silver Creek corridor protected as part of the Panoche Valley Solar Farm settlement? No mention of PVSF in this assessment of the impacts of this project on connectivity
Bean	3	46	"Where large tracts of non-native plants become established, they might decrease the overall fitness of giant kangaroo rats who over time, as they animals did not evolve as seed specialists" [sic] I'm honestly not sure what this is trying to say. GKR aren't seed specialists?
Bean	3	48	"continuous habitat" vs. "probably never ubiquitous" I think the later statement is more accurate, but there are a few places where you imply they were found throughout their estimated historical distribution
Bean	3	49	"Tim Bean, pers. Comm. 2019" - you can just cite the Prugh et al. paper you've already cited elsewhere, or her 2017 annual report

Bean	3	49	"and the Cuyama Valley" - we have evidence that they're still there, but that's not been confirmed. I think it's fairly urgent that we get into Cuyama to assess whether GKR are still present or not
Bean	3	52	"Data were extracted from PRSIM … from 1980-2010…to give an average outside of the droughts. We considered excluding years within the current decade because the recent drought was especially severe. However, we decided to include those years in our analysis..." I'm not following this at all. You say the data's from 1980-2010, but then say you include the drought years (2012-2016) in the analysis?
Bean	3	52	Same comment as earlier - can't assume a max dispersal of 5km, can only assume 2.5km
Bean	3	52	"survival is not directly assessed in the table but is strongly correlated with the habitat components described above" I don't think that's true - actually, Bean et al. (2014 in Journal of Applied Ecology) found that identifying high habitat suitability (based on many of your factors plus more) was not correlated with survival. Unless I'm misunderstanding what part of the document you're referring to as "above"
Bean	3	54	Average % slope w/in unit. I don't think that AVERAGE slope is a very good metric. I would say an estimate of the total acreage that is in 0-6% slope is probably better, or the total acreage under protection that's in 0-6% slope. Your current approach is always going to make Panoche come out as lower condition than it should be - there's a lot of topographical complexity, but there's also a substantial amount of habitat that is flat enough for GKR to persist.
Bean	3	54	This is to say nothing about the importance of soil type, which is probably far more important than slope (i.e. a flat area with overly sandy soils will not have GKR; a slope >6% with loamy soils very well could)
Bean	4	59	Westerling et al. 2011 isn't cited in your lit cited, but it's a paper primarily interested in forested habitats in California; they say that for desert environments, wildfire intensity will decrease because of decreased fuel load
Bean	4	59	Regarding Dipdomys genetics, see also Busch et al. 2007 in Molecular Ecology - another kangaroo rat species go through regular boom and bust cycles, but they show no signature of a genetic bottleneck; there's increasing evidence that that's the case for many Dipodomy species. I don't think that inbreeding is a substantial concern for the species
Bean	4	59	Ag and urban areas aren't used, but there's a fair amount of evidence that giant kangaroo rats (And other species) will use unpaved roads (e.g. Alexander et al. 2019 and references therein)
Bean	4	62	"not possible to project future occupancy with any degree of accuracy. Therefore, we relied on population trend to project demographics into the future." It's always going to be easier to project occurrence than demographics. Occurrence just means N>0; if you think you can project population trend, you can project occupancy

Bean	4	64	I understand that this is a difficult exercise to create an easily replicatable approach that can be re-done over time. But these results don't fit with other projections of climate change impacts on GKR (i.e., Widick + Bean 2019). The multiple models of climate change in that paper (see fig 7) generally proejct moderate, or high, condition for at least the Carrizo, Panoche, and Cuyama populations.
Bean	5	65	"abundant throughout their historical range" - see your own text earlier in the document. All evidence suggests their distribution was patchy in their historical range, but they were dominant in places where they occurred
Bean	5	65	"narrow strip of gently sloping habitat on the western plains of the San Joaquin Valley" again, different description than other places in the text
Bean	5	66	"precincts are not as abundant or dense as they once were." Not sure I agree - in protected areas of Carrizo and Panoche, density in some places are probably as high as they ever were
Bean	5	66	"However, populatoin numbers are currently low throughout the range.." they're about average in Carrizo
Bean	5	67	"Currentl, three of the geographic units are in low condition" I think it's important to acknowledge here, again, that that's because you intentionally downgraded some of the conditions because we just don't know about their occupancy status over time in some of the regions. They could be in higher condition, we just don't know.
Bean	5	67	"Carrizo plain is the largest continuous habitat for the species…" Most of the threats to GKR in the Plain are outside of the Monument; most of the best habitat for GKR is within the Monument. It would be great to continue to protect habitat in the northern end of the Plain, but I'm not sure it's critical for their RRR there

Species Status Assessment Report
for the
Giant Kangaroo Rat
(*Dipodomys ingens*)

Photo by Elizabeth Bainbridge

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Version 1.0

Month Year

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We would like to thank the following people for providing substantial information and insights for our SSA Analysis:

Prepared by the
U.S. Fish and Wildlife USFWS
November 2019

EXECUTIVE SUMMARY

The giant kangaroo rat was listed under the Endangered Species Act in 1987 due to the increasing threats of habitat loss and rodenticide use (USFWS 1987, entire). The giant kangaroo rat is the largest species in the genus containing all kangaroo rats. This family contains small mammals which are specialized for rapid travel by hopping on their elongated hind legs. The giant kangaroo rat is found only in south-central California, on the western slopes of the San Joaquin Valley and adjacent areas. The preferred habitat of the giant kangaroo rat is native, sloping annual grassland with sparse vegetation (Grinnell, 1932; Williams, 1980).

This report summarizes the results of a species status assessment (SSA) that the U. S. Fish and Wildlife (USFWS) completed for the giant kangaroo rat (*Dipodomys ingens*). To assess the species' viability, we used the three conservation biology principles of resiliency, redundancy, and representation (together, the 3 R's). These principles rely on assessing the species at an individual, population and species level in order to determine whether the species can maintain its persistence into the future and avoid extinction by having multiple resilient populations distributed widely across its range. The species occurs in portions of its former range, although portions of the range have not had documents occurrences for 30 years or more. There are six, geographic units where the species can be found, representing the northern, middle, and southern portions of the range. These regions are based on the 1998 recovery unit and occurrence data for the species (USFWS 1998, p. 86). Geographic units are separated by many miles of inhospitable habitat, representing a barrier to dispersal for the species. For this SSA, the giant kangaroo rats were assessed at the geographic unit as a surrogate to the population level in order to distinguish areas which might be more or less resilient than others. Data on long-term occupancy of these known sites suggest that giant kangaroo rats still have relatively high resiliency in the areas where they still occur, despite frequent and sometimes extreme population fluctuations. For the giant kangaroo rat, resiliency was assessed for the individual needs of Occupancy, fecundity, connectivity, abundant vegetation (grasses and forbs), seed abundance, friable soils, and survival.

Our analysis of the past, current and future influences on the giant kangaroo rat needs for long-term viability revealed that there are several factors that contribute to the current condition and pose a risk to the future viability of the species. These risks, or stressors as we call them in this document, include habitat modification or destruction, climatic variability, rodenticide use, inbreeding and genetic drift, invasive species and wildfire. Under current conditions, we predict the giant kangaroo rat has one geographic unit in high condition, two in moderate condition, and three in low condition.

The influences to viability described above play a large role in the future resiliency, redundancy, and representation of the giant kangaroo rat. If geographic units lose resiliency, they are more vulnerable to extirpation, which results in losses of representation and redundancy for the species. The rates at which future stressor might act on specific regions and the long-term efficacy of the current conservation actions are unknown. Therefore, we forecasted how possible future conditions could impact the resiliency, redundancy, and representation and overall condition of the giant kangaroo rat. In order to assess future condition, we have developed three future, plausible scenarios. The

following is a description of these future scenarios, the status of the giant kangaroo rat when analyzed under each scenario, and a summary of the assumptions we made under each scenario:

In scenario 1, we assume there will be warm and wet conditions as described under climate change predictions. In this scenario, warm and wet conditions will increase heavy winter rainfall events and summer rains, which will result in increased non-native plant growth, and result in more food spoilage in stored caches for giant kangaroo rats. We assume urban and agricultural development will continue at current rates on unprotected lands. There will be limited opportunities for habitat patches to increase in size, or for connectivity to increase or improve throughout the range. We assumed conservation efforts and restoration activities will remain the same as current levels.

In scenario 2, we assume there will be hot and dry conditions as described under high greenhouse gas concentrations and climate change predictions. In this scenario, hot and dry conditions will result in decreases in overall precipitation and an increase in drought intensity and duration. While all future scenarios are impossible to predict with any certainty, current trends show greenhouse gas concentrations are continuing to rise in our atmosphere, consistent with the assumptions of RCP 8.5. If trends do not change, this future scenario could be the most likely to occur. We assume that with hotter and drier conditions there will be an increase in fallowed croplands, without active restoration, within the Central Valley. We assume that development from urbanization will continue at current rates on unprotected lands, with the potential to decrease habitat size and connectivity. Lastly, we assumed conservation efforts and restoration activities will remain the same as current levels.

In scenario 3, we assume there will be hot and dry conditions, similar to scenario 2 (above). We also assume there will be an increase in land protections in the central part of the species range, such that urban and agricultural development will slow and land protections will increase. We assume aggressive habitat restorations will take place on the fallowed croplands throughout the range of the species. Under these assumptions, connectivity and land protections will increase throughout the range.

In all scenarios, we assume increased, stochastic precipitation extremes, meaning droughts, and heavy rainfall events are likely to become more frequent.

Over the next 40-50 years, we believe scenario 1 or 2 are the most likely to occur. We believe these scenarios are the most likely because threats are likely to continue at the current conservation efforts have remained relatively stable over the past 20-30 years. It is possible that increased management will result in decreased habitat loss and fragmentation but currently these radical management changes are unlikely to occur. However, it is still important to consider the possibility for widespread, increased management.

Contents

CHAPTER 1. INTRODUCTION

This report summarizes the results of a Species Status Assessment (SSA) conducted by the U.S. Fish and Wildlife Service (USFWS) for the giant kangaroo rat (*Dipodomys ingens*). The giant kangaroo rat is a federally and state endangered mammal, found only on the southwestern plains in California's central valley.

Commented [MS1]: This is not accurate.

Here is the description from later on in the document.

Giant kangaroo rats were found only in the western slopes of the San Joaquin Valley; the Tulare Basin and in the adjacent Carrizo Basin and Cuyama and Panoche valleys (Williams 1992, p. 307).

This Species Status Assessment (SSA) report is a summary of the information assembled and reviewed by the USFWS and incorporates the best scientific and commercial data available. We used the SSA framework to conduct and in-depth review of the species' biology and the stressors which impact the species. This information allowed us to evaluate its current biological status, and to predict the possible future status of resources and environmental conditions as a means of assessing the giant kangaroo rat's long-term survival. This SSA report summarizes the results of our analysis. As new information becomes available, we intend to update this SSA report as needed so that it can support all functions of the Endangered Species program. This might include candidate assessments, listing decisions, consultations, and species recovery.

The purpose of this SSA report is to provide the biological and scientific foundation of the USFWS's eventual decision to change the status of the giant kangaroo rat; to downlist it from endangered to threatened or to remove it from the endangered species list of 1973, as amended (Act)(16 U.S.C. 1531 et seq.). Importantly, this SSA report does not result in a decision document, but instead provides the biological information and scientific analysis needed to support future decisions made by the USFWS under the Act. Decisions for the changing the status of the giant kangaroo rat will be made by the USFWS after reviewing the SSA report and all relevant laws, regulations, and policies, and the USFWS will announce the policy decision independently in the Federal Register.

Petition History and Previous Federal Actions

On December 30, 1982, the USFWS put forth a proposed rule, identifying the giant kangaroo rat as a taxon for which the USFWS had substantial information to support the appropriateness of listing as endangered or threatened throughout its entire range (47 FR 58454). On August 13, 1985 the USFWS proposed to list the giant kangaroo rat as endangered (50 FR 32585). On January 5, 1987 the final rule designating the giant kangaroo rat was put forth by the USFWS (52 FR 283). A recovery plan was completed for the species in 1998. There has been one 5-year review completed for the species in 2010 which outlined its current status at that time. This SSA will inform an updated 5-year review for the giant kangaroo rat, which will be made available to the public.

The Species Status Assessment (SSA) Framework

This SSA report summarizes the results of in-depth review of the giant kangaroo rats' biology and stressors, an evaluation of the species' biological status, and an assessment of the resources and conditions needed to maintain long-term viability. For the purposes of this assessment, we define viability as the ability of the species to sustain populations in the wild into the future in a biologically meaningful timeframe (explanation for our timeframes are given in **Chapter 4. Future Condition**). Using the SSA Framework (Figure 1), we consider what the giant kangaroo rat needs to be viable into the future by characterizing the current and future status of the species using the concepts of

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resiliency, redundancy, and representation (the "3 Rs") from conservation biology (Shaffer and Stein 2000, p. 308-311; USFWS 2016, p. 12).

- *Resiliency* is the ability of populations to tolerate natural, annual variation in their environment and to recovery from periodic or random disturbances, known as stochastic events. Resiliency can be measured using metric like vital rates, such as annual births and deaths, and population size. In general, populations with high abundance and stable or increasing populations. Populations with high resiliency can better withstand stochastic change in demography or their environment due to natural or anthropogenic disturbances.
- *Redundancy* is the ability of a species is the ability of a species to withstand catastrophic events, such as a rare, destructive natural event that affects multiple populations. Redundancy is measured by the duplication and distribution of populations across the range of the species. The more redundant a species, or the greater number of populations a species has distributed over a larger landscape, the better able it is to recovery from catastrophic events. Redundancy helps "spread the risk" across habitats and landscapes, ensuring all populations are not extirpated at once due a single catastrophic event.
- *Representation* is the ability of a species at adapt to changing physical (climate, or habitat) and biological (diseases, predators, etc.) conditions. Representation can be measured by looking at the genetic, morphological, behavioral, and ecological diversity within and between populations across a species' range. The more representation, or diversity, a species has, the more likely it is to adapt to and persist with natural or human-caused changes to its environment.

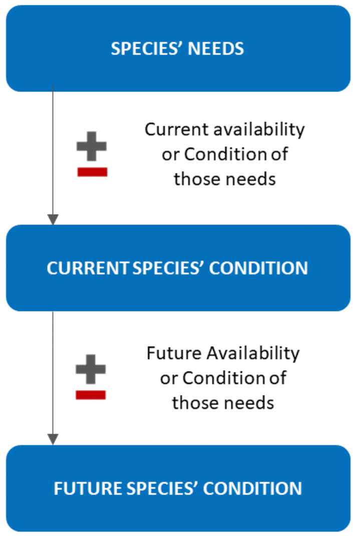

Figure 1. The three phases (blue boxes) of the SSA Framework used to guide this analysis. To assess the viability of the giant kangaroo rat, we evaluated the species' needs, the current availability and condition of those needs, and the species' current condition. We then predicted the species' future condition based on the future availability.

For the purpose of this SSA, viability is defined as the ability of a species to sustain populations in the wild over time. Viability is not a single state; rather, there are degrees of viability. In other words, we do not conclude that a species is or is not viable upon completion of an SSA. Instead, we characterize the resiliency, redundancy, and representation a species currently presents and predict how these characteristics might change into the future. Generally, species with greater resiliency, redundancy, and representation are more protected from the vagaries of the environment, can better tolerate stressors and adapt to changing conditions, and are thus more viable than species with low levels of the 3Rs.

To assess the viability of the giant kangaroo rat, we analyzed the species' ecology, historical and current conditions, and projected the viability of the species under a number of future scenarios, all in the context of the 3Rs and using the best scientific data available. Chapter 2 of this SSA report summarizes the biology, ecology, and needs of the giant kangaroo rat at the individual, population, and species level. Chapter 3 examines the stressors (and conservation measure) which impact the resiliency of giant kangaroo populations and analyzes the historical and current conditions of the species. Chapter 4 predicts the future condition of the species under three potential scenarios. In Chapter 5, we summarize all of the information presented in this SSA and analyze the viability of the giant kangaroo rat.

In summary, this SSA is a scientific review of the best available information, including scientific literature and discussions with experts, related to the biology and conservation status of the giant kangaroo rat.

Summary of New Information

Since the completion of the 5-year review for the giant kangaroo rat in 2010, we studied new peer-reviewed literature and solicited data and new information from partner agencies within the state of California, including, but not limited to, state wildlife management agencies, universities, private contractors, and the Bureau of Land Management (BLM). Specifically, we requested new information (after 2010) on:

- The species' distribution, population sizes, population trends, and any updates to the species range or mapped colonies;
- The magnitude and severity of ongoing habitat loss;
- Other threats to the species including energy development, wildfire and rodenticide use.
- Updates to laws, regulations, or policies that might apply to the species; and
- Any ongoing conservation for the species and its habitats.

Our literature review and data solicitation resulted in new information on the genetic structure, population dynamics, and management and conservation efforts on state and BLM-managed public lands.

We incorporated these data, which include spatial data, peer-reviewed literature, reports, and personal communications, into various parts of the SSA, including the analysis of the current distribution of the giant kangaroo rat and the severity of stressor and related conservation actions. If we lacked specific data for some aspect of our analysis, we used information from other kangaroo rat species including the Heerman's kangaroo rat (*Dipodomys heermanii*), the California kangaroo rat (*Dipodomys californicus*), the San Joaquin valley kangaroo rat (*Dipodomys nitratoides*) and the banner-tailed Kangaroo rat (*Dipodomys spectabilis*).

CHAPTER 2. SPECIES ECOLOGY AND NEEDS

This chapter provides basic, biological information about the giant kangaroo rat, which includes its taxonomic history, relationships to other species, morphological description, physical environment, reproductive biology and other life-history traits. The survival needs of the giant kangaroo rat are then presented at the individual, population, and species levels. This is not an exhaustive review of the species' natural history; rather, this section provides the ecological basis for SSA report.

Life History

Taxonomy and Description

The giant kangaroo rat is a small, burrowing mammal which lives only in the central valley of California (Merriam 1904. P. 141). Kangaroo rats belong to the family Heteromyidae, and are native to arid deserts and grasslands of North, South and Central America (Genoways and Brown, 1993, p. 489-617; Alexander and Riddle 2005, p. 366). Heteromyid rodents have many adaptations to survive in dry environments (Grinnell 1932, p. 320; Alexander and Riddle 2005, p. 366). Kangaroo rats have physical and physiological adaptations to enhance water conservation, making them highly specialized to arid habitats (MacMillen 1983, p. 65-68). There are more than twenty species kangaroo rats in the genus *Dipodomys*, of which the giant kangaroo rat is the largest (Merriam 1904, p. 139; Williams and Kilburn 1991, p. 1; table 1).

Mean Measurements (mm) of Giant Kangaroo Rats			
	Total Length	Tail Length	Hind Foot
Male	334.4	185.7	50
Female	332.9	181.2	50

Table 1. Mean measurements for male and female giant kangaroo rats. Males are generally larger than females (Grinnell 1932, p. 1).

Giant kangaroo rats can be distinguished from other large kangaroo rats by the presence of five, rather than four, toes on their hind feet (Grinnell 1922, p. 6). All kangaroo rats are adapted for bipedal, ricochetal locomotion; they are capable of moving quickly by hopping on their elongated hind limbs (Williams and Kilburn 1991, p. 2). In comparison, the forelimbs appear small, being used mainly to collect seeds and grasses while foraging; enlarged claws on both front and back limbs aid in burrowing and self-defense (Williams and Kilburn, 1991, p. 1).

The giant kangaroo rat has a proportionately large head, and a shortened neck, with the eyes and ears positioned high on the sides of the head (Williams and Kilburn, 1991, p. 3). The tail makes up most of the length of the animal, being longer than the length of the head and body combined (Williams and Kilburn, 1991, pp 1). Fur-lined cheek pouches open on either side of the mouth, forming deep, folded pockets along the head where the animal stores seeds while foraging (Grinnell, 1932, p. 23). Giant kangaroo rats have a counter-shaded coat, with tan fur on the dorsal (head and back) surface and cream-colored fur on the ventral surface (underside of the body and tail); the tail has a black stripe dorsally (top) ending in a large tuft of longer hairs (Grinnell 1922, pp 29; Williams and Kilburn 1991, p. 1). Juveniles can be distinguished from the adults by a light-gray dorsal coat, which becomes tan as the animal matures (Williams and Kilburn, 1991, p. 1).

Habitat

Historically, the San Joaquin valley floor was a mosaic of different habitats, with extensive wetlands, uplands, and long riparian corridors along streams which carried large amount of runoff from the nearby Sierra Nevada Mountains into seasonal wetlands which surrounded shallow lakes (Griggs *et al.* 1992, p. 112-118). Outside of wetland areas, much of the southwestern San Joaquin Valley was desert-scrub with alkali-sink habitats (Germano *et al.* 2011, p. 139). Within the San Joaquin Valley there are several kangaroo rat species, which occupy a range of desert, grassland, scrub and chaparral communities; these are typically arid and semi-arid areas, although some species are found within smaller valleys of the coastal mountains, which have slightly greater rainfall (Williams 1992, p. 301). Giant kangaroo rats are found only on the arid uplands on the western side of the San Joaquin valley, where gently sloping hills and grasslands meet the coastal range of low mountains (Grinnell 1932, p. 306-307). The scrub habitats were, and are, dominated by saltbush (*Atriplex spinifera* and *A. polycarpa*) as well as native and non-native annual grasses (Germano *et al.* 2011, p. 139).

The Central Valley of California is characterized by a Mediterranean climate (O'Farrell *et al.* 2016 p. 4). Winters within the range of the giant kangaroo rat are cool and daytime temperatures rarely fall below 10˚C; overnight temperatures do not often drop below freezing (Williams 1992, p. 302). Summers are long and hot with midday temperatures that regularly exceed 38˚C (Williams 1992, p. 302; O'Farrell *et al.* 2016 p. 4). The San Joaquin Valley receives little rain annually (<20 cm) (Williams and Kilburn 1991, p. 6). Most rain that does fall, occurs during the winter months - between November and April (Williams and Kilburn. 1991, p. 2). Due to limited annual rainfall and high summer temperatures, the southwestern portion of the San Joaquin Valley characterized as a climatic desert (Germano *et al.* 2011 p. 139-145). Even so, the cool wet winters allow rich grasslands to form on the western slopes of the valley, which support a wide diversity of endemic plants and animals (Williams 1992, p. 302-303).

Giant kangaroo rats are uniquely adapted for living in an arid environment. Distribution models for the species show that the amount of rainfall during the driest month of the year was the most important variable in predicting giant kangaroo rat distribution (Bean *et al.* 2014, p. 6). Mostly likely, giant kangaroo rat abundance was highest in areas where the driest month received a mean of 0 mm of precipitation (Bean *et al.* 2014, p. 6). Similarly, the probability of finding giant kangaroo rats was highest in areas where the driest annual quarter received a mean of 4mm of precipitation, and where average annual temperatures were between 14℃ and 16℃ (Bean *et al.* 2014, p. 6).

There is evidence that heavy rainfall years, or years where the driest quarter receives rain, can be detrimental to the survival of giant kangaroo rats. Researchers attempting to relocate giant kangaroo rats on unoccupied habitat saw initial population growth for several years, until the population crashed when the climate became wet (Germano, 2010, p. 86).

Optimal habitats for giant kangaroo rats are usually annual grassland communities with few or no shrubs on gentle slopes which do not flood in winter (Grinnell 1932, p. 306; Shaw 1934, p. 275; Hawbecker 1951, p. 50-54; Williams *et al.* 1993 p. 9; Figure 2). A few populations of giant kangaroo rats can be found in shrub communities and can occur on slopes up to 22% in grade, but these areas are generally considered marginal habitat (Williams 1992, p. 302; O'Farrell *et al.* 2016, p. 2). Researchers have recently found that slopes less than 5% facilitate the most dispersal and gene flow across the landscape (Alexander *et al.* 2019 p. 1533). Small, scattered populations of giant kangaroo rats can also occur atop hills and ridges, where slopes are flat enough (<10% slope) and soils are

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Formatted: Font: 12 pt, Not Italic, Font color: Auto, Complex Script Font: 12 pt deep enough to allow for burrowing activity (O'Farrell *et al.* 2016, pp 10). It has been suggested that along with other native vertebrates, giant kangaroo rats are ill equipped to survive in extremely dense stands of non-native grasses, preferring a more open, diverse plant communities (Germano et. al. 2001, p. 550). These non-native species can also grow too tall for giant kangaroo rats to harvest seeds successfully. High rainfall encourages the growth of tall, non-native grasses (Cone, 2008, p. 1). While giant kangaroo rats might exist on marginal habitat, large populations continue to be found within habitats which were historically described as optimal (O'Farrell *et al.* 2016, p. 10).

Figure 2. An example of giant kangaroo rat habitat within the Carrizo Plain National Monument. The image shows multiple burrow entrances conglomerated around a shallow mound, forming a classic precinct. Vegetation in the area is primarily sparse annual grasses and small forbs, both native and non-native. The area surrounding the burrow has been grazed and clipped by giant kangaroo rats, while larger grasses still stand off-site of the precinct. Habitat is on sandy-loam soils on gently sloping topography.

The soils of the San Joaquin Valley floor are alluvial or residual, which were formed from ancient marine sediment deposits and eroded from the surrounding mountains (O'Farrell *et al.* 2016, p. 4; Williams 1992, p. 302). Within low-slope areas, soils are predominantly sandy-loams, loams, and clay-loams (Nelson *et al* 1921, p. 35-39). In the Elk Hills region of Kern County, giant kangaroo rat burrows were found on a variety of revised soil series, but most were characterized as some type of fine, sandy-loam (O'Farrell *et al.* 2016, p. 10). The highest number and density of burrows were found in Kimberlina and Tupman gravelly sandy-loam, both of which are deep (115-150 cm), well-draining soil types (O'Farrell *et al.* 2016, p. 10-11; Williams 1992, p. 302).

The native plant community within the range of the giant kangaroo rat has changed since Europeans colonized California. Livestock, such as sheep and cattle, which overgrazed native plant communities, allowing exotic species of plants to take hold in the plains of the central valley (Williams 1992, p. 303). Within the elk hills area of their range, giant kangaroo rats are found in vegetation communities dominated by invasive Eurasian species including red brome (*Bromus rubens*) and red-stem filaree (*Erodium cicutarium*) (O'Farrell *et al.* 2016, p. 5). Other plant species reported to commonly occur are summarized in Table 2.

Common Name	Scientific Name
Non-Native	
Oats	*Avena* spp.
Red Brome	*Bromus rubens*
Red-stem filaree	*Erodium cicutarium*
Arabian schismus	*Schismus arabicus*
Native	
Iodine bush	*Allenrolfea occidentalis*
Fiddleneck	*Amsinkia* sp.
Allscale	*Atriplex polycarpa*
Spiny Saltbush	*Atriplex spinifera*
California Ephedra	*Ephedra* sp.
California buckwheat	*Erigonoum fasciculatum*
Snakeweed	*Guterrezia* sp.
Cheesebush	*Hymenoclea salsola*
Winter fat	*Krascheninnikovia lanata*

Table 2. Common plant species which occur within giant kangaroo rat habitat. Where giant kangaroo rats occur, much of the native community has been altered due to non-native plant introductions by Europeans in the 1800s. Today, Red-brome and Red-stem filaree often dominate the vegetation community composition. Still, many plants native to the San Joaquin valley are also found in abundance (O'Farrell *et al.* 2016 p. 5; Williams *et al.* 1993, p. 9 Williams *et al.* 1993, p. 9).

Feeding Habits

Giant kangaroo rats consume a variety of food resources, including seeds, invertebrates, and green plant material, the latter of which is usually only available in the spring (Grinnell 1932, p. 6; Shaw 1934, p. 276). Throughout most of the year, giant kangaroo rats primarily consume seeds, which they forage for with their small fore-limbs, and then transport in their fur-lined cheek pouches (Williams and Kilburn 1991, p. 377; Williams *et al.* 1993, p. 10). Seeds not eaten immediately are cached in small pits near burrows, or taken back to the burrow itself (Shaw 1934, p. 277; Hawbecker 1951, p. 55; Williams *et al.* 1993, p. 10). Pregnant and lactating females have been found with green matter in their cheek pouches, leading some to suggest early spring plant growth aids in reproduction and lactation (Grinnell 1932, p. 377).

Giant kangaroo rats cut the ripening heads of grasses and forbs (Shaw 1934, p. 275). The species also gather individual seeds which are scattered over the surface of the ground, and mix in the upper layer of soil (Shaw 1934 p. 277; Williams *et al.* 1993, p. 10). Seed species consumed include filaree

(*Erodium*), peppergrass (*Lepidium nitidum*), fiddle neck (*Amsinckia douglasiana*) and brome (*Bromus rubens*) among many others (Shaw 1934, p. 275). Before moving seeds into underground caches or pits, all forage is dried in the sun, which prevents molding (Shaw 1934, p. 277; Williams *et al.* 1993, p. 10). During their lifetime, kangaroo rats rarely drink water; getting most of the moisture they need from the seeds and grasses which make up their diet (Williams and Kilburn 1991, p. 7).

Behavior

Giant kangaroo rats are crepuscular, foraging on the surface during sunset and sunrise – although most activity takes place in the evening, during the first two hours after dark (Shaw 1934, p. 276; Braun 1985, p. 7). Annual activity patterns vary by season; foraging activity is highest in the spring as seeds of annual plants ripen (USFWS 1988 p. 88). The ability to transport large quantities of seeds and other food in cheek pouches and their highly developed caching behaviors allows giant kangaroo rats to survive annual periods of drought (Williams *et al.* 1993 p. 11).

All species within the *Dipodomys* genus are solitary and live alone within their burrows; however, giant kangaroo rats are unique, in that their burrows are often conglomerated to form colonies (Cooper and Randall 2007, p. 1000). These colonies of burrows are called precincts (Shaw 1934, p. 276). Although they live in close proximity, animals within precincts are territorial, and are not thought to share burrows or food resources with neighbors of the same species (Shaw, 1934, p. 276; Murdock and Randall 2001 p. 152). Male and female giant kangaroo rats use smell to distinguish between individual neighbors (Murdock and Randall 2001, p. 152). All adults show high intraspecific aggression throughout most of the year (Eisenberg 1963a, p. 63; Murdock and Randall 2001, p. 153). Both males and females are territorial, due to the fact that their survival depends on building and defending seeds in a larder within their burrows, or in pit caches near the burrow entrance (Randall 1997, p. 1172-1173; Shaw 1934, p. 276). Individuals will guard their seed caches from others who might try to steal their food (Eisenberg 1963a, p. 7). Each territory contains 2-4 burrow openings, and an underground system of complex tunnels and aboveground activity areas such as sand-bathing sites (Grinnell 1932, p. 308-310; Shaw 1934, p. 276; Randall 2007, p. 368-379). Male and female giant kangaroo rats show differences in home-range partitioning throughout the year; the size of home ranges varied seasonally for males but not for females (Cooper and Randall 2007, p. 1003-1005).

Kangaroo rats are fossorial, spending the majority of time underground to avoid hot, daytime temperatures; sometimes emerging for only a few moments to forage after dusk (Braun 1985, p. 7). Because of this behavior, they are limited to areas with specific soil composition which allows for stable, deep burrows to be built (O'Farrell *et al.* 2016, p. 2). Giant kangaroo rat burrows have multiple, horizontal entrances within a circular, mounded area, vertical holes around 5cm in diameter, which they sometimes plug with soil, and 'haystacks' of clipped, annual grass seed heads in the vicinity of the mound (O'Farrell *et al.* 2016, p. 6).

Recent studies show that giant kangaroo rats can disperse up to 5.52 kilometers from their natal den (Alexander et al. 2019 p. 1539-1540). These long-distance dispersal events appear to be small, and other researcher have found that they more commonly disperse 700 meters from their natal den (Loew et al. 2005, p. 496) suggesting that giant kangaroo rats are generally philopatric. It appears that while giant kangaroo rats have strong habitat preferences, they are more generalized during dispersal events (Alexander et al. 2019 p. 1541). It is possible, therefore, for giant kangaroo rats to pass through high slope or inappropriate habitat to get to new habitat. However, medium to low precipitation and low slope seemed to allow for greater gene flow when models were tested

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As you cited earlier, slope <5 degrees promoted connectivity (Alexander et al. 2019)

(Alexander et al. 2019 p. 1541). It is likely that high habitat connectivity is needed for adequate gene flow across landscape which support these species.

As grasses begin to senesce in April, giant kangaroo rats remove all herbaceous vegetation from the top of their burrows (Bean *et al.* 2014, p. 2). This behavior results in clear circles of bare soil, 2-7 meters in diameter; these bare areas are a good indictor or giant kangaroo rat presence (Bean *et al.* 2014, p. 2). These areas are even visible through aerial surveys (Semerjan p. 2019 p. 5). Attempts have been made to survey precinct abundances using satellite images as well (Cone, 2008, p. 1)

Giant kangaroo rats appear to show little fear in the face of adversity. Researchers who handle them remarked at the apparent lack of fear the animals showed during mark-recapture studies; once released they were quickly more occupied by collecting seeds, and did not seem concerned with their captors' presence (Shaw 1934, p. 276). This behavior is likely driven by instinct to collect and store as many seeds as possible, even in the face of danger, in order to thrive in an arid environment (Shaw 1934, p. 277).

Life Cycle and Reproduction

The giant kangaroo rat has an adaptable reproductive pattern that is affected by both population density and environmental conditions (USFWS 1998, p. 88; Figure 3). Breeding occurs annually, or bi-annually depending on available resources, between January and May (Randall *et al.* 2002, p. 16; Williams and Kilburn 1991, p. 377; Figure 3). In highly productive seasons, giant kangaroo rats can breed during the year of their birth, and mature females may breed twice (USFWS 1998, p. 88).

Observations on mating suggest that males visit the burrows of females during the winter breeding season (Randall et. al. 2002, p. 15). In other species of kangaroo rat, males have been observed to den with females during estrus, at which time mating likely occurs (Eisenberg 1963b, p. 62). Mating behavior varies with population density, the number of females in estrus, and the operational sex ratio (Randall et. al. 2002, p. 18; Cooper and Randall, 2007 p. 1005). In years with relatively high densities and/or skewed sex ratios, multiple males compete for access to females; in contrast, during low density years, each male appeared to mate only with a single female neighbor (Cooper and Randall 2007 p. 1006).

For large species of kangaroo rat, such as the giant kangaroo rat, gestation lasts between 29 and 34 days (Eisenberg 1963b, pp 63). Females usually give birth to litters of one or two pups at a time, but can have more (Randall *et al.* 2002, p. 16). Kangaroo rat pups are born blind and hairless, and remain so until after the first two weeks of life (Reynolds 1958, p. 114). The hind feet finish developing between 6 and 10 weeks, at which time young animals begin exploring outside of the natal den; by 3-4 weeks of age, the young are weaned from the mother (Reynolds 1958, p. 114). Dispersal happens soon after the young emerge from the natal den, when the either the mother, siblings, or both chase them off (USFWS 1998, p. 88). The average longevity of the giant kangaroo rat is unknown. Similar species of kangaroo rat live approximately two years in the wild (Tappe 1941, p. 146). While some individuals might live longer, the average lifespan for giant kangaroo rats is probably similar (Semerdjian pers. comm. 2019).

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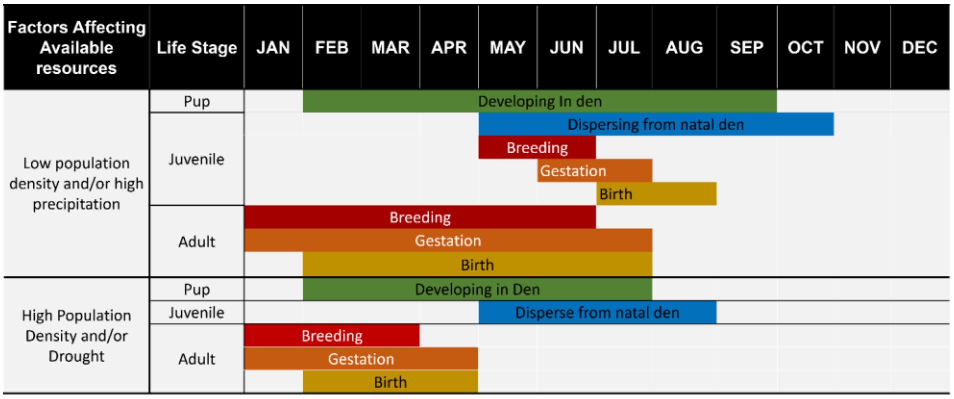

Figure 3. Gant timeline-chart for one year in the life cycle of a giant kangaroo rat adult, pup and juvenile. Life cycles vary for individuals depending on various factors which affect available resources. During years of drought females only give birth once annually, and the juveniles do not breed. During years of normal to high rainfall, one female can sustain multiple litters and juveniles might breed successfully. Local population density can also affect the breeding rates of individuals in similar ways.

Metapopulation dynamics

Where giant kangaroo rats still persist, individuals are scattered in pockets of optimal habitat as demographically-distinct populations in discrete locations, which are difficult to identify due to annual population fluctuations (Statham *et al.* 2019, 8; San Joaquin Valley Upland Species SSA: Expert elicitation meeting, 2019). Researchers hypothesize these fluctuating population numbers are due to climatic conditions and primary productivity, and as such, some areas of marginal habitat are only occupied during highly productive years (San Joaquin Valley Upland Species SSA: Expert Elicitation Meeting, 2019). Some habitat patches within geographical units support populations with growth rates which encourage emigration, while other habitat patches are less favorable (expert elicitation). In fact, past reports have documented the disappearance of colonies within the Panoche region, which have since been recolonized (Williams et al. 1995, p. 3-6). These source-sink dynamics are characteristic of a metapopulation, which often have a finite lifetime, and are prone to local extinction (Hanski, 1991, p. 4). Within some areas of the range, there is genetic evidence of source-sink dynamics and genetic drift across the landscape, which supports the metapopulation hypothesis (Statham *et al.* 2019, p. 8) (See 'Genetic Diversity and Range partitioning' below).

Commented [MS3]: This is true for the northern population, but is not the case for the southern, which exists as a large continuous population across much of the Carrizo plain.

Genetic Diversity and Range Partitioning

A goal of this SSA is to identify evolutionary potential through management of populations which preserve the full spectrum of species diversity (i.e. redundancy) across the species' range. Genetic studies have found evidence of two, geographically distinct, genetic lineages of giant kangaroo rat, which correspond to the northern and southern portions of the species' range (Good *et al.* 1997, p. 1308). The northern genetic lineage of giant kangaroo rat is equivalent to the Panoche geographic unit. Currently the population structure within the northern range is comprised of many 'metapopulations' with varying degrees of gene flow across the landscape (Statham *et al.* 2019, p. 8). The southern genetic lineage is comprised of the Carrizo Plain and Western Kern county geographic units. Cuyama Valley probably has a similar genetic origin as well, but there is limited genetic data

Commented [MS4]: Northern GKR exists as a metapopulation, with many subpopulations, with varying degrees of gene flow across the landscape from this geographic unit. Northern and southern genetic lineages appear to have been separated between ~two thousand to thirteen thousands years ago (Statham *et al.* 2019, p. 7). The two populations likely represent peripheral segments of a much larger histrorical population. This divergence appears to have been driven by changing climate conditions after the most recent glacial maximum, resulting in genetic divergence and local adaptations (Statham *et al.* 2019, p. 7). Subpopulations within the northern metapopulation appear to show some signature of genetic drift, which is characteristic of small, localized populations. Genetics analyses of migration rates resolved the uggest source-sink dynamics, and identified the large centrally located Tumey Hills population as a source population (See metapopulation dynamics above), (Statham *et al.* 2019, p. 7). It has been hypothesized that the genetic diversity in the Panoche region is maintained by the topographic diversity within this area (Good et al. 1997, p. 1307).

The northern and southern genetic lineages of giant kangaroo rats are spatially and genetically disjunct, separated by approximately 150 km; these populations represent the northern and southernmost range limits and as such represent geographically distant peripheral segments of a once larger range (Good *et al.* 1997, p. 1307). Genetic studies have shown a high level of genetic diversity still exists throughout the range of the giant kangaroo rat, despite population fluctuations (Good *et al.* 1997, p. 1306-1307; Statham *et al.* 2019, p. 8). High diversity in both of the extreme ends of the range (northern and southern) contributes to the redundancy across the range of the species. Genetic analysis of both northern and southern genetic lineages show declines in effective population size after European colonization and land-use changes in the central valley (Statham *et al.* 2019, p. 7). Although genetic diversity remains high, it is unknown how much diversity was lost due to habitat loss throughout the species' range as a result of human land-use changes (Good *et al.* 1997, p. 1308-1309), making conservation of current genetic diversity important for long-term species viability.

Status as Ecosystem Engineers and a Keystone Species

Ecosystem engineers are organisms that affect resource availability within an ecosystem by physically changing the biotic or abiotic materials within their environment (Jones et. al. 1994, p. 374). Engineers are also considered keystone species if they have a high environmental impact relative to their abundance (Write and Jones 2006, p. 205). Giant kangaroo rat burrowing activities modify the surface topography of the landscape and change the mineral composition of the soil (USFWS 1998, p. ix). Where present, the giant kangaroo rat occurs in such abundance that their burrowing activity can dramatically change the habitat composition (Shaw 1934, p. 2; Prugh and Brashares 2012, p. entire). Their precincts are large enough to be seen through satellite imagery and have been shown to alter the community composition of the local vegetation (Semerdjian 2019, p. 7; Prugh and Brashares 2012, p. 671). Thus, giant kangaroo rats are considered ecosystem engineers and a keystone species within the upland habitat of the western San Joaquin Valley (Schiffman 1994, p. 525; Goldingay *et. al.* 1997, p. 49-50; Bean *et al.* 2019 p. 1).

Many plants grow on the soil disturbed by giant kangaroo rats as they burrow (USFWS 1998, p. 91). The California Jewel flower (*Caulanthus californicus*), a federally endangered plant, is one of several species which grows on burrow systems (USFWS 1998, p. 89). Native plants growing on giant kangaroo rat precincts appear to be more robust and healthy (USFWS 1998, p. 91). However, some studies show that the disturbance by giant kangaroo rats allows for colonization of invasive, non-native species of plant (Schiffman 1994, p. 524-537).

Commented [MS5]: There is no genetic data, so the relationship of this population to others has been never been assessed.

Commented [MS6]: More accurate and informative to give range to provide uncertainty.

Commented [MS7]: This information is in regard to the response of the species as a whole to changing climate after the last glacial maximum.

The information is not relevant to the thread about splitting time between N and S. I suggest deleting or moving elsewhere.

Commented [MS9]: Bear this in mind.

Yes, the North and South are both diverse. But both are genetically distinct with unique genetic diversity not found in the other population. For example, virtually none of the mtDNA haplotypes are shared between populations. So the northern population is not a genetic or evolutionary backup for the south and vice versa. As you reference earlier, both populations have been separated for thousands of years. And may have evolved distinct evolutionary adaptations.

The burrow structures of the giant kangaroo rat are commonly used by other vertebrate and invertebrate species, some of which are state and federally classed as endangered or threatened (USFWS 1998, p. 91). Other species occupying the burrows of giant kangaroo rats include the blunt-nosed leopard lizard (*Gambelia sila*), and the San Joaquin antelope squirrel (*Ammospermophilus nelsi*) along with many species of invertebrate (Goldingay *et al.* 1997 p. 49). When abundant at a site, giant kangaroo rats are significant prey items for many predators, such as the federally endangered San Joaquin kit fox (*Vulpes macrotis mutica*), making them an important part of the ecological food chain (USFWS 1998, p. 91). Some studies suggest that kangaroo rat burrowing activity can change the local plant community (Goldingay et. al. 1997). It is clear that giant kangaroo rats have the ability to alter the plant and animal communities surrounding them, making them a central, possibly essential, part of a healthy, native ecosystem.

Giant Kangaroo Rat Needs

A species can only survive if its basic ecological needs are met. In this section, we translate our knowledge of the giant kangaroo rat's biology and ecology into needs. We do this at the level of the individual animal, the local population, and finally for the entire species. For individual giant kangaroo rats, we describe the habitat resources and conditions that are needed for pups, juveniles, and adults to complete the stage of their life cycle. We then describe the habitat and demographic conditions that giant kangaroo rat populations need to be resilient. Finally, we describe what the species needs in order to be viable in terms of resiliency, redundancy, and representation (**Error! Reference source not found.**).

Individual Needs

Individual needs for the giant kangaroo rat vary by life stage (**Error! Reference source not found.**). Little is known about the first few months of a giant kangaroo rat's life. The pups are born underground in burrows between February and March (Grinnell 1932, p. 314). In order for pups to survive this life stage, females need access to friable soils which are deep enough to build safe burrows for young. In average rainfall years, water does not penetrate the ground far enough to flood burrows or spoil seed stores. Adequate vegetation is also needed in order for females to provide enough milk for young to grow rapidly during this time. Young are born during the brief rainy season in the San Joaquin Valley, which triggers rapid vegetation growth. Females have been observed consuming large amounts of green vegetation in early spring, which might give them enough energy to offset the cost of feeding young (Grinnell 1932, p. 313).

Once the young emerge from the burrows, they must find their own territories of appropriate habitat. The primary time for dispersal seems to follow maturation at around 12 weeks of age (USFWS 1998, p. 89). In years of high population density, or low food resources, young appear to stay near their natal burrow until they are driven off by the mother or litter mates (USFWS 1998, p. 89). Dispersal behaviors can be different for males and females; more females have been found dispersing, but males appear to disperse further distances (USFWS 1998, p. 89). Based on capture-mark/recapture data, male giant kangaroo rats on average disperse 122m and females 99m; rarely, individuals disperse distances of over 700m (Loew *et al.* 2005, p. 496). However, genetic studies have

Commented [MS10]: One single genetic study, not plural found siblings in territories 5 kilometers apart, suggesting on rare occasions individuals disperse further than was once thought (Alexander 2016, p. 16) Still, it is unlikely individuals move more than

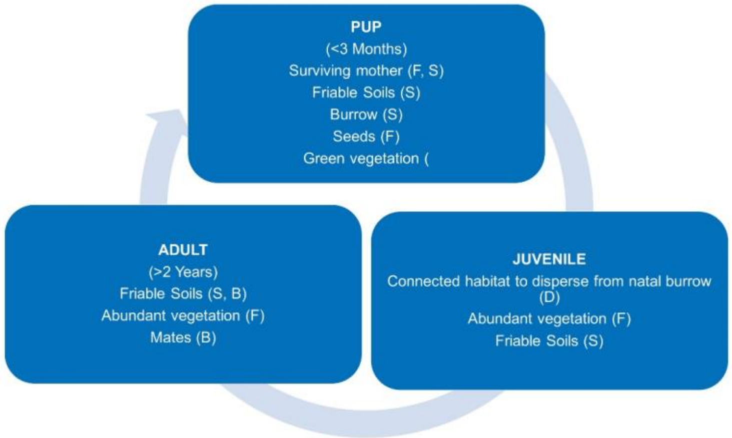

Figure 4. Life cycle diagram with the resource needs for individual giant kangaroo rats - pups, juveniles, and adults. Every need fulfills an aspect of the stage in the life cycle, shown in parentheses. Individual giant kangaroo rats need these resources to breed (B), feed (F), shelter (S), and disperse (D).

a few kilometers within their lifetime. Because of their limited dispersal capabilities, habitat connectivity is essential for giant kangaroo rat viability.

Giant kangaroo rats are restricted to grasslands-dominated landscapes on sandy-loam soils, which are not subject to frequent flooding (Loew *et al.* 2005, p. 496). Being primarily granivorous (Williams and Kilburn, p. 377), adult giant kangaroo rats need access to abundant seed resources to survive (Shaw 1934, p. 282). Although they have been observed feeding on green plant material and invertebrates (Grinnell 1932, p. 23) giant kangaroo rats collect and store seeds, which sustain them throughout the hot, dry summers which characterize their habitat (Williams 1992, pp 302). Therefore, seeds are the primary food resource needed by the species.

In addition to the other resources needed at early life stages, adult giant kangaroo rats need access to mates. During their lifetime, they do not appear to move far from their burrows (Braun 1985, p. 8) suggesting they do not move large distances in search of mates. Therefore, giant kangaroo rats need to have overlapping territories with individuals of the opposite sex. Studies show there is no significant difference in size of male and female home range size (Braun 1985, p.10; Cooper and Randall 2007, p. 1003) so habitat requirements for adults are likely the same between sexes throughout the majority of the year. During the winter breeding season males are more likely to overlap with females; females rarely overlap with other females during the breeding season (Cooper and Randall 2007 p. 1003).

Population Needs

For the purposes of this SSA, we define a giant kangaroo rat population as a complex of precincts within dispersal distance of one another (<5km) on appropriate habitat with a high degree of connectivity. The San Joaquin Valley floor has largely been converted to agriculture, fragmenting much the historical range for the giant kangaroo rat, and isolating existing populations from one another. Highly connected habitats still have the largest, most robust populations of giant kangaroo rat, suggesting that contiguous habitats are needed for long-term species' survival. Populations likely need habitat patches of an appropriate size in order to sustain over time.

Throughout its evolutionary past, giant kangaroo rats have been subjected to annual cycles of drought and rainfall. However, under current climate change scenarios climatic variability in the San Joaquin Valley is likely to increase. The Valley will likely see prolonged periods of drought (5 years or longer) punctuated by uncharacteristically heavy rainfall events. Individual giant kangaroo rats will need to move throughout the environment to find enough mates and resources to survive and reproduce during times of drought and increased temperatures. Therefore, areas of contiguous habitat are needed to ensure the species can survive harsh conditions.

Heavy precipitation might also affect the persistence of giant kangaroo rats. Although the direct effect to individuals is unclear, studies have shown that populations of giant kangaroo rats decline during winters with extremely high rainfall (Single *et. al.* 1996, 34-40). Studies on other species of kangaroo rats also suggest that populations respond negatively to high-rainfall years. Banner tailed kangaroo rats (*Dipodomys spectabilis*), a large kangaroo rat species from Arizona, exhibited steep declines in population numbers during wet, El Niño years with high precipitation (Valone, et. al. 1995, pp 430). While the reason for declining kangaroo rat populations during wet years is still unclear, researchers have hypothesized that seed caches spoil and animals eventually starve, or suffer from mold-toxins which result from moisture in seed caches (Valone et. al. 1995, p. 430). Still, others suggest that wet years spur changes in vegetation composition, which can have a cascading effect on the ecosystem, ultimately causing a decline in the seed producing grasses which kangaroo rats need to survive (Waster and Ayers 2003, p. 1038). Giant kangaroo rat populations have seen similar population fluctuations throughout periods of drought and wet years (Prugh *et al.* 2018 p. 1-5). Because extremely wet years can pose a threat to the survival of the giant kangaroo rat, adequate levels of precipitation which do not persist into the driest quarter of the year (when seeds are dried and cached) are needed for long term persistence of the species. Conversely, prolonged droughts are also stress populations, suggesting there is a minimum precipitation amount needed for population viability, although no research exists to determine what amount that might be.

Large tracts of habitat, with a variety of microclimates and population connectivity can help mitigate the effects of climatic stress to the species by increasing survival of individuals, and allowing for population recruitment from other areas. Therefore, to remain ecologically functional throughout these increasingly variable precipitation cycles, populations need high levels of fecundity and juvenile survival as well as habitat connectivity between subpopulations.

Species Needs

The giant kangaroo rat is limited to a narrow band of habitat in the western San Joaquin Valley. As a species, the giant kangaroo rat needs multiple, resilient, connected populations that display genetic diversity across its range and a suitable annual climate (USFWS 1998 89; Lowe, *et al.* 2005 Germano *et al.* 2001, 553). Currently, there is still a high degree of genetic diversity within across all populations. However, these populations exist in small, isolated areas of habitat across the range (Statham *et al.* 2019 p. 8). Populations with these characteristics are more prone to genetic drift, which leads to loss of diversity over time, and, in many cases, extinction. Maintaining this diversity, i.e. protecting as many populations as possible and increasing connectivity between them, is important for the species to persist in the future in response to changing climatic variables or stochastic events.

Commented [MS11]: This is good where the populations likely had historical connectivity. Not true where there is evidence of longer term isolation. Perhaps this will come up again later.

Species distribution models suggest the strongest predictor of giant kangaroo rat presence are areas where the driest month received a mean of 0 mm of precipitation (Bean *et al.* 2012, p. 6). Therefore, the species must exist within a narrow range of climatic conditions, where there is just enough, but not too much, precipitation during the right time of the year; extremely wet years, extreme dry years, and precipitation during the summer months could hinder the species' long-term viability.

Giant kangaroo rat habitat, although once widespread and abundant, has decreased dramatically since the early 1900s due in part to agricultural development since the 1960s (Blackhawk *et al.* 2016, p. 261; Williams and Kilburn 1991, p. 3). Today, the six remaining analysis units of giant kangaroo rat are highly fragmented and there is little chance of gene flow across the range of the species (USFWS 2010, p. 87; **Error! Reference source not found.**, p. 31). Because kangaroo rats rarely disperse as adults, and have a relatively short dispersal distances (less than a kilometer) connected habitats of appropriate compositions are essential to the species survival; habitat fragmentation and decreased habitat connectivity can be detrimental to the long-term survival of the giant kangaroo rat species as a whole (Blackhawk *et al.* year p. 263).

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Or refer to Figure 6.

Summary of the Species Needs in terms of the 3 R's

When individual giant kangaroo rats have access to seeds, friable soils, adequate habitat, appropriate climatic conditions, and access to mates throughout the year, reproductive rates increase and precincts multiply (Loew *et al.* 2005, p. 496; Shaw 1934, p. 282; Williams and Kilburn 1991, p. 3). These conditions create resilient populations that are able to withstand periodic natural disturbances, such as prolonged winter droughts, heavy rainfall events, or wildfires (resiliency). At the population level, giant kangaroo rat juvenile survival and dispersal drives annual population growth (Germano and Saslaw 2017, 1624). In order to adapt to changing physical and biological conditions, the species must maintain genetic and ecological diversity (representation) and maintain a wide distribution of resilient populations across its range (redundancy). Because the species does not disperse long distances, large areas of contiguous habitat are needed to allow for gene flow across the species' range (Germano and Saslaw 2017, p. 1625). With many colonies spread across geographical units within the range, and a high potential for migration within these areas, populations are better able to withstand catastrophic events (redundancy) (Germano and Saslaw 2017, p. 1625). At the species level habitat connectivity facilitates a network of multiple (redundant), self-sustaining (resilient) populations distributed across the range of the giant kangaroo rat, which display the breadth of their genetic and ecological diversity (representation). This increases the ability of the species to adapt to changing physical and biological conditions (representation) (Table 2).

Level	Need	Function of Need	Association with the 3 Rs
Individual	Friable Soils,	Digging burrows, caches, and larders to store food and escape from predators	Resiliency
	Seeds	Maintain food resources through cyclical dry periods; water resources	Resiliency
	Appropriate Habitat	Habitat for dispersing individuals	Resiliently, Redundancy
	Abundant vegetation	Meet caloric and nutritional needs during the breeding and pupping season; increase seed production to facilitate seed storage and caching	Resiliency
	Access to Mates	Reproduction; Fecundity	Resiliency
Population	Individual Survival	Increase population growth	Resiliency
	Habitat Connectivity For Dispersal	Increase genetic diversity, allows for immigration following catastrophic events, increase the abundance within populations and the number of populations across the range	Resiliency, Redundancy
Species	Connected populations across the range	Improves the viability of the by reducing risks posed by catastrophic events	Redundancy
	Maintain genetic and ecological diversity throughout the range of the species	Preserves diversity and provides for adaptability in the face of changing environmental conditions	Representation

Table 3. Summary of individual, population, and species' needs for the giant kangaroo rat in terms of the 3Rs.

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CHAPTER 3: CURRENT AND HISTORICAL CONDITION

In this chapter, we summarize the historical and current conditions of the giant kangaroo rat at the level of a population, and the species as a whole. We do this by introducing stressors, which are sometimes synonymous with threats, and have and continue to influence the species' condition and the current conservation efforts which help to ameliorate these stressors. We then detail how the abundance of giant kangaroo rats has changed over time. Finally, we put the species' historical and current conditions in the context of redundancy, resiliency, and representation to assess the current viability of the species.

The giant kangaroo rat's range extends along the western the San Joaquin Valley and inner-coastal ranges, within the state of California (Figure 6). Until the mid-20th century, giant kangaroo rats were spread over thousands of acres of continuous habitat (USFWS 1998, p. 85). This range was characterized by gently sloping grasslands from the base of the Tehachapi Mountains in the south, to near Los Banos, Merced County in the north; the Carrizo and Elkhorn Plains and San Juan Creek watershed west of the Temblor Mountain, which form the western boundary of the Southern San Joaquin Valley; the upper Cuyama Valley is nearly adjacent to the Carrizo Plain; scattered colonies exist on steeper slopes and ridge tops in the Ciervo, Kettleman, Panoche and Tumey Hills in the Panoche Valley (USFWS 1998, p. 85).

Commented [MS13]: The kettleman hills are in the central valley, the others are near each other to the north

Data Use Statement

For the purposes of this SSA we compiled spatial data from the International Union for Conservation of Nature (IUCN 2019), the California Natural Diversity Database (CNDDB 2019), California Conservation Easement Database (2019), California Protected Areas Database (2019) and data provided by researchers (Bean *in litt*. 2019; H. T. Harvey and Associates *in litt*. 2019).

We used ESRI ArcGIS Pro for the spatial analyses conducted within this chapter. The data sources for these analyses are cited throughout this section.

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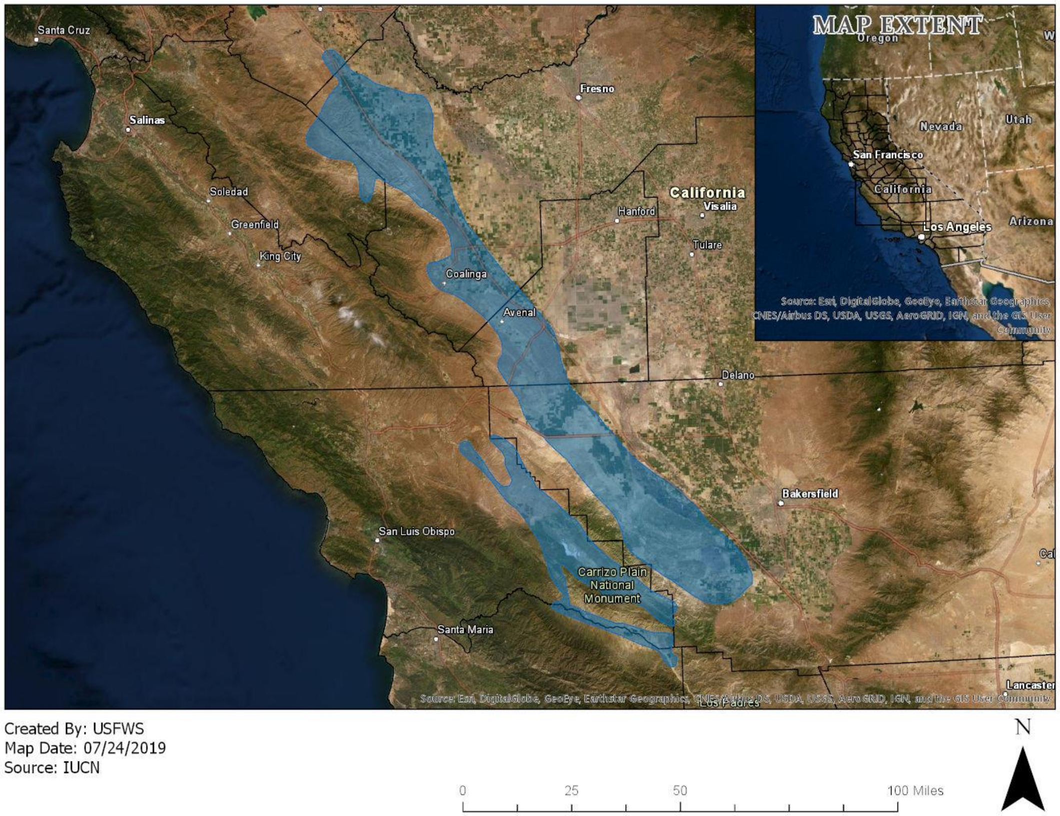

Figure 5. The historical range of the giant kangaroo rat. This boundary represents the outer boundary of areas where giant kangaroo rats could have occurred prior to land use changes by humans in the 20th century. This predicted, historical range extends over as many as 1.9 million acres on the western slopes of the San Joaquin Valley, California.

Analysis units

Because metapopulation dynamics of the giant kangaroo rats are not fully understood at the population level, we chose larger geographic units on which to base our analysis of species condition. Units were selected based on the dispersal limits of the species and features such as human land use changes or topography were used to describe their boundaries. While populations might exist outside of these units, they are not consistently occupied or are located on private lands that have not been systematically surveyed.

Throughout the historical range of the giant kangaroo rat, populations exist in six distinct geographic units. Within these units, individuals are scattered in pockets of optimal habitat as demographically-distinct populations in discrete areas, which are difficult to identify due to annual population fluctuations.

Today there are six, geographic units where giant kangaroo rats are still known to occur: (1) the Ciervo-Panoche Region in western Fresno and eastern San Benito Counties; (2) Kettleman Hills in southwestern Kings County; (3) San Juan Creek Valley in eastern San Luis Obispo County; (4) the Lokern area, Elk Hills (previously Naval Petroleum Reserves Number 1 and 2; NPR-1 and NPR-2), Taft, and Maricopa in western Kern County; (5) the Carrizo Plain in eastern San Luis Obispo County; and (6) the Cuyama Valley along the eastern Santa Barbara-San Luis Obispo County line (USFWS 1998, p. 87; Figure 6). For a full description of these units see the recovery plan (Service 1998, p 87).

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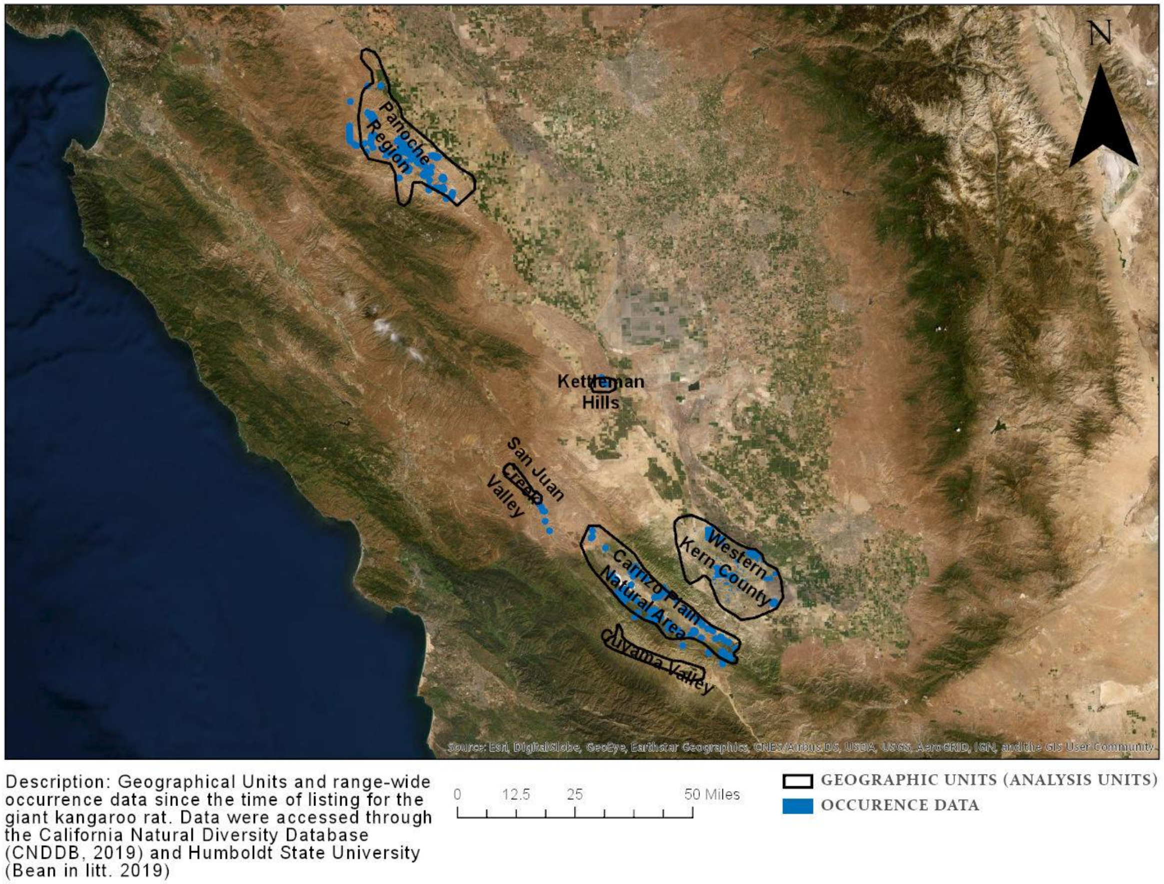

Figure 6. Six geographic Units used to analyze the condition status of giant kangaroo rats across the species' range. Occurrence data collected by various agencies since the time of listing are shown in blue.

Geographic Unit	Acres	Approximate Percent of Historical Range
Ciervo-Panoche	199,870	10.5%
Kettleman Hills	8,942	0.5%
San Juan Creek	14,074	0.7%
Western Kern County	185,553	9.8%
Carrizo Plain Natural Area	184,740	9.7%
Cuyama Valley	37,311	2%

Table 4. Acres of land within the Geographic Units used to analyze the condition of the giant kangaroo rat across the species range. The historical range encompasses approximately 1.9 million acres. However, the analysis units represent a much smaller area.

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Historical Range

Historically, giant kangaroo rats existed only in the southwestern plains of the San Joaquin Valley and select valleys of the inner coastal range (Bowers 2004, p. 202; Grinnell 1922, p. 30). Colonies were spread over a large area of continuous habitat within the gently rolling plains on the western slopes of the San Joaquin Valley, Carrizo Plain, and Cuyama Valley (Grinnell 1932, p. 306; Shaw 1934, p. 275; Hawbecker 1944, p. 1944; 1951, p. 161). This area encompasses an estimated area between 1.6 and 1.9 million acres (**Error! Reference source not found.**)(USFWS 1998, p. 85).

Current Range

Until the mid-20th century, land within the historical range of the giant kangaroo rat remained largely in its natural configuration (USFWS 1998, p. 92). Once the state of California completed water infrastructure projects, land was rapidly cultivated and irrigated along the west side of the San Joaquin Valley (Williams 1992, p. 303). Between the 1950s and 1980s, vast portions of the San Joaquin valley were quickly converted from natural ecosystems to crop-land, due primarily to advancements in industrial agricultural practices (Williams *et al.* 1995, p. 1). By the end of the 1980s, nearly all natural ecosystems which provided habitat for the giant kangaroo rat had been converted to irrigated agriculture – reducing habitat for rare species native to the grasslands of the Central Valley (USFWS 1998, p. 92).

Currently, the giant kangaroo rat is found on less than 5 percent of its historical range (CNDDB; USFWS 2010, p. 3). Populations of giant kangaroo rat are fragmented into the six major geographic units (described above) which represent two genetic lineages. These units are themselves fragmented into smaller, demographically independent populations, many of which are isolated by several miles of barriers such as steep terrain or unsuitable habitat, including agriculture and urban development (USFWS 1998, p. 87).

The largest, most robust populations exist at the range limits and as such represent geographically distant peripheral segments of a once large contiguous range (Statham *et al.* 2019, p. 2). The northern area of the range (Ciervo-Panoche geographic unit) is characterized by small, isolated habitat patches separated by agriculture or steep, sloping hills, which are unlikely to be occupied by the species (Williams *et al.* 1995, p. 2-6; Alexander 2016, p. 4-6). Individual giant kangaroo rats within these smaller 'metapopulations' interact somewhat, contributing to gene flow across the northern spatial-unit of the giant kangaroo rat range (Statham *et al.* 2019 p. 2). Not all subpopulations contribute the same amount of genetic flow across the range, because migration rates between subpopulations are asymmetrical (Statham *et al.* 2019, p. 9). For instance, giant kangaroo rats in Tumey hills contribute a disproportional amount of genetic material to other areas within the Panoche geographic unit, while other populations contribute relatively little genetic material to other areas (Statham *et al.* 2019, p. 9).

The southern genetic lineage is comprised of three geographical units (Table 5). The Carrizo plain geographical unit harbors the largest population which exists on contiguous, protected habitat. Western Kern County harbors another area with some protected land, known as the Lokern lowlands, where populations have fluctuated during cycles of drought and wet years, but have nonetheless persisted. Less is known about the Cuyama Valley population abundance over time, and the unit contains little protected habitat. The three geographical units which comprise the southern genetic lineage are separated by topographic features where populations of giant kangaroo

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rat are not likely to persist, but where gene flow is hypothetically possible between units (Good *et al.* 1997, p.1308).

Less is known about the Kettleman Hills and the San Juan creek units, and it is unclear if these areas are more closely related to the northern or southern genetic lineages. For the purposes of this document, and to assess representation for the species, we acknowledge this uncertainty by placing them within their own "middle" genetic lineage.

In the central portion of the species range are two, smaller geographical units (USFWS 1998, p. 87). Large populations appear to exist in the Kettleman Hills area of northwestern Kern/southwestern Kings County (Bean *et al.* 2019, p. 3). Little is known about the San Juan Creek unit, although aerial surveys suggest that smaller populations might be scattered across hills and small valleys in this area (Bean *et al.* 2019, p. 3). Genetic analysis suggest the Kettleman Hills population might be the most distinct population within the species range (Statham *et al.* 2019, p. 3, 16). However, this area also has the lowest heterozygosity, suggesting this geographic area has already experienced genetic drift due to isolation and small population size (Statham *et al.* 2019, p. 3).

Genomic analyses suggest that the northern and southern populations might be under divergent selection pressures (Statham *et al.* 2019, p. 17). Morphological comparisons of giant kangaroo rat populations at the ends of the range suggest that Carrizo Plain individuals are larger than those in the Ciervo-Panoche (Statham *et al.* 2019, p. 17). Northern and southern animals occur is habitats at the opposite ends of the precipitation regime tolerated by the species, which could be driving local adaptation (Stan tham *et al.* 2019 p. 17).

Of the available habitat patches where giant kangaroo rats still occur, the largest and most continuous portion is the Carrizo Plain National Monument ("Carrizo") (Statham *et al.* 2019). The Carrizo plain lies at the southern portion of the species' range, and is nestled between the central valley floor, and the Cuyama valley (**Error! Reference source not found.**) (Widick and Bean 2019, p. 2). Populations within the Carrizo Plain Natural Area appear to be robust, and there has been recent evidence that the range within the local area has expanded in recent years (Ian Axsom in litt. 2019). Together, the Carrizo plain, Cuyama Valley, Lokern ecological preserve on the central valley floor comprise the southern portion of the species' range, and represent a unique genetic lineage. Large areas within this southern portion of the range of the giant kangaroo rat have been set aside on federal land and state lands, along with and private easements, for preservation of the species (**Error! Reference source not found.**).

Habitat for three of the six regional populations of giant kangaroo rats include little protected public or conservation lands (USFWS 1998, p. 93). This includes the Cuyama Valley, Kettleman Hills, and San Juan Creek Valley. All are small and vulnerable to extirpation from demographic and random catastrophic events and inappropriate land uses.

Commented [MS14]: Carrizo and Lokern are closely related to on another and are a unique genetic unit.

There has never been any genetic assessment of the Cuyama population. We don't know if it is belongs to the southern group (with Carrizo and Lokern), or is distinct.

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Genetic Lineage	Geographic Unit
Northern	Ciervo-Panoche
Middle	San Juan Creek
	Kettleman Hills
Southern	Western Kern County
	Carrizo Plain Natural Area
	Cuyama Valley

Table 5. Catigorization of the genetic lineages and geographic units (analysis units). There is little genetic data from Kettleman Hills and and none from the San Juan creek unit, and it is unclear if these areas are more closely related to the Northern or Southern genetic lineages (It is also worth noting that the genetic relationship between the Kettleman Hills and the San Juan creek units is also unknown). For the purposes of this document, we acknowledge this uncertainty by placing them within their own "middle" genetic lineage.

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For three off the geographic units there is little genetic info on their relationship to other populations (Kettleman, San Juan, Cuyama)

So, in reality they are being grouped based on geographic proximity.

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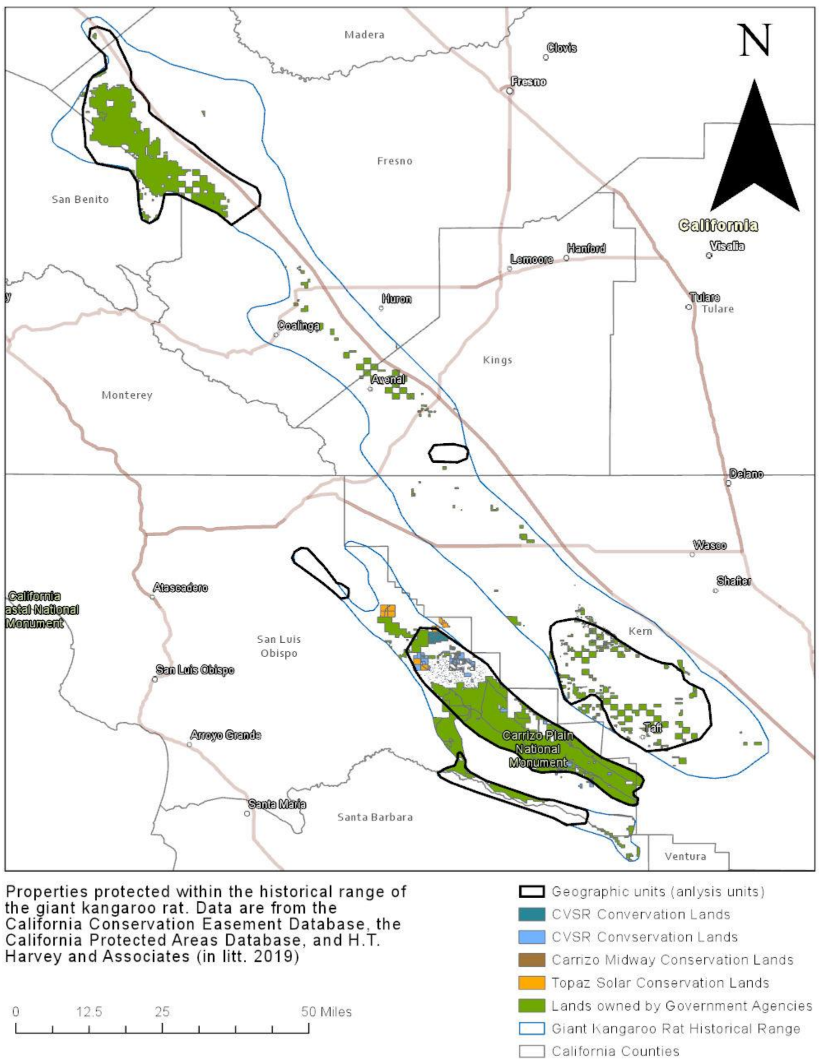

Figure 7. Protected lands throughout the historical range of the giant kangaroo rat. Within some geographic units, such as the Carrizo Plain Natural Area (National Monument) much of the land has been protected by federal and state land management agencies with conservation measures to protect giant kangaroo rats. Other units have no such protections in place, or the protections within the geographic unit are patchy and discontinuous. Areas without protections allow for continued land-use changes and anthropogenic development, meaning the long-term viability of the giant kangaroo rat in these units is uncertain.

Geographic Unit	Percent of Protected Land Within Unit
Ciervo-Panoche	40.7%
Kettleman Hills	0.0%
San Juan Creek	0.0%
Western Kern County	19.2%
Carrizo Plain Natural Area	76.8%
Cuyama	24.5%

Table 6. Percent of land within geographic units which is protected by federal or state agencies, which include conservation easements on private lands. Some public lands are specifically managed for endangered species, while others do not have such management assurances in place.

Regulatory mechanisms and other influences on the protected status and viability of the species

State Laws

When the giant kangaroo rat was listed as endangered in 1987 (52 FR 283), we identified the inadequacy of State law to curtail habitat loss, secure high density population sites, or arrest declines and extirpation of remaining colonies from a variety of causes. Additionally, we stated that a joint program in effect between the California Department of Fish and Game, the California Department of Food and Agriculture and various county agencies had been ineffective in reducing the decline of the giant kangaroo rat. At the time of listing, regulatory mechanisms thought to have some potential to protect giant kangaroo rat included the listing of the species under the California Endangered Species Act (CESA); the listing rule (52 FR 283) provides an analysis of the level of protection that was anticipated from those regulatory mechanisms. This analysis appears to remain currently valid. As explained in the listing rule (52 FR 283) joint efforts between the State and counties to protect the giant kangaroo rat are not successful in securing extant habitat and preventing the further decline of the species.

California Endangered Species Act (CESA): The CESA (California Fish and Game Code, section 2080 et seq.) prohibits the unauthorized take of State-listed threatened or endangered species, The CESA requires State agencies to consult with the California Department of Fish and Wildlife that might affect a State-listed species and mitigate for any adverse impacts to the species or its habitat. Pursuant to CESA, it is unlawful to import or export, take, possess, purchase or sell any species or part or product of any species listed as endangered or threatened. The State may authorize permits for scientific, educational, or management purposes, and to allow take that is incidental to otherwise lawful activities.

The California Environmental Quality Act (CEQA): The CEQA (Chapter 2, section 21050 et seq. of the California Public Resources Code) requires review of any project that is undertaken, funded or permitted by the State or a local government agency. If significant environmental effects are identified, the lead agency has the option of requiring mitigation through changes in the project or to decide that overriding consideration make mitigation infeasible (CEQA Sec. 21002). In the latter case, projects may be approved that cause significant environmental damage, such as destruction of listed endangered species or their habitat. Protection of listed species through CEQA is, therefore, dependent upon the discretion of the lead agency involved.

Natural Community Conservation Planning Act: The Natural Community Conservation Program is a cooperative effort to protect regional habitats and species. The program helps identify and provide for area wide protection of plants, animals, and their habitats while allowing compatible and appropriate economic activity. Many Natural Community Conservation Plans (NCCPs) are developed in conjunction with Habitat Conservation Plans (HCPs; See below) prepared pursuant to the Federal Endangered Species Act.

Federal Laws and Regulations

National Environmental Policy Act (NEPA): NEPA (42 U.S. C. 4371 *et seq*.) provides some protection for listed species that may be affected by activities undertaken, or funded by Federal agencies. Prior to implementation of such projects with a Federal nexus, NEPA requires the agency to analyze the project for potential impacts to the human environment, including natural resources. In cases where that analysis reveals significant environmental effects, the Federal agency must propose mitigation alternatives that would offset those effects (40 CFR 1502.16). These mitigations usually provide some protection for listed species, However, NEPA does not require that adverse impacts be fully mitigated, only that impacts be assessed and the analysis disclosed to the public.

Clean Water Act: Under section 404, the U.S. Army Corps of Engineers (Corps or USACE) regulates the discharge of fill material into the waters of the United States, which include navigable and isolated waters, headwaters, and adjacent wetlands (33 U.S.C 1344). In general, the term “wetland” refers to areas meeting the Corps’ criteria of hydric soils, hydrology (either sufficient annual flooding or water on the soil surface), and hydrophytic vegetation (plants specifically adapted for growing in wetlands). Any action with the potential to impacts waters of the United States must be reviewed under the Clean Water Act, National Environmental Policy Act, and Endangered Species Act. These reviews require consideration of impacts to listed species and their habitats, and recommendations for mitigation of significant impacts.

Although the giant kangaroo rat is an upland species typically found in landscapes with limited jurisdictional waters under the Clean Water Act, the Corps has frequently assumed the role of the Federal nexus for both large and small projects in their entirety, even though these projects might only impact a minor amount of jurisdictional water. The approach by the Corps has facilitated numerous consultations under section 7 of the Act that would have otherwise likely required a section 10 permit.

Endangered Species Act of 1973m as amended (Act): The Endangered Species Act of 1973, as amended (Act), is the primary Federal law providing protection for the giant kangaroo rat. The Service has responsibility for administering the Act, including sections 7, 9, and 10 that address take. Section 9 prohibits the taking of any federally listed endangered or threatened species. Take is defined in Section 3 as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. Harass is defined by Service regulations at 50 CFR 17.3 as an intentional or negligent act or omission which creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, breeding, feeding, or sheltering. Harm is defined by the same regulations as an act which actually kills or injures wildlife. Harm is further defined to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavior patterns, including breeding, feeding, or sheltering. The Act provides for civil and criminal penalties for the unlawful taking of listed species.

Since listing, the Service has analyzed the potential effects of Federal projects under section 7(a)(2), which requires Federal agencies to consult with the Service prior to authorizing, funding, or carrying out activities that may affect listed species. For projects without a Federal nexus that would likely result in incidental take of listed species, the Service may issue incidental take permits to non-Federal applicants pursuant to section 10(a)(1)(B). Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity (50 CFR 402.02). To qualify for an incidental take permit, applicants must develop, fund, and implement a Service-approved Habitat Conservation Plan that details measures to minimize and mitigate the project's adverse impacts to listed species. Many of these Habitat Conservation Plans are coordinated with the State of California's related Natural Community Conservation Planning program.

The status of the giant kangaroo rat as a species listed under the Act can reduce the severity of the effects of habitat degradation and destruction caused by anthropogenic sources, such as agriculture, urban development, and solar power generation, which continues to be a threat to the giant kangaroo rat throughout its range (See Section: Habitat Modification and Destruction, below). Development projects that are subject to section 7 consultation or result in the issuance of an incidental take permit under section 10 typically include habitat compensation, which can reduce the severity of overall habitat loss typically associated with these projects. Habitat compensation can occur via a variety of mechanisms, including the purchase of credits at approved conservation banks, through permittee responsible mitigation, and through the development of habitat conservation plans (HCP's) and Safe Harbor Agreements. In addition to reducing the amount of overall habitat loss for the species, Section 10(a)(1)(A) of the Act allows for permits to be issued for recovery activities that result in take. Recovery activities are those activities that are specifically implemented for scientific purposes or to enhance the propagation or survival of the affected species, including interstate commerce activities.

Conservation Banks: A conservation bank is a site, or suite of sites (i.e., umbrella bank), that is conserved and managed in perpetuity, and provides ecological functions and services for specified listed species or resources. Conservation banks function to offset adverse impacts to these species that occurred elsewhere; therefore, the Service approves a specified number of credits that the bank owner may sell to developers or other project proponents for use as compensation for adverse impacts their projects have on those species. The bank owner then uses the money from the credit purchases to permanently protect and manage the land for those species and resources. More information about conservation banks within the Sacramento Fish and Wildlife Office's Service area can be found at: https://www.fws.gov/sacramento/es/Conservation-Banking/Banks/In-Area/.

There are currently no active conservation banks for the giant kangaroo rat. The Service is currently considering several areas with active giant kangaroo rat populations for the establishment of conservation banks for the species.

Permittee responsible Mitigation: Permittee-responsible mitigation includes activities or projects undertaken by a permittee (or authorized agent) to provide compensatory mitigation for which the permittee retains full responsibility. Permittee-responsible mitigation projects are typically not established in advance of the impacts they are offsetting and they do not have credits that can be used at a later time to offset different impacts, like conservation banks.

Habitat compensation through permittee responsible mitigation for the giant kangaroo rat has occurred throughout the species range for a variety of projects. Some of the agencies implementing permittee responsible mitigation for the giant kangaroo rat include the California Department of Transportation (CalTrans), Panoche Valley Solar Farm, and the U.S. Coast Guard.

HCPs: Habitat Conservation Plans (HCPs) provide a pathway forward to balance wildlife conservation with development. The primary objective of the HCP program is to conserve species and the ecosystems they depend on while streamlining permitting for economic development. Being included as a covered species under an HCP means that habitat will be set aside and managed for the species as compensation for covered activities, such as planned urban development, within the area the HCP covers (Table 7). In addition, within the permitted area avoidance, minimization, and other conservation measures (e.g. monitoring, seasonal work windows, habitat management, etc.) will be put into place.

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Habitat Conservation Plan	Year the Permit was Issued
Seneca and Enron Oil and Gas	1998
PG&E San Joaquin Valley Operations & Maintenance HCP	2007
Nuevo-Torch	1999
Metropolitan Bakersfield	1994
Kern Water Bank	1997
Kern County Waste Facilities	1997
EnviroCycle, Inc.	1993
Cenvron Pipeline	1996
ARCO Coles Levvee (ARCO Western Energy)	1996

Table 7. There are nine HCPs which include the giant kangaroo rat as a permitted species. More information about HCPs which include the giant kangaroo rat as a covered species can be found at: https://ecos.fws.gov/ecp0/profile/speciesProfile?spcode=A08P

Safe Harbor Agreements: The Safe Harbor Policy provides incentives for property owners to restore, enhance and maintain habitats for listed species. Because many endangered and threatened species occur exclusively, or to a large extent, on non-Federally owned property, the involvement of non-Federal property owners in the conservation and recovery of listed species is critical to the eventual success of these efforts. Under the policy, the Service will provide participating property owners with technical assistance to develop Safe Harbor Agreements that manage habitat for listed species, and provide assurances that additional land, water, and/or natural resource use restrictions will not be imposed as a result of their voluntary conservation actions to benefit covered species. When the property owner meets all the terms of the Agreement, the Service will authorize incidental take of the covered species at a level that enables the property owner to return the enrolled property back to an agreed upon baseline condition. There are currently no safe harbor agreements for the giant kangaroo rat.

Recovery Permits: Recovery permits, also referred to as 10(a)1(A) permits, allow scientists to take listed species as a means to ultimately contribute to the recovery of the listed species. The data acquired from some actions covered under recovery permits (e.g., occurrence, abundance, distribution, etc.) allow the Service to make informed decisions for the species that will enhance their survival and recovery. Recovery permits can be issued for activities that directly aid the recovery of a species, such as captive breeding, reintroductions, habitat restoration, removal or reduction of threats, and educational programs. The Service's recovery permitting program aids in the conservation of listed species by ensuring permittees have adequate field experience and qualifications for conducting activities with the target listed species and, for most species, ensures that permittees are following standardized protocols while surveying. The recovery permitting application process ensures that scientific proposals are crafted using the recommended actions laid out in the Recovery Plan for the target species. There is currently no protocol survey guidance for the giant kangaroo rat; however, there are minimum qualifications to obtain a recovery permit for the subspecies. Minimum qualifications and species specific protocols can be found at: https://www.fws.gov/cno/es/Recovery_Permitting/mammals/giant_kangaroo_rat/GiantKangarooRat_MinimumQuals_20020801.pdf

There are several long-term monitoring efforts which are permitted through section 10(a)1(A). Through these projects, scientists are able to gain a better idea of how the species responds to climatic fluctuations, changes in land management. Population trends data collected from long term monitoring projects are instrumental for understanding if current, service approved management plans are effective as well. There have been several, small giant kangaroo rat population expansions reported to USFWS through recovery permit reporting; in 2019 there was a range expansion of giant kangaroo rats in the northern portion of the Carrizo plain (Axom, 2019).

Sikes Act: The Sikes Act (16 U.S.C. 670 authorizes the Secretary of Defense to develop cooperative plants with the Secretaries of Agriculture and the Interior for natural resources on public lands. The Sikes Act Improvement Act of 1997requires Department of Defense installations to prepare Integrated Natural Resource Management Plants (INRMPs) that provide for the conservation and rehabilitation of natural resources on military lands consistent with the use of military installations to ensure the readiness of the Armed Forces. The INRMPs incorporate, the maximum extent practicable, ecosystem management principles and provide the landscape necessary to sustain military land uses. While INRMPs are not technically regulatory mechanisms because their implementation is subject to funding availability, they can be an added conservation tool in promoting the recovery of endangered and threatened species on military lands. Currently, there are no known populations of giant kangaroo rats existing on military lands.

Federal Land Policy and Management Act of 1976 (FLPMA): The Bureau of Land Management is required to incorporate Federal, State, and local input into their management decisions through Federal law. The FLPMA (Public Law 97-579, 43 U.S.C. 1701) was written "to establish public and land policy; to establish guidelines for its administration; to provide for the management, protection, development and enhancement of the public lands, and for other purposes."

Section 102(f) of the FLPMA states that "the Secretary [of the Interior] shall allow an opportunity for public involvement and by regulation shall establish procedures … to give Federal, State, and local government and the public, adequate notice and opportunity to comment upon and participate in the formulation of plants and programs relating to the management of the public lands." Therefore, through management plants, the Bureau of Land Management is responsible for including input from Federal, State, and local government and the public. Additionally, Section 102(c) of the FLPMA states that the Secretary shall "give priority to the designation and protection of areas of critical environmental concern" in the development of plants for public lands. Although the Bureau of Land Management has a multiple-use mandate under the FLPMA which allows for grazing, mining, and off-road vehicle use, the Bureau of Land Management also has the ability under FLPMA to establish and implement species management areas such as Areas of Critical Environmental Concern, wilderness, research areas, etc., that can reduce or eliminate actions that adversely affect species of concern (including listed species).

The Carrizo Plain National Monument was created by the BLM in 2001 to protect species native to the California's central valley, including the giant kangaroo rat. Over two-hundred thousand acres of public land are managed to conserve natural resources for benefit to the public.

National Wildlife Refuge System Improvement Act of 1997: This act establishes the protection of biodiversity as the primary purpose of the National Wildlife Refuge system. This has led to various management actions to benefit federally listed species. The giant kangaroo rat does not exist on any established national wildlife refuge lands.

Stressors Affecting the Species' Condition and Related Conservation Measures

In this section, we discuss how the long-term viability of the giant kangaroo rat is affected by the 3R's (Figure 8). Here, we discuss the external factors (stressors) that might influence the 3R's, and thus the viability of the giant kangaroo rat (Figure 9). Previous documents which address the status of the species (USFWS 1987, 1998, 2010) describe some of these influences as threats. Here, we will use the term 'stressor' to include previously identified threats, as well as other factors which might affect the overall viability of the species. For a review of threats please see the most current 5-year review on the species (USFWS 2010, p. 19-37).

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Through review of the available literature, we chose to evaluate stressors for which there is broad consensus of the potential to impact the species. These stressors include habitat modification and destruction, drought, flooding, disease or pathogens, rodenticides, wildfire, overgrazing, inbreeding, and genetic drift. There are other possible stressors identified as potentials threats in other documents, which were considered in the course of our analysis, such as off road vehicle use, mining, predation, and solar energy development (USFWS, 2010, p. 36) but these stressors are most often associated with negative effects to individual animals rather than entire populations. Therefore, these stressors are excluded from further analysis in our SSA report. For the stressors which are included, we provide a description of the magnitude of the stressor, and an influence diagram modelling the potential impacts of the stressor on population resiliency, and a summary of ongoing and potential conservation that might lessen these impacts.

Habitat loss and fragmentation are largely believed to be the main stressors which negatively impact the resiliency of giant kangaroo rat populations (USFWS 1998, p. ix; 2010, p. 19-27). However, there are many factors for which the impacts are not well understood. The Sustainable Groundwater Management Act (SGMA) could have a positive impact to the species, as agricultural fields are projected to be taken out of operation, and might be restored to its native configuration (Kelsey *et al.* 2019 pers. comm.). Strategic land retirement and restoration might allow for species to recolonize previously occupied habitat, reducing habitat fragmentation and increasing gene flow across the environment (Kelsey et al. 2019 pers. comm.). However, the future of this program is uncertain, and currently habitat continues to be converted for agriculture and other commercial activities within the central valley of California (expert elicitation meeting, 2019, pers. comm.).

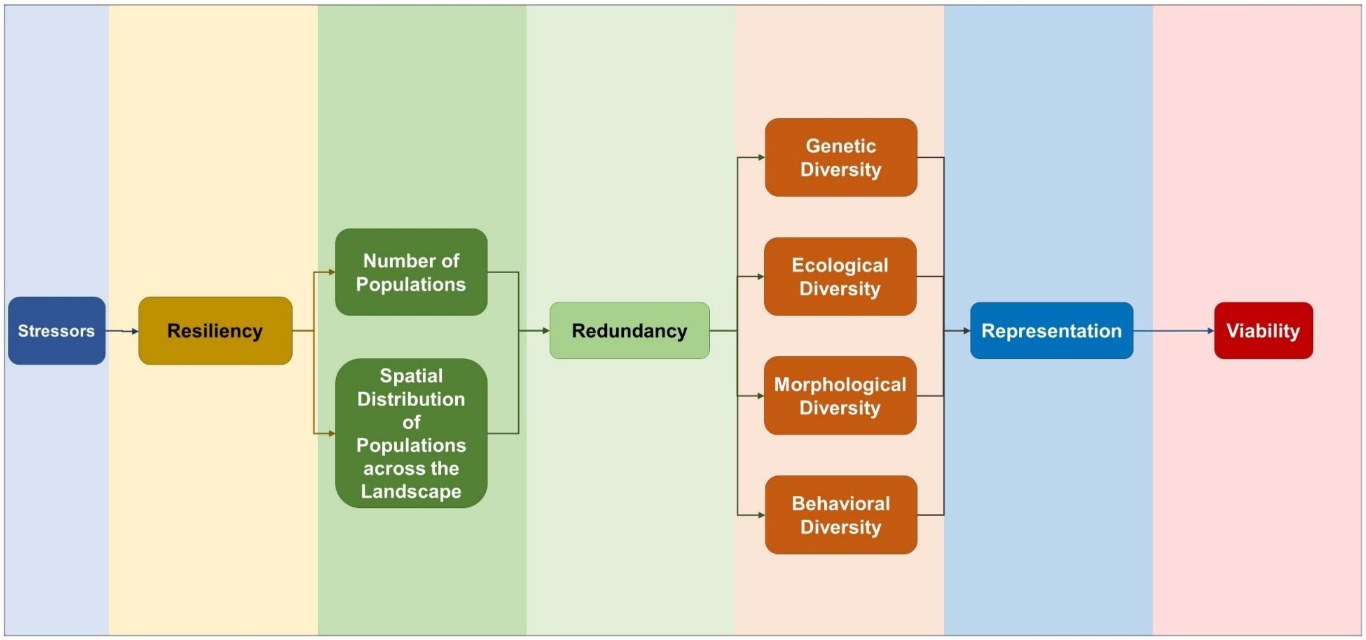

Figure 8. General influence diagram modeling how stressors can impact the viability of the giant kangaroo rat. Stressors act on the ability of a population to respond to environmental change (resiliency). The number and spatial distribution of populations across the species' range characterize its redundancy. Any differences in the genetic, ecological, morphological, or behavioral features of these populations influence the species representation. Together, the 3Rs describe the overall ability of the species to maintain populations in the wild into the foreseeable future. That is the 3R's impact the species viability.

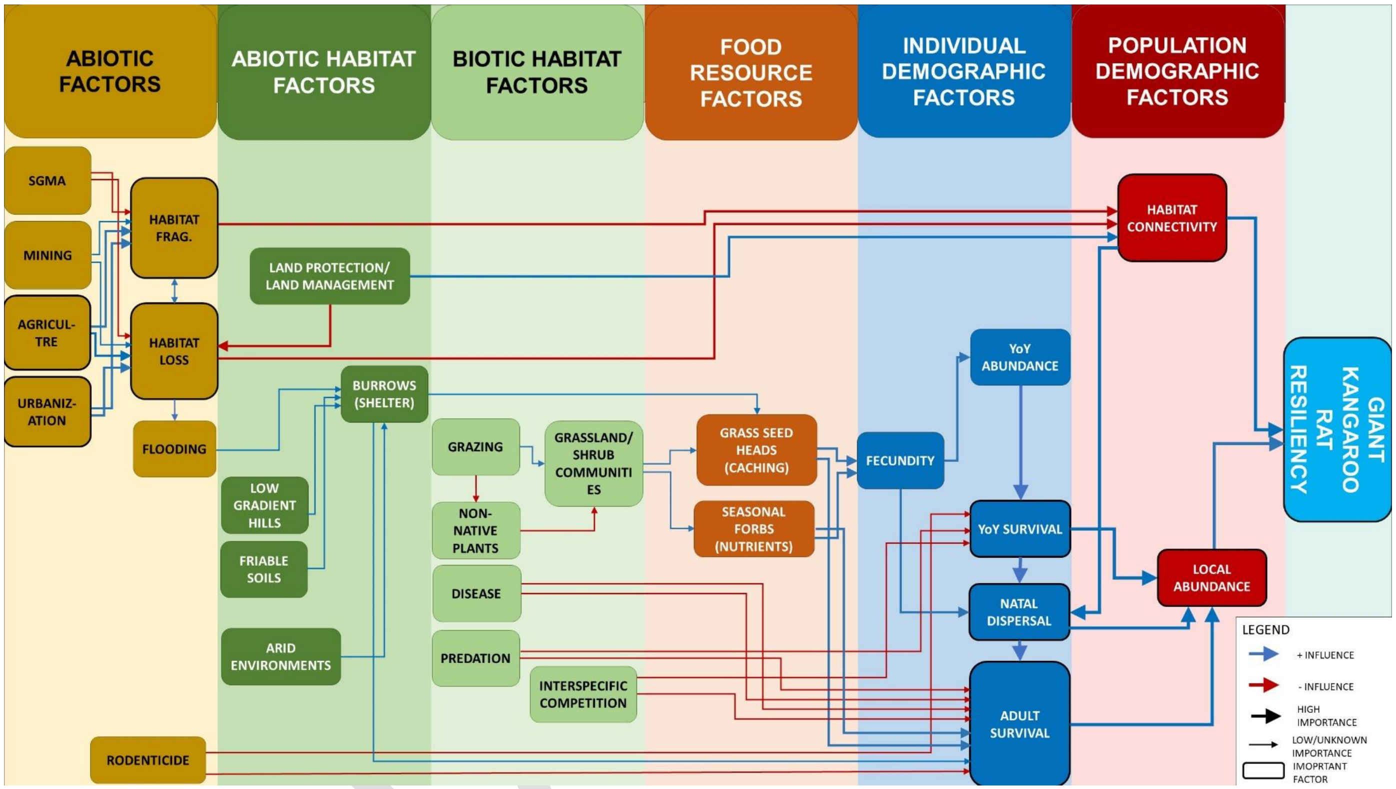

Figure 9. Influence diagram modeling how various factors influence population resiliency of the giant kangaroo rat.

Habitat Modification or Destruction

The giant kangaroo rat historically existed on low, sloping grassland habitat in the western margins of the San Joaquin Desert, which today has largely been converted for human land use, leaving remaining habitat fragmented and patchy (Williams 1992, p. 303). The giant kangaroo rat now exists in a restricted portion of its historical range (Blackhawk *et al.* 2017, p. 261). Habitat loss is the primary cause of species endangerment to flora and fauna in the San Joaquin Valley (USFWS 1998, p. ix).

As habitat loss increases, so does habitat fragmentation, leading to a decrease in habitat patch size and an increase in non-habitat, or matrix habitat, between patches. Both the loss of habitat and the increase of isolation of habitat patches can reduce populations to such low levels that local extirpation is likely (Figure 10)(Gaines *et al.* 1997, pp 294). The 1998 recovery plan estimated that less than 5 percent (approximately 150 thousand acres or 60,700 hectares) of habitat on the San Joaquin Valley floor remained in native habitat (USFWS 1998, p. 1). Today, at least 59% of habitat in the San Joaquin Valley has been converted to agriculture and or urban areas (Germano *et al.* 2011, p. 140-145). At the time of listing (52 FR 283), the USFWS identified land conversion to agriculture as the main stressor leading to the decline of the giant kangaroo rat (USFWS 1987 p. 283). Land conversion due to agriculture, mining, road widening, and urban and residential development were all identified as threats (i.e. Stressors) within the listing rule (USFWS 1987 p. 283-284).

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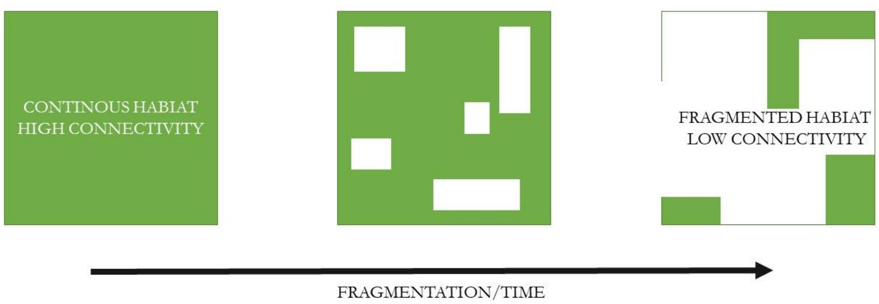

Figure 10. Habitat fragmentation model. This model shows the inverse relationship between increasing fragmentation and decreasing habitat connectivity in the San Joaquin Valley. Over time, as Europeans settled the valley and began farming, habitat fragmentation increased, as habitat connectivity decreased, eventually leading to the highly fragmented habitat patched within a matrix of non-habitat we see today.

Today, land conversion due to transportation, energy development, agriculture, and urbanization continues to stress the giant kangaroo rat and its habitat while also presenting an obstacle to recovery efforts. However, conservation practices and land acquisitions since the time of listing have increased the amount of protected land, and the species' has expanded to nearly 5 percent of its historical range (USFWS 2010 p. 19). Still, small remnant habitat patches, primarily on private land, continue to be altered for agricultural use. Although conservation efforts have helped the species in recent years, habitat loss in general remains the greatest factor which negatively affects the viability of the giant kangaroo rat (USFWS 2010, p. 19).

Agriculture

During the time of listing, conversion of habitat to agriculture was the main stressor causing the decline of the giant kangaroo rat (USFWS 1987). Surveys do not find giant kangaroo rat populations on cultivated lands and it is widely accepted that agriculture destroys local populations and presents a barrier to dispersal for giant kangaroo rats (Williams 1992, p. 313). Today, agricultural conversion from native habitat has slowed substantially, because most tillable land has already been cultivated due to lack of water or irrigation, and the remaining land is ill suited to agricultural development (USFWS 1998, p. 92). The remaining natural lands are too rugged for successful conversion to agricultural practices, other than grazing (B. Cypher, Endangered Species Recovery Team, *in litt.* 2009). Therefore, there are now few additional lands in the giant kangaroo rat range available to convert to agriculture (USFWS 2010, p. 20). The previous 5-year review did not consider land-use conversion due to agriculture to present a substantial stress to the species (USFWS, 2010 p. 19).

However, small isolated patches of giant kangaroo rat habitat on private land continue to be converted for agricultural purposes, but the rate at which this conversion is happening is unclear. Also, large swaths of land which were converted to agriculture in the previous century remain unsuitable habitat for the giant kangaroo rat and present barriers to dispersal. Due to the fact that agricultural conversion of lands has not completely halted, and lands which were previously converted to agriculture increase habitat fragmentation and reduce connectivity, current agricultural processes still reduce species resiliency across the range. In general, habitat conversion to agriculture does not require additional permits in areas zoned for agriculture (Cates 2017 *in litt.*). Although rates of agricultural conversion might have slowed, habitat loss and fragmentation to agricultural practices still presents a challenge to recovery efforts and conversation of the species.

Urban and Residential Development

Some areas of the giant kangaroo rat habitat, particularly on the floor of the Central Valley, are impacted by urban and residential development (USFWS 2010, p. 24). In areas where development has already removed habitat, kangaroo rats are rarely ever found again, suggesting they do not survive in urbanized areas (USFWS 2010, p. 24). There have been some Habitat Conservation Plans (HCPs) issued help reduce the effect of urban development into native habitat.

The Metropolitan Bakersfield HCP was permitted to allow development, but has conservation measures in place to preserve and enhance native habitat for endangered species, including the giant kangaroo rat in the southwest portion of the HCP (City of Bakersfield 1994, p. i). This area of the habitat was marginal, and no evidence of giant kangaroo rats was found during initial surveys (City of Bakersfield 1994, p. 65-66). While this HCP did not permit the take of giant kangaroo rats, it is possible other plans will in the future as urbanization continues on the valley floor (USFWS 2010, 24-25). Even though conservation measures will be put in place, and lands will be set aside through the development of HCPs, habitat connectivity can still be reduced through urban development activities (Barrows *et al.* 2014, p. 683). Urbanization continues to negatively affect giant kangaroo rats by altering habitat in small areas of its current range.

Solar Power Development

In recent years, solar power developments have been proposed on lands within the range of the giant kangaroo rat (USFWS 2010, p. 20-22). We do not know of any studies which address the potential effect of solar plants on the presence of giant kangaroo rats; however, these projects could impact the species negatively. Solar installations might alter landscape topography, vegetation communities, and precipitation drainage (USFWS 2010, p. 20-21). The construction of large-scale transmission lines associated with solar power generation, can destroy or fragment giant kangaroo rat habitat if they pass through natural lands. Additional impacts could occur as there would need to be regular maintenance activities for solar panels and transmission lines, which would require the construction of roads and right-of ways, which would further negatively impact habitat. (USFWS 2010, p. 21).

To date, two solar installations have been completed within the range of the giant kangaroo rat; the Topaz Solar Farms Project (Topaz Solar) and the California Valley Solar Ranch (CVSR)(H. T. Harvey & Associates 2015, 2017; Ian Axsom *in litt* 2019). Both of these facilities have set aside areas of natural habitat to offset the effects of habitat lost for solar production totaling over 14,000 acres of protected habitat within the Carrizo plain (Ian Axsom in litt 2019; Figure #). These properties consist of mainly low, rolling hills with some flat areas; most of the vegetation is annual grassland dominated by invasive grasses (Ian axom in litt. 2019). They are generally considered to be marginal habitat for giant kangaroo rats. However, in 2016 giant kangaroo rat sign was first noted by biologists in the area and by 2018 populations were confirmed on conservation lands (Ian axsom in litt. 2019). This could mark a range expansion by the species into habitat which has not been occupied in many years.

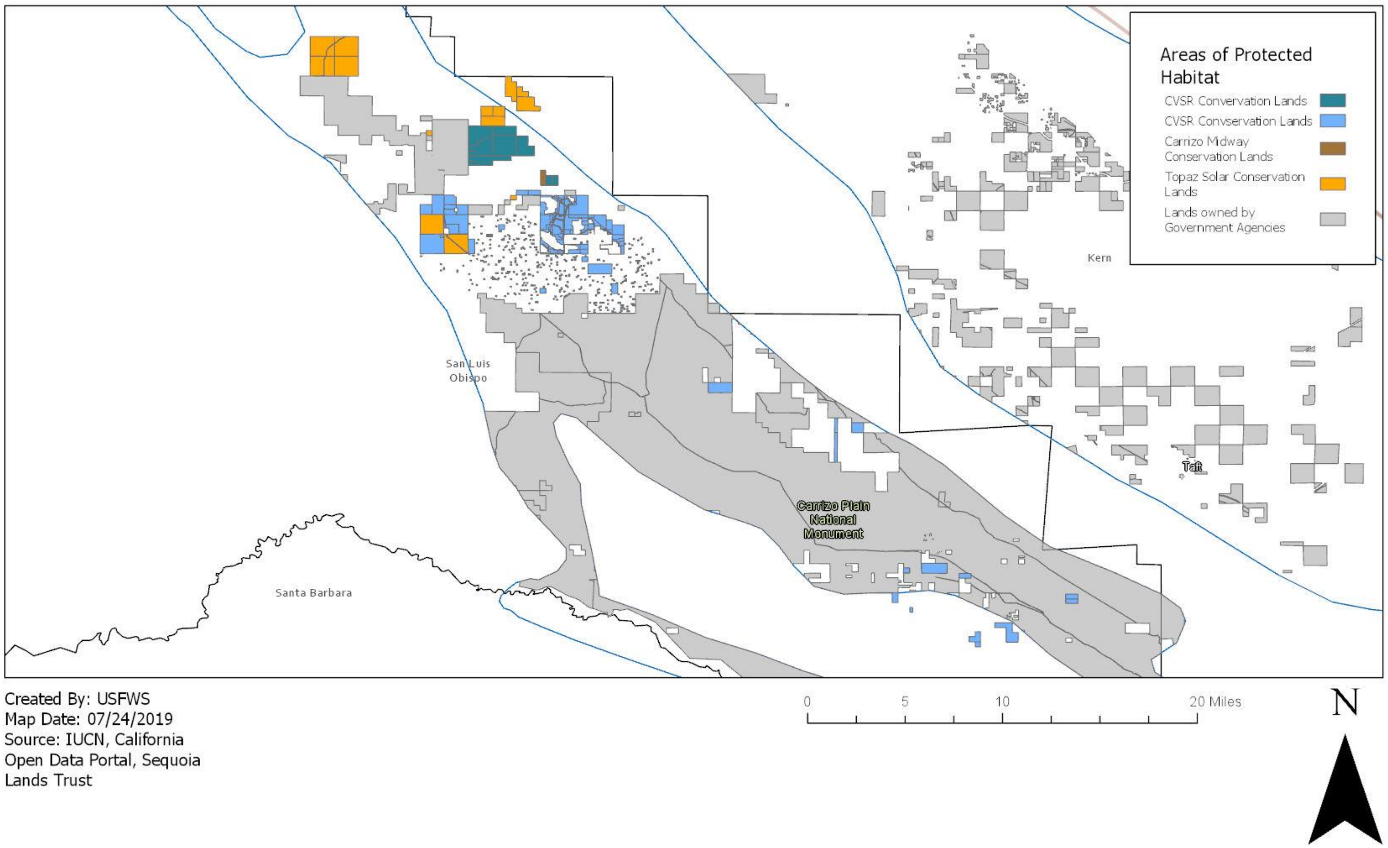

Figure 11. Conservation areas set aside for large solar projects, Topaz Solar and CVSR, in the Carrizo Plain. In recent years, giant kangaroo rats have expanded onto these large areas of continuous habitat. This is a recent increase in the species range since the time of listing.

Oil and Gas Extraction
Oil and gas exploration and development continue to degrade giant kangaroo rat habitat in western Kern, Kings, and Fresno Counties. Studies show that giant kangaroo rat burrows occur most frequently, and in the greatest densities, on the valley floors in areas which are not underlain by extensive petroleum where the potential for negative impacts are low (O'Farrell et al. 2016, p. 12). In fact, over a four-year span, only 8 burrows were found near proposed construction surveys in oil and gas fields, and no proposed projects had to be modified to avoid effects to the species (Kato et al. 1985, entire).

The BLM California has proposed the expansion of oil and gas development on federal lands in California within the San Joaquin Valley (Bureau of Land Management, 2019, online access). Activities, if approved, could include hydraulic fracturing and other enhanced extraction techniques (Bureau of Land Management, 2019, online access). Previously, there have been extraction activities in the Ciervo-Panoche Natural area, as well as Elk Hills-Lokern sites owned and operated by the BLM, where giant kangaroo rat colonies still continue to persist (USFWS 2010, p. 23). Construction of facilities related to oil and natural gas production and associated service roads can fragment and degrade habitat through the construction of service roads and other infrastructure around well pads (USFWS 2010, p. 22). Near oil and gas extraction sites, giant kangaroo rats have been known to build burrows close to dirt access roads, although they do not appear to do so frequently (O'Farrell *et al.* 2016 p. 2). This suggests that fragmented habitat due to oil and gas extraction becomes unsuitable or marginal for the species.

Permanent modification to habitat due to oil and gas activities can reduce the species' ability to disperse and find new habitat. As more land affected by extraction of natural resources, there could be population level responses associated with habitat degradation and habitat modification. The full extent of the effect to the giant kangaroo from current or future mining and extraction is not fully understood at this time.

Transportation Infrastructure
Road construction and maintenance can destroy giant kangaroo rat habitat, fragment existing habitat, and alter vegetation, while increasing the likelihood of mortality from vehicle strikes (USFWS 2010, p. 25). The expansion of highways within the range of the giant kangaroo rat has permanently removed large areas of habitat, and temporarily disturb additional habitat, creating long-lasting population level effects to the species (USFWS 2010, p. 25). However, California Transportation (CalTrans) often offsets these effects to the giant kangaroo rat by purchase and protection of habitat outside of the highway project footprint (USFWS 2010, p. 25).

Habitat Modification Summary of impacts to the 3Rs
Reduction in habitat quality and quantity due to human induced land use change can alter the local habitat composition of an area making populations of giant kangaroo rat less resilient and more vulnerable to stochastic events. Habitat fragmentation can also reduce connectivity and prevent gene flow among precincts, leading to a reduction in population resiliency and species redundancy. In some areas, land protections have been put in place to prevent further alterations to native habitat. In other areas, mitigation and restoration is being done to restore lands that were once habitat back to their native state. In fact, these conservation lands have allowed for a possible range expansion into habitat which has not been occupied for decades.

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While conservation and restoration efforts have had positive effects to the species, habitat loss and fragmentation from permanent land conversion has already impacted the resiliency, redundancy, and representation of the species throughout its range. Giant kangaroo rats are less resilient and more vulnerable to stochastic events now than they were historically. Habitat fragmentation due to the construction of access roads could also reduce connectivity and limit gene flow across the landscape, leading to a reduction in population resiliency and species redundancy. While conditions have improved since the time of listing, habitat modification and destruction still remains a stressor to the long term viability, and to the eventual recovery, of the giant kangaroo rat species.

Climatic Variability

Under current, reasonable climate change scenarios, the San Joaquin Valley is likely to see changes in current ecosystem processes (Nogeire-McRae et al. 2019, p. 2, 4). Currently, the western slopes of the San Joaquin Valley are a climatic desert with low annual rainfall. Precipitation which does fall, typically occurs in the winter months – primarily between October and April (Galloway and Riley, 2006, p. 25). Historically there has always been inter-annual variation in precipitation and temperature (see above section *Habitat*). These are processes to which native species have adapted. However, future climatic processes are projected to change and become more variable under predicted future climate scenarios, and extreme droughts punctuated by heavy, episodic rainfall are both reasonable climate predictions (Widick and Bean 2019, p. 2). Both of these processes have caused population declines of giant kangaroo rats in the past (Williams 1995 p. 3-6 Single et al. 1996 entire; Bean et al. 2018, p. 37).

Increasing variability in inter-annual precipitation is already affecting portions of southern California, including the San Joaquin Valley (Stewart *et al.* 2019, p. 6; Widick and Bean 2019 p. 2-3). Weather patterns altered from historical norms are likely to affect annual rainfall; variation in annual rainfall can affect food availability for individual giant kangaroo rats, causing population level responses (Williams 1992; Williams and Germano 1994). Similar changes in weather patterns have been linked to expansions and contractions of range and population numbers for the species (USFWS 1998, p. 92).

Cycles of Population Fluctuations

Rodents living in arid environments are resource-limited by water availability (Brown and Ernest, 2002, p. 979-980). Populations of desert rodents often fluctuate greatly because they experience boom-and-bust cycles caused by pulses in primary production tied to episodic rainfall (Ostfeld and Keesing 2000 p. 232-236; Previtali et al. 2009 p. 2003-2004). These episodic rains be attributed to annual precipitation variation, or less predictable weather events, such as the El Nino Oscillation, and can affect abundances of rodents (Brown and Ernest 2002, pp 983; Thibault and Brown 2008, p. 3411-3414).

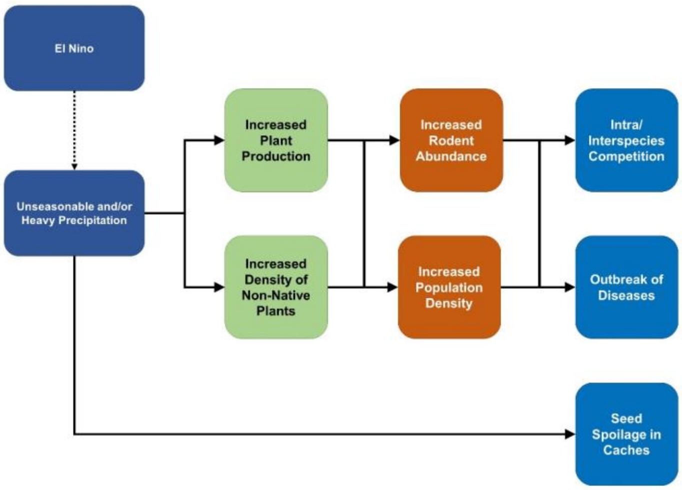

Figure 12. A conceptual model showing how pulses in resource availability are thought to be transmitted up a food chain to affect higher trophic levels, specifically desert rodent species. El Nino events lead to above-average precipitation, which over the course of a season, spurs increased plant production. Abundant plant resources can cause an overabundance of rodents in an area, increasing the risk of disease due to increased population density. Additionally, in the SJV, increased precipitation causes non-native grasses to out-compete native plants, causing dense stands of grass to grow, which could impede the movement of giant kangaroo rats. In the case of *Dipodomys* species, precipitation can cause spoilage of cached food resources or food related illness and death (adapted from Brown and Ernest 2002, p. 980).

In arid portions of North America, many species of kangaroo rats experience cycles of population expansion and contraction (Thilbault and Brown 2007, p. 3411). Such species experience high, inter-annual population fluctuations, the low point of which can be of great conservation concern (Germano and Saslaw 2017, p. 1615). Populations existing on fragmented or isolated habitat patches (such as metapopulations) can be permanently eliminated because severe declines in local abundance can cause local population extinctions with little chance of reestablishment (Germano and Saslaw 2017, p. 1615). Giant kangaroo rat populations are greatly affected by changes in precipitation and herbaceous plant growth (Germano and Saslaw 2017, p. 1616). An extreme drought in California which lasted approximately from 2013 – 2016 saw precipitous declines in giant kangaroo rat numbers (Prugh 2018, p. 2). Episodes of unseasonable, heavy rainfall have also been correlated with declines of giant kangaroo rats in past years (Single *et al.* 1996, p 36; Germano *et al.* 2001 p. 553). In 2019, a high rainfall year across the range of the species, similar declines were seen in the Carrizo national monument (Semerdjian *in litt* 2019).

Drought

As our climate warms due to increasing greenhouse gases emissions, droughts have become more frequent and severe (Trenberth et al. 2019 p. 21). Since the beginning of the 20th century, annual, average air temperatures have increased in California by about 0.84℃ (1.5℉)(Bales 2013, p. 2; Romero-Lankao et al. 2014 p. 1452-1453). Although drought is a relatively normal process throughout southern California, under climate change scenarios natural, historical stressors (i.e. drought, wildfires, flooding, etc.) have the potential to become exacerbated and extreme, due to anthropogenic factors. The severity of droughts in the western United States has already doubled between 1900 and 2000, a trend which is expected to continue (Cook et al. 2004, p. 1016). This has produced an irregularly trend of increasing drought severity during in recent years (Cook et al. 2004, p. 1016).

The most recent severe drought in the San Joaquin Valley lasted for five years from 2012-2017, and was the driest period on record for the region throughout the past 1,200 years (Prugh *et al.* 2018, p. 1). This was widely considered to be the worst drought in history, causing declines in abundance for many flora and fauna of the region (Prugh *et al.* 2018, p. entire). Giant kangaroo rats are physically and behaviorally adapted to living in and arid environment, and thrive during periods of annual aridity. However, prolonged droughts (>2 years) reduce the annual, available food supply and cause populations to crash (Germano and Saslaw 2017, p. 1624). Researchers in the Carrizo Plain geographic unit marked that giant kangaroo rats were resistant to one-year water deficits, hypothesizing that large seed caches helped them survive short-term resources shortages (Prugh et al. 2018, p. 4). However, once the drought took hold of the region, there was an 11 fold decrease in numbers (Prugh et al. 2018 p. 4-5). In fact, many researchers marked dramatic declines in abundance across the range of the species during the 2012-2017 drought in California (Germano and Saslaw 2017, p. 1624; Prugh *et al.* 2018 p. 2; Bean et al.). Therefore, prolonged dry periods place a significant stress on the species viability. Low connectivity, increased fragmentation, and other anthropogenic habitat factors further exacerbate these effects on the landscape.

High Precipitation

Precipitation appears to play a role in limiting giant kangaroo rat distribution (Bean et al. 2014, p. 6) However, the specific mechanisms by which precipitation limits the range of the species still not well understood (Bean 2012, p. 2). In general, small mammals in the San Joaquin Valley decline precipitously during especially wet years (Germano *et al.* 2001, p. 553). It has been hypothesized that seasonal flooding can affect giant kangaroo rats negatively in three ways. First, it is possible for burrows to flood, causing direct mortality by drowning (Single et al. 1996, p. 38). Observations submitted to I-naturalist suggest there have been direct mortalities due to flooding in 2019, an unseasonably wet year for the San Joaquin Valley (California Academy of Science 2019, retrieved from "Inaturalist.org"). Secondly, any precipitation which falls during the normally dry summers can affect seeds caches; moisture can increase the likelihood of mold and other fungi to cause seeds to spoil harming individual giant kangaroo rats through toxins or spores which when ingested, appear to be lethal (Germano et al. 2001, p. 553; Germano and Saslaw 2017, p. 1624). The development of pathogenic toxic molds has been recognized by several observers. (Frank 1988 p. 358; Single et al. 1996 p. 40; Germano et al. 2001). Third, it has been suggested that greater than normal rainfall and associated dense grass growth could make it harder for giant kangaroo rats to move throughout their environment using their distinctive ricochetal movement (Germano *et al.* 2001, p. 559).

Rodenticides

The giant kangaroo rat was once widespread, but populations have decreased since the early 1900s, in part due to non-target exposure to rodenticides when ranchers attempted to eliminate the California ground squirrel (*Spermophilus beecheyi*) on grazing land. From the 1960s into the early 1980s rodenticides were often broadcast over large areas by airplane (USFWS 1998, p. 92). There continue to be large areas previously treated with rodenticides in western Kings and Kern County and the foothills of Fresno County that once supported giant kangaroo rats but records of giant kangaroo rats have not been reported in many years (Williams 1992; Semerdjian 2019, p. 29).

Today, it is difficult to assess the magnitude of stress rodenticides continue to pose to giant kangaroo rat populations. The state of California no longer broadcasts rodenticides over large areas of habitat (USFWS 2010, p. 33). However, anticoagulant rodenticides are still used in agriculture to prevent damage to plants by wild rodent species (Franklin et al. 2018, p. 1). Anticoagulant rodenticide exposure and poisoning has emerged as a conservation concern for non-target wildlife on public lands (Garbriel et al. 2012. P. 1). Many agricultural lands have seen conversion to orchards and vineyards in recent years (U.S Department of Agriculture, 2019, online access). Therefore, we believe anticoagulant rodenticides might be a current stressor to individual kangaroo rats in areas where habitat is adjacent to agricultural lands, or where private cultivation is carried out on public lands.

Additionally, the number and extent of cannabis farms have increased since the 1990s, and in 2018 the state of California legalized cultivation the crop (California Department of Fish and Wildlife 2018, p. 2; Franklin et al. 2018, p. 1). The past several years have seen an "explosion" of cannabis farms, legal and illegal, have develop on the Carrizo Plain Geographic unit, where giant kangaroo rats have persisted in high numbers (Vaughan 2017, entire). One of the environmental effects of cannabis cultivation in California is the extensive use of anticoagulant rodenticides to prevent damage to plants caused by wild rodents (Franklin et al. 2018, p. 1). Intensive use of cannabis cultivation causes a potentially significant stressor to giant kangaroo rats, especially populations within the Carrizo plain geographic unit (Vaughan 2017, entire). Already, reports of dead kangaroos have been reported from California Valley, at the northern end of the Carrizo Plain, where cultivation has been more intensive (Vaughan 2017, entire).

Rodenticides Summary of Impacts to the 3R's

In the latter half of the 20th century, rodenticides played a large role in reducing the overall resiliency, redundancy, and representation across the range of the species, by causing widespread mortality to individuals who were exposed to aerial application of rodenticides. Today, the magnitude of effects to the species from rodenticides is much more difficult to assess, but many individuals are likely still exposed annually. In recent years, legal and illegal cannabis cultivation has probably increased the likelihood of exposure to rodenticides. Local representation and redundancy will be reduced by rodenticides if large numbers of giant kangaroo rats are exposed.

Inbreeding and Genetic Drift

Small isolated populations, such as those on fragmented habitat, are at risk of extinction through random catastrophic or demographic events (Frankham 1998, p. 665). Several populations of giant kangaroo rats, particularly those in the Ciervo-Panoche region of the northern population of giant kangaroo rats are small and fragmented (USFWS 2010, p. 34). These populations are genetically isolated and at an increased risk of extinction (Good et al. 1997, p. 1297; Loew et al 2005, p. 496). Additionally, populations with low genetic diversity are at increased risk that random environmental events such as disease will eliminate them (Loehle and Eschenbach 2012, p. 87-89).

Genetic analysis shows that populations of giant kangaroo rats has fluctuated over time, and/or that populations have not been isolated from one another for a substantial period of time (Good et al.

1997, p. 1306; Loew et al. 2005, p. 504-506). One population appeared to contribute more to the genetic maintenance of the entire region (Good et al. 1997 p. 1307). The northern populations exhibit nonrandom mating and genetic drift within the metapopulation (Loew et al. 2005, p. 506).

Although researchers found low levels of genetic diversity within each population, there was a high degree of genetic diversity among populations (Good et al. 1997, p. 3016; Loew et al 2005, p. 503). Recent surveys suggest there is still high genetic diversity among populations in the northern portion of the giant kangaroo rat range (Statham et al. 2019, p. 4-6). However, even small changes in population structure due to habitat loss can further affect the population size and dispersal, compromising long-term sustainability of each fragmented population (Blackhawk et al. 2016. p. 261). Therefore, loss of any of these small, unique subpopulations will reduce the overall high genetic diversity of the northern range metapopulations (Good *et al.* 1997; Loew *et al.* 2005).

Within the Panoche Valley, Panoche Creek and Silver Creek are important dispersal corridors, which help alleviate the risk to the species due to genetic isolation (Loew et al 2005). However, giant kangaroo rats have a small dispersal distance, and removal of even small areas within this corridor could further isolate individuals across the north geographic unit. These corridors remain unprotected and subject to residential, agricultural or power development. Panoche Valley is an important source of genetic diversity for the species, with the potential for regional expansion of the giant kangaroo rat within the northern geographic unit highlighting the importance of protecting the populations in this valley (Good et al 1997; Loew et al. 2005). However, to date the majority of the Panoche Valley is unprotected private lands. Habitat loss in areas that link subpopulations magnify the threats of genetic isolation by reducing the opportunities for immigration between subpopulations.

Within the southern genetic lineages, there is also evidence of genetic drift in populations in western Kern County (Blackhawk et al. 2016 p. 271). Among all of the sampled populations there were significant amounts of inbreeding as well. This is likely to contribute to random fixation and loss of alleles within populations (Blackhawk et al. 2016, p. 271). Dramatic population fluctuations experienced by giant kangaroo rats can accelerate genetic drift, decreasing diversity within populations and increasing differentiation among fragmented populations (Blackhawk et al. 2016, p. 272).

Inbreeding and Genetic Drift Summary of Impacts to the 3

There are currently high levels of genetic diversity among populations of giant kangaroo rats, contributing to surprisingly high representation across the species range. However, there might only be high genetic diversity because populations have declined in the recent past. If local extinctions continue at the current rate, the existing diversity could be lost within a few years, and representation would be diminished. Already there is evidence of high genetic drift in many of the isolated populations. Small populations are particularly prone to local extinction and genetic drift because populations of giant kangaroo rat fluctuate significantly on an inter-annual basis. Representation and redundancy would be greatly reduced if local populations are lost or succumb to genetic drift and inbreeding.

Invasive Species

Historically, the deserts of the San Joaquin Valley were open saltbush habitat (Germano *et al.* 2011). Researchers claim the plants and animals of the San Joaquin Valley are adapted to arid, open

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For instance, giant kangaroo rats in Tumey hills contribute a disproportional amount of genetic material to other areas within the Panoche geographic unit, while other populations contribute relatively little genetic material to other areas (Statham et al. 2019, p. 9).

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Commented [MS22]: Otherwise it sounds like there is evidence across all southern populations...

Which there is not!

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However, it can take time for population size reductions to lead to diversity loss, especially if it is mitigated by animal movement and associated gene flow.

environments, and are therefore ill-equipped to survive in a dense-grass stands created by invasive species (Germano, *et al.* 2001, p. 552). In fact, some evidence suggests that kangaroo rat abundance increases as grasses and forb cover decreases (Germano *et al.* 2001 553). Native plant communities were drastically altered in the central valley once Europeans introduced livestock and non-native plants (Williams 1992, p. 303). Within past 200 years, native plant communities were largely replaced by highly invasive bromes and filarees as a result of livestock grazing (Williams 1992, p. 303). Since European settlement, dense, non-native, invasive grass species have invaded the San Joaquin Valley (Germano *et al.* 2001 p. 553) and altered the native habitat in which native animals evolved.

The effect of invasive grasses on giant kangaroo rats is complicated. Giant kangaroo rats do not appear to show a preference for native plant seeds over invasive grass and forb seeds (Schiffman 1994, p. 525) and can promote the growth of invasive grasses through caching seeds. The animals continuously modify the ground around precincts through burrowing activity. Within the Carrizo Plain, this chronic disturbance of soil and vegetation promotes the establishment of non-native plant species (Schiffman 1994, p. 524). The invasive grass *Hordeum spp*. (a European species) was significantly more likely to grow on precinct mounds and excluded other plant species (Casto *et al.* 2017 p. 8). When allowed to grow unchecked these plants will often exclude native plant species from persisting and cause the plant community to change drastically (Williams 1992, p. 304).

Additionally, the caching behavior of giant kangaroo rats undoubtedly contributes to which plant species germinate near on and around precincts (Schiffman 1994, p. 534). Both of these have been shown to increase plant diversity of both native and non-native plants where giant kangaroo rats occur (Prugh and Brashares 2012, p. 675). In some areas where giant kangaroo rat burrows are quite dense, as many as 69 precincts per hectare, meaning the disturbance by giant kangaroo rat burrowing can have a significant impacts on the community composition and density of non-native plant species, increasing the abundance of invasive plants (Schiffman 1994, p. 533). This mutualistic relationship between giant kangaroo rats makes it difficult to manage for native plants without disturbing the mammal's burrows (Schiffman 1994, p. 536).

<u>Invasive species impacts to the 3Rs</u>

Communities of the San Joaquin valley have already been significantly altered by introduced, non-native plant species (Germano *et al.* 2001, p. 555). Where non-native plants are allowed to grow unchecked, resiliency is reduced as individuals attempt to survive in an altered landscape. Over time, representation would also be reduced, if grasses and forbes are allow to reach densities where landscapes can no longer support populations within certain parts of the range. Where large tracts of non-native plants become established, they might decrease the overall fitness of giant kangaroo rats who over time, as they animals did not evolve as seed specialists and probably have a hard time navigating in tall grasses.

Wildfire

There have not been any comprehensive studies which describe the effect of fire on giant kangaroo rats or their habitat (Williams 1992, p. 314). Some expects maintain that fires are not a regular part of desert ecosystems (Germano *et al.* 2001, p. 555). Still, it is possible that fire is somewhat beneficial to giant kangaroo rat habitat, although it would have a localized negative effect on individuals and populations (Williams 1992, p. 314). Fires can temporarily remove non-native plant species on the landscape and have been associated with increased abundances of terrestrial invertebrates (Germano *et al.* 2001 p. 555). In fact, fires might maintain alien grasslands in habitats throughout the world, including the San Joaquin Valley (Germano et al. 2001 p. 555). However, it is important to bear in mind that the persistence of non-native grasses artificially increase the frequency and intensity of fires from what historically existed in the San Joaquin Valley ecosystem (Germano et al. 2011 p. 671).

Unlike many other areas, little is known about the natural fire regime in the San Joaquin Valley (USFWS 2010 p. 35). Evidence suggests that native plant species are not fired adapted (Germano et al. 2011, p. 671). Changes in fire frequency on the land scape, which began with European colonization, might have increase the frequency of wildfires within the range of the giant kangaroo rat (Williams 1992, p. 303). The Bureau of Land Management has experiment with fire as a conservation tool within the range of the giant kangaroo rat, but controlled burns were not as effective as grazing at controlling non-native species, and giant kangaroo rats, along with other small mammals were asphyxiated in their burrows (USFWS 2010, p. 35).

Wildfire Summary of impacts to the 3Rs

While fire is a natural process throughout the range of the giant kangaroo rat, it is possible that anthropogenic factors have increased the timing and intensity of rangeland burns. This could have an impact to individuals or populations, but it is not likely to significantly impact the viability of giant kangaroo rats in the wild.

Grazing

The native plant community within the range of the giant kangaroo rat has changed since Europeans colonized California and introduced livestock which overgrazed native plant communities and exotic species of plants were able to take hold in the plains of the central valley (Williams 1992, p. 303). Grazing occurs throughout the range of the giant kangaroo rat (USFWS 2010, p. 33). Results of studies which sought to quantify the effects of grazing on giant kangaroo rats have been mixed (Williams 1989; Williams and Germano 1994; Germano et al 2001 Kelly et al. 2004; Germano et al 2005). Some studies showed declines of giant kangaroo rats on grazed plots during wet years, but it is possible that the giant kangaroo rats declined due to other stressors (See discussion on flooding and increased precipitation).

Within Elk Hills, prescribed sheep grazing has disturbed much of the habitat occupied by giant kangaroo rats on former Naval Petroleum Reserves 1 and 2; in areas where flocks congregate or bed down, vegetation becomes so trampled, only soil remains (O'Farrell et al. 2016 p. 5). Within trampled areas, no colonies of giant kangaroo rat were found, suggested that intense grazing is not compatible with long-term population viability.

On rangelands which are not managed or grazed giant kangaroo rats appear to decline as well (Williams et al. 1993 p. Dense, non-native grasses are allowed to grow unchecked in un-grazed lands, which inhibits the giant kangaroo rat's ability to forage and escape predators (Germano et al. 2001). Non-native grasses also increase soil moisture, which can lead to spoiled cached seeds (Williams and Germano 1994, p. 14; Germano et al. 2001, p. 553).

Grazing Summary of Impacts to the 3R's

While overgrazing can disturb individual giant kangaroo rat precincts, intermediate levels of grazing might improve habitat quality overall. It is not thought that grazing significantly decreased giant kangaroo rat viability. Where giant kangaroo rats already exists, grazing likely has a neutral effect on the species. However, grazing can reduce density of exotic grasses during wet years, which could facilitate dispersal into unoccupied habitat by giant kangaroo rats. This interaction would mean there is a positive effect from grazing to the species, especially in areas where fragmentation and connectivity continue to be an issue.

Historical Condition

Distribution

Historically, Giant kangaroo rats were found only in the western slopes of the San Joaquin Valley; the Tulare Basin and in the adjacent Carrizo Basin and Cuyama and Panoche valleys (Williams 1992, p. 307). Up until the Mid-20th century, colonies of giant kangaroo rats were spread over hundreds of thousands of acres of continuous habitat within this region (USFWS 1998, p. 85). This historical distribution nearly coincided with the distribution of marine sediment-derived soils on the south and west margins of the valley (Williams 1992, p. 307). While the giant kangaroo rat range was probably never ubiquitous across these soils, they were locally abundant and widespread throughout their historical range (Grinnell 1932, p. 305).

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Abundance

Historical abundances of giant kangaroo rats are difficult to discern, as there were no range-wide studies done prior to the 1930's, and few museum specimens (Williams 1992, p. 307). Early studies of the giant kangaroo rat suggest that their precincts dominated the community to the exclusion of other rodent species; colonies were spaced out over the landscape in patches but where giant kangaroo rats did occur, they did so in high numbers (Grinnell 1932, p. 305). Based on best estimates, giant kangaroo rat populations were always widely scattered across the landscape and locally abundant throughout their range (Grinnell 1932, p. 306-306; O'Farrell 2016 p. 3). It seems as though areas which had the highest abundance of giant kangaroo rats historically are those which still have the largest populations today: Ciervo-Panoche in the North, and the Carrizo Basin, Lokern and Elk Hills and Cuyama Valley's to the South (Williams 1992, p. 307).

Stressors

The magnitude of the stressors affecting the giant kangaroo rat has changed over time. Historical populations of giant kangaroo rat were exposed to periodic droughts, wildfires, annual weather patterns, and occasional flooding. Habitat conversion to agriculture during the latter half of the 20th century caused the initial decline of the species. (Williams 1992, p. 303). Along with agricultural conversion, livestock grazing and non-native, invasive plant species were introduced to California in the early 1800s (Germano et. al. 2001, p. 551-552). The magnitude of stress from natural processes (i.e. drought, wildfire, and weather patterns) is exacerbated through the processes of habitat fragmentation and reduced habitat connectivity across the range. We do not have information on rates of historical agricultural land conversion prior to the 1950's, but we can assume that rates have increased dramatically during the latter half the 20th century. Rodent eradication programs, which included aerial application of rodenticides aimed at destroying ground squirrels had an effect on local populations of giant kangaroo rat as well (USFWS 1998, p. 92).

Current Condition

Since the most recent status review, populations of giant kangaroo rat have fluctuated on a semi-annual basis. From 2012 – 2016 California experienced a prolonged drought, during which time populations across the range saw declines in species' abundance. Populations of giant kangaroo rat on the Carrizo plain decreased dramatically during the drought (Tim Bean, pers. comm. 2019). Once the drought ended, populations appeared to rebound fairly quickly within the affected regions (Bean, pers. comm. 2019). However, in the summer of 2019 researchers across the range have documented additional population declines (Semerjian in litt. 2019). The cause of these declines is unknown, but could be due to unseasonably wet weather and a prolonged wet season which lasted well into the normally dry summer months (Semerjian in litt 2019). Populations of giant kangaroo rat have seen similar population trends in years with high summer precipitation and have rebounded successfully. Because of inter-annual population fluctuations, it is difficult to determine long-term population trends in many places.

Abundance

Populations have persisted in at least four of the six geographic units throughout the range: Ciervo-Panoche Region, the Lokern and Elk Hills area of western Kern County, the Carrizo Plain Natural area, and the Cuyama Valley in the south. Little is known about populations of the San Juan Creek and Kettleman Hills Units. These units are in private ownership, and regular studies have not been possible. Recent trapping efforts were able to confirm the presence of giant kangaroo rats in both of these units (Semerdjian 2019, p. 23). Aerial footage and personal observations suggest, small, isolated populations have been able to persist in these units (Expert Elicitation Meeting. 2019; Semerdjian 2019, 25-26).

Within the area of currently occupied habitat, Giant kangaroo rats experience annual population fluctuations. Populations have expanded and declined with changing weather patterns since 1979 (USFWS 1998, p. 87). During high population years there can be 6 to 10 times more individuals than during low population years (Williams and Kilburn 1992, p. 333-334: Williams 1993, p.##; Williams et al. 1995, p. ##). Because of population fluctuations, measuring changes in occupied areas through surveys has been a more effective way of assessing long-term populations viability rather than population numbers.

Stressors

The current condition of stressors affecting the giant kangaroo rats are provided in section stressors affecting species' condition and related conservation measures, which discuss habitat modification or destruction, climate change, diseases and pathogens, rodenticides, inbreeding and genetic drift, wildfire, invasive plant species, and grazing. We did not carry forward all of these stressors into our current condition analysis. A stressor was not considered in the current condition analysis if the magnitude of the stressor across the giant kangaroo rat range is unknown, a negative effect of the stressor has never actually been quantified, or the stressor does not affect giant kangaroo rat does at the species level (Table 8). For a stressor to have a negative effect on giant kangaroo rats, both exposure and response must occur. In some cases, we cannot estimate the level of exposure and/or response currently occurring, so we cannot generate an estimate of associated impacts to giant kangaroo rat populations. In other cases we can measure exposure, but there is evidence to suggest giant kangaroo rats are relatively resilient to the stressor and do not exhibit a measurable negative response, so there is not likely a negative impact to populations.

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We acknowledge that some stressors have localized impacts within some giant kangaroo rat populations, but this SSA seeks to quantify the giant kangaroo rat's viability at the species' level.

Stressor	Effect to Individuals or populations is known	Negative Response has been Quantified	Species or Population Level Response	Stressor Carried Forward in Analysis
Habitat Modification or Destruction	Yes	Yes	Yes	Yes
Stochastic Precipitation Patterns	Yes	Yes	Yes	Yes
Drought	Yes	Yes	Yes	Yes
Rodenticides	Yes	Yes	Unknown	No
Wildfire	Yes	No	No	No
Inbreeding and Genetic drift	No	No	No	No
Disease and Pathogens	No	No	No	No
Invasive Plants	No	No	No	No
Grazing	No	No	No	No

Table 8. Consideration of stressors for inclusion in our current conditions analysis for the giant kangaroo rat. To be carried forward into our analysis, the magnitude of the stressor needs to be known, there needs to be a quantified negative response, and the negative response needs to be at the species' level. The only stressors that meet all these criteria are habitat modification, flooding and drought.

Analysis of Current Condition

In this section, we analyze the current conditions of the geographic units of giant kangaroo rats as a way of assessing the species' viability. The goal of this analysis is to evaluate resilience of individual populations and representation and redundancy of the species as a whole in order to evaluate current range-wide viability. Assessing current condition as part of the SSA analysis is associated with, but independent from, assessing habitat suitability. Habitat suitability analyses use a suite of habitat predictor variables known or hypothesized to be important to the ecology and distribution of the species to create models that assess habitat and classify it according to suitability. Thus, different habitat sites that are modeled as "suitable" may be based on varying combinations of predictor variables. Models can be tested using historical or current occurrence data, but habitat modeled as suitable may or may not actually be occupied by, or accessible to, the species. Therefore, while habitat suitability can be an important component of understanding population resiliency and can inform future conservation efforts, habitat suitability alone may not accurately reflect the current condition of a specific population or of the species as a whole. When assessing population condition in the SSA framework, we identify specific habitat and demographic variables thought to be the main drivers of viability of the species. In doing so, we address the individual and population needs of the species, as well as the main factors influencing viability. We use quantitative or qualitative assessments to classify these categories into high, moderate, and low conditions in a Condition Category Table (CCT), and analyze the overall condition of each analysis unit across all of the categories. Using the same table to assess the current and future condition of our analysis units allows for comparison and projection of how the species is doing now verses in future scenarios (described in Chapter 4 of this document). That being said, we refer to "suitable habitat" when analyzing current and future condition of the populations, using modeled or otherwise projected habitat suitability in relation to current and future habitat factors and threats.

We analyzed the current condition of giant kangaroo rats within the six, geographic units identified in the Recovery Plan, as described above (USFWS 1998, p. 87). These areas continue to encompass the known extant locations for giant kangaroo rats thought to be necessary for the recovery of the species (USFWS 1998, p. 87). For a geographic unit to be considered in high condition, it must meet the needs listed in Section: *giant kangaroo rat needs*. At the individual level, these needs include low slopes, seasonal seed-producing plants, and appropriate habitat for dispersal (**Error! Reference source not found.**). A complete description of these units can be found it Section *current range*. Initially, we sought to include all species needs in our analysis of current condition. However, after consulting with experts and taking into account the data which was available to us, we identified average slope within the unit, winter precipitation, summer precipitation, connectivity, land protection, population trends, and frequency of occupancy as the most important needs to include in this analysis for the reasons described below.

Because it is not possible to attain range-wide data on seed-producing plants and vegetation, we used annual precipitation as a proxy for plant communities. Distribution models for the species suggest that the amount of rainfall during the driest month of the year was the most accurate predictor of giant kangaroo rat presence; areas which received an average of 0cm of rain during dry appear more suitable (Bean et al. 2014, pp 6). Mean annual temperature also appears to be important as giant kangaroo rats appear in areas with temperatures between 14°C and 16°C (Bean et al. 2014, p. 6). Additionally, two of the main stressors affecting giant kangaroo rats range-wide, flooding and drought, are directly related to annual precipitation cycles. Therefore, we considered precipitation variability to be an indicator of giant kangaroo rat habitat.

Average slope was included in our analysis because studies show giant kangaroo rats do not occupy areas of steep terrain (Alexander *et al.* 2019 p. 1540). While it is unclear if high-slope areas might be used for dispersal, it is unlikely that high hills or mountains are used as dispersal corridors for the species, based on their limited dispersal capabilities. Therefore, in our analysis areas of high slope within the geographic units was assumed to be unsuitable for the species dispersal needs.

Giant kangaroo rats need primary productivity of grasses and forbes in the winter months for breeding and caching seeds. Primary productivity is difficult to assess at a landscape level scale, and cannot be easily predicted into the future. Because sufficient rain must fall in the winter months for seasonal plants to grow, winter precipitation was included in our assessment as a proxy for primary productivity. Data were extracted from PRISM interpolated weather surfaces (4-km resolution) from October through April over a thirty year average, from 1980 – 2010 (Similar to Westphal et al. 2016, p. 3). These years were selected to give an average outside of the droughts. We considered excluding years within the current decade because the recent drought was especially severe. However, we decided to include those years in our analysis because the most recent drought might still have a lasting effect on the current condition of the species. We chose centroids for each unit as the point from which to extract PRISM data. To assess the current condition in relation to winter precipitation, we used 15 cm as the amount of precipitation needed for high primary productivity growth (Grinnell 1934, p. 320;, Williams 1992. p. 302). Consecutive years with less than 15cm of precipitation were considered as lower categories. Frequency and duration of these periods were taken into account while setting thresholds for our categories (Table 9).

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Summer precipitation was analyzed separately from winter precipitation because the effect to the species is dramatically different. While giant kangaroo rats need primary productively in the winter months, they rely on their seed caches to sustain them through summer months. If too much precipitation falls, seed caches begin to spoil, likely causing starvation or poisoning from toxic molds (Banner tailed citation). Therefore, dry summers are assessed in our condition category table. We extracted data from PRISM similar to the winter data. Our thresholds were created using species distribution models for giant kangaroo rats (Bean et al. p. 6).

There is general consensus among experts that habitat loss and fragmentation are the main stressors to the giant kangaroo rat (Expert elicitation workshop, 2019). We assess the connectivity across each unit to capture the ability of an individual to move across the landscape. We assumed a maximum dispersal distance for an individual to be no more than 5km, based on the best available genetic data (Alexander *et al.* 2019, p. 1540).

At the species and population level, giant kangaroo rats need space and suitable habitat in order for populations to be viable over time. Land protection is important to ensure the long-term viability of the species. The percentage of land within each unit was assessed to determine how much protected land was available to the species. This analysis is consistent with the down- and delisting criteria outlined in the Recovery plan for the species (USFWS 1998, p. 186).

The demographic needs of the species are presented in two categories in our analysis of current condition: population trend and frequency of occupancy. Survival is not directly assessed in the table but is strongly correlated with the habitat components described above. Similarly, a proxy for fecundity is included through our use of precipitation in the table, because drought years are associated with low reproductive success. Trapping data and aerial imagery of precincts were used to assess the frequency of occupancy throughout the range of the species (Bean, BOR report, 2019).

We assumed that positive identification of a precinct shows giant kangaroo rat activity within the past 10 years. If there have been positive trapping surveys within the past 5 years, the unit was assumed to be currently occupied.

The criteria presented in our condition category table (Table 9) were used to determine the overall current condition of each giant kangaroo rat population (Table 10). The habitat and demographic factors included in Table 9 were not weighted equally in this analysis. Specifically, in our literature review and discussions with experts, we determined that habitat connectivity, land protection, and frequency of occupancy were the most important factors affecting resiliency (Expert elicitation meeting, 2019). Land protection and habitat connectivity were weighted equally, while frequency of occupancy was considered as important as both of these factors combined.

Relative weights were assigned to each factor to maintain these relationships: 2x for land protection and frequency of occupancy, and 1x for all other categories. Each geographic unit was given numeric score relative to each category (1 for low condition, 2 for moderate condition, and 3 for high condition), and a population's overall condition score was then calculated as the sum of all the factor scores multiplied by their relative weights. Categories with unknown conditions were conservatively given a score of 1, or low. We then translated the overall condition score into a current condition category of low, moderate or high (Table 10).

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	Habitat Factors					Demographic Factors	
Condition	**Average %Slope Within Unit**	**Winter Precipitation**	**30 Year average Summer Precipitation (May-September)**	**Habitat Connectivity**	**Land Protection**	**Population Trend**	**Frequency Of Occupancy (Persistence)**
High	0-6% Slope	There are no periods of drought (<15cm precipitation) lasting longer than 2 years within the past 30 years	No precipitation in the driest two months	Populations within the unit are well connected to other populations and there is evidence of dispersal	>80% of natural lands protected within unit	Populations Stable or Increasing	Evidence of persistence over the past 10 years and positive trapping results within the past 5 years
Moderate	6-10% Slope	There are no more than 2 periods of prolonged drought (>5 years) throughout the last 30 years	0 - 1 cm of precipitation during driest quarter	Populations within the unit are isolated from one another by 0-5 km of matrix habitat	Between 50% and 80% of natural lands protected within the unit	Populations exhibits a slight decline; at least one period shows significant annual declines, but there has been evidence of recovery	Evidence of activity within the past 10 years but negative trapping results/no available data
Low	>10%	There are more than 2 periods of drought, or severe droughts lasting more than 5 years within the past 30 years	>1 cm of precipitation during the driest quarter	Populations within the unit are isolated by >5 km of matrix habitat	<50% of natural lands protected within the unit	Populations shows consistent, substantial decline	Infrequent detectability/ no evidence of activity

Table 9. Condition category table outlining the criteria for ranking populations as low, medium or high condition for specific habitat and demographic factors important for the resiliency of giant kangaroo rat populations. For our analysis average slope, winter precipitation, summer precipitation, habitat connectivity, land protection, population trend, and persistence were considered.

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Uncertainty of Current Condition Analysis

As discussed in our analysis of current condition, we had to make many assumptions, both in defining condition categories and in assessing condition relative to these categories. These assumptions were informed by a thorough literature review and discussions with species experts. The SSA framework requires us to assess a species' biological status such that the analyses and information provided in this report could be used for a multitude of decisions and activities carried out under the authority of the act (USFWS 2016, p.7). Describing the giant kangaroo rat's biological status, and ultimately its viability, is difficult because of the complex, and sometimes unknown, interactions among the stressors that might impact population resiliency. However, we must complete our analysis using the best available information, while acknowledging any key uncertainties or assumptions along the way.

Precipitation was used as a metric to assess aridity and primary productivity throughout the range of the species. While giant kangaroo rats do not respond directly to changes in precipitation, we assumed that habitat suitability was linked to the abundance of giant kangaroo rats. We assumed winter precipitation is needed in order to facilitate primary productivity of plants and seeds. However, the literature show that when rain falls in the summer months, populations of giant kangaroo rats decline. Habitat suitability models show a trend that low summer precipitation is needed for giant kangaroo rats to persist. However, the exact mechanism for how and why these declines occur is not well understood. There might be better ways of assessing habitat suitability and primary productivity, but assessing these unknowns is beyond the scope of this SSA document.

Population demographics are also hard to asses for the giant kangaroo rat. Abundance fluctuates with changing weather patterns, and huge declines and increases have been seen from one year to the next in many giant kangaroo rat populations. Therefore we assumed many of the typical metrics for assessing population health and resiliency, such as population size, sex ratio, effective population size, etc. were not appropriate for this analysis. We used frequency of occupancy to assess the long-term population trends within each geographic unit instead. While this might not capture the entire picture of giant kangaroo rat viability at each location, it does help us understand which populations have been resilient to stochastic changes in the past, and are best suited to future changes and long term viability.

Other assumptions had to be made with regard to rate of land-use change, fragmentation, and climatic variability. We also assumed how the species would respond to these changes based on the best available science and our understanding of the species biology.

Genetic Lineage	Population unit	Average Slope Within Unit	Winter Precipitation	Summer Precipitation	Connectivity	Land Protection	Population Trend	Frequency of Occupancy	Overall
Northern	Panoche Region	Low	High	Moderate	Moderate	Low	Moderate	High	**MODERATE**
Middle	Kettleman Hills	High	Moderate	High	Low	Low	Unknown	Low	**LOW**
	San Juan Creek Valley	Moderate	High	Moderate	Low	Low	Unknown	Low	**LOW**
Southern	Cuyama Valley	Moderate	Moderate	Moderate	Low	Low	Unknown	Low	**LOW**
	Western Kern County	High	Moderate	High	Moderate	Low	Moderate	Moderate	**MODERATE**
	Carrizo Plain Natural Area	High	Moderate	High	High	Moderate	Moderate	High	**HIGH**

Table 10. Current condition table rating for all geographic units. These units were rated using high, moderate, or low condition based on seven habitat and demographic factors: slope, winter precipitation, summer precipitation, connectivity, land protection, population trend, and frequency of occupancy. Condition ratings are based on the categories given in Table 9 (conditions category table). The tree habitat and demographic factors were not weighted equally in our determination of overall current condition, as explained in section analysis of current condition by population.

Commented [MS25]: Perhaps this should be changed to geographic groups. This better reflects how the populations have been grouped. It is also in keeping with the table legend.

Commented [MS26]: We don't know if the populations in the Middle group are in anyway related to one another.

Commented [MS27]: There has never been any genetic assessment of this population.

Commented [MS28]: No genetic assessment of this either

Commented [MS29]: There are several genetically distinct populations within the Northern area that could be considered separately (especially the Ciervo Hills and Panoche East [in the SJ Valley]). If that does not happen here it would be important to note somewhere that Panoche East population (in the SJ Valley) has seen substantial range reduction in the last few decades (Statham et al. 2019).

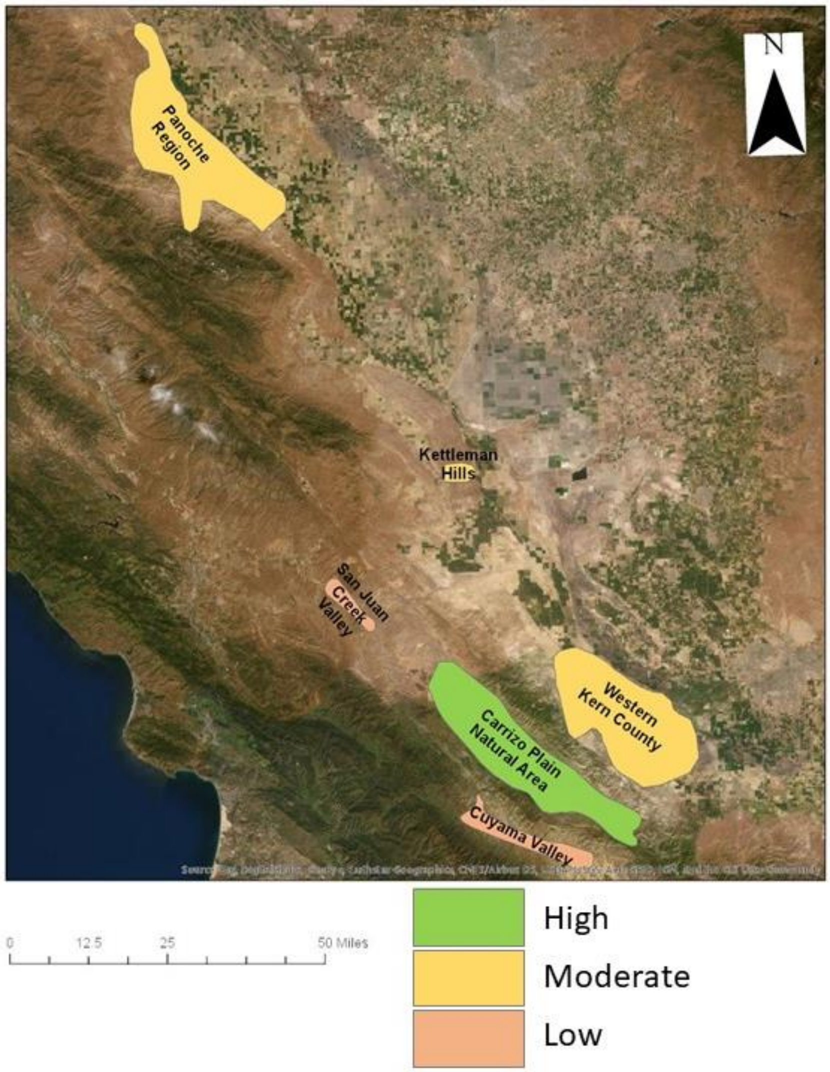

Figure 13. Current condition of geographic units.

CHAPTER 4: FUTURE CONDITION

In this chapter, we predict the future viability of the six giant kangaroo rat population under three, plausible future scenarios. These scenarios use different combinations of climate change impacts, land-use change, and conservation measures to assess overall condition within each unit. This analysis will help predict how viability of the giant kangaroo rat might change in the future and can help guide future conservation efforts.

Factors influencing Viability

In this section, we discuss factors that might influence giant kangaroo rat viability in the future. All the factors which influence viability discussed previously are still applicable to the future condition of the species. However, they are not expanded on here, unless interactions and species responses are expected to change, which are then discussed in the context of emerging threats, or when trends or models can predict changes to these factors.

Climate Change

There is consensus that increases in greenhouse gas (GHG) emissions during the 20th century have resulted in global climate change characterized by: warming atmospheric and ocean temperatures, diminishing snow and ice, and rising sea levels (Intergovernmental Panel on Climate Change (IPCC) 2014, p. 2-3). Climate change might affect giant kangaroo rats through changes in precipitation and temperature, which can drive associated changes to plant productivity, vegetative communities, and the longevity of seed caches. Climate change is also associated with increased risk of catastrophic events, including floods and wildfires.

Climate models for California under different emission scenarios predict an overall warming effect somewhere between 1.7 and 5.8 degrees Celsius (3.0 to 10.4 degrees Fahrenheit) before 2100 (Cayan et al. 2008, p. 7). Giant kangaroo rats are adapted for arid survival and can withstand periods of high temperature. However, the thermal limits of giant kangaroo rat survival have never been tested, and it is unclear how higher average annual temperatures might affect individuals. Studies on banner-tailed kangaroo rats in Arizona found that during daytime summer high temperatures, body temperatures rose within the burrows much higher than expected (Moses et al. 2012 p. 262-263). As air and surface temperatures rise, it is possible that kangaroo rats will no longer be able to escape the heat by burrowing, as ground and soil temperature would rise as well.

Climate change is also associated with changes in precipitation cycles. Extremes in precipitation are expected to increase; current climate models predict a higher frequency of both extremely wet and extremely dry years (Swain et al. 2018 p. 427-433). Precipitation extremes are expected to reduce the resiliency of giant kangaroo rat populations, as discussed in *Climatic Variability* above. Giant kangaroo rat survival is expected to decrease in extremely wet years, and during prolonged periods of drought (droughts lasting longer than two years) (Swan et al. 2018, p. 427-433). Extremely wet years can cause over-abundance of dense, non-native grasses, and food spoilage. Stochastic flooding events could also occur, which could negatively affect populations, especially in areas with high slope and topography, such as the Panoche geographic region.

The occurrence of drought years has been higher in the past two decades than in the preceding century, and hot, dry conditions are that are correlated with drought are expected to continue

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(Diffenbaugh et al. 2015, p. 3932-3933). Some future climate projections suggest drought will be more intense; both longer, and dryer than in previous centuries (Trenberth et al. 2014, p. 17).

Additional climate change effects are varied. They include those from small, isolated habitat patches, with small populations might be at higher risk from long-term, intensive droughts (Westphal et al. 2016, p. 6); decreases in reproduction and abundance could have irreversible consequences on the Population. Within-patch heterogeneity, between patch connectivity, and habitat patch-size, will be important to mitigate population declines from both dry and we years. Changes to climate are also associated with increased risk of wildfires, including both the occurrence of large fires, and the size of burned areas (Westerling et al. 2011, p. 457). Large-scale fires have the potential to cause catastrophic declines in giant kangaroo rat populations.

Small population size

Genetic studies have shown there are lasting changes to the genome of the giant kangaroo rat at the species level from habitat loss during the 20th century as a result of genetic drift due to small population sizes (Statham *et al.* 2019, p. 2). Habitat loss and fragmentation are the primary causes of biodiversity loss, including loss of genetic diversity. Small populations can lead to inbreeding depression, which threatens the survival of the species as a whole (Statham *et al.* 2019, p. 2). This is a concern for giant kangaroo rats, because there is little gene flow across the geographic units (USFWS 1998, p. 92) and populations fluctuate with annual weather cycles (Germano and Saslaw 2019 p. 1624). Still, the genetic diversity for the giant kangaroo rat remains high (Statham *et al.* 2019, p. 2). No one knows exactly how much diversity was lost due to drastic population declines during the 20th Century. Low population abundances in small, fragmented habitat patches can lead to inbreeding depression and decreased genetic diversity. These genetic factors often contribute to increased extinction risk (Frankham et al. 2014 entire). Small populations have lower fecundity because they difficulty finding mates. Populations in highly fragmented habitat with small areas of suitable habitat, or that lack connectivity to larger source populations are particularly vulnerable. Populations within the Panoche region, San Juan Creek, and Kettleman Hills have are isolated, patchy, and discontinuous. While the Panoche populations are frequently detected, the genetic structure of the region reveals that metapopulation dynamics may currently be limiting genetic and demographic resilience of these populations (Statham et al. 2019, p. 7). This is characteristic of a patchy, discontinuous range.

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We found that the main N v S pops became genetically differentiated from one another long prior to the 20th C.

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Habitat Modification and Destruction

Habitat modification and destruction caused by land use changes (e.g. agricultural development, and urbanization) are expected to continue, and most likely to affect habitat on privately held lands. Giant kangaroo rats have never been found on agricultural fields or urban areas, and it is unlikely they will use such modified habitats for any part of their life history (Williams 1992, p. 313).

Agricultural development will be influenced by changes to the climate. Some climate models predict increases in retired croplands in response to increased aridity. Land retirement of agricultural fields across the San Joaquin Valley could result in significant changes to overall land cover; as many as 500,000 acres could be restored to natural habitat by 2040 to meet requirement of existing groundwater regulations (Hanak et al. 2017, p. 29). Strategic restoration of retired agricultural land has the potential to aid the recovery of endangered species, including the giant kangaroo rat. The

Land Retirement Demonstration Project included a Habitat Restoration Study to investigate the efficacy of restoration techniques on vegetation and wildlife (Uptain et al. 2005, p. 107-175).

Scenarios

For our analysis of the giant kangaroo rat's future condition, we constructed three future scenarios focused on changes in stressors, climate change projections, and levels of conservation efforts (Table 11). While there are an infinite number of potential future scenarios we could have considered, these scenarios are meant to cover a large breadth of future conditions that could occur in the giant kangaroo rat's range. All scenarios might not be equally plausible. To analyze future condition under these scenarios, we projected each scenario 50 years into the future, corresponding to our climate models.

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Scenario 1

In scenario 1, we assume there will be warm and wet conditions as described under climate change predictions (CNRM-CM5, RCP 4.5). In this scenario, warm and wet conditions will increase heavy winter rainfall events and summer rains, which will result in increased non-native plant growth, and result in more food spoilage in stored caches. We assume urban and agricultural development will continue at current rates on unprotected lands. There will be limited opportunities for habitat patches to increase in size, or for connectivity to increase or improve throughout the range. We assumed conservation efforts and restoration activities will remain the same as current levels.

Scenario 2

In scenario 2, we assume there will be hot and dry conditions as described under high greenhouse gas concentrations and climate change predictions (MIROC-ESM, RCP 8.5). In this scenario, hot and dry conditions will result in decreases in overall precipitation and an increase in drought intensity and duration. While all future scenarios are impossible to predict with any certainty, current trends show greenhouse gas concentrations are continuing to rise in our atmosphere, consistent with the assumptions of RCP 8.5 (Riahi et. al. 2011, 38-51). If trends do not change, this future scenario could be the most likely to occur (Riahi et. al. 2011, p. 54). We assume that with hotter and drier conditions there will be an increase in fallowed croplands, without active restoration, within the Central Valley. We assume that development from urbanization will continue at current rates on unprotected lands, with the potential to decrease habitat size and connectivity. Lastly, we assumed conservation efforts and restoration activities will remain the same as current levels.

Scenario 3

In scenario 3, we assume there will be hot and dry conditions, similar to scenario 2 (above). We also assume there will be an increase in land protections in the central part of the species range, such that urban and agricultural development will slow and land protections will increase. We assume aggressive habitat restorations will take place on the fallowed croplands throughout the range of the species. Under these assumptions, connectivity and land protections will increase throughout the range.

In all scenarios, we assume increased, stochastic precipitation extremes, meaning droughts, and heavy rainfall events are likely to become more frequent.

Scenario 1 (CNRM-CM5, RCP 4.5)	Scenario 2 (MIROC-ESM, RCP 8.5)	Scenario 3 (MIROC-ESM, RCP 8.5, Restoration)
Warm and Wet	Hot and Dry	Hot and Dry
Low Emissions	High Emissions	High Emissions
Land conversion continues at current rates	Land conversion continues at current rates	There is active restoration of fallowed croplands in the central valley and aggressive land restoration and increased protections
Precipitation increase and become more variable and extreme, leading to more heavy precipitation events, and food spoilage	Increases in suitable habitat and more intense droughts (both duration and intensity)	Increases in suitable habitat and more intense droughts (both duration and intensity)
Increases in precipitation extremes, meaning droughts can still occur between periods of heavy precipitation	Increased precipitation extremes and stochastic weather patterns, meaning drought years can be punctuated by heavy rainfall events	Increased precipitation extremes and stochastic weather patterns, meaning drought years can be punctuated by heavy rainfall events

Table 11. Three scenarios used for predicting the future condition of the giant kangaroo rat. The IPCC emissions scenario used for evaluating each future scenario are included in parentheses below the scenario titles.

Analysis of Future Scenarios

Future conditions were projected for each geographic unit based on the variations in precipitation, climate, extent of suitable habitat, and restoration as specified in our scenarios. We predicted changes in four of the five habitat needs, and two demographic factors described in our current condition analysis. The habitat factor of slope was held constant under future scenarios, as it is not expected to substantially change under any scenario. We assessed changes related to habitat factors by making qualitative assumptions about habitat suitability and land protections, and made changes to demographic factors in accordance with related changes in habitat in the various scenarios.

Winter precipitation is difficult to predict in future scenarios, so assumptions were made under all future conditions. In Scenario 1, we expected that warm and wet conditions would increase winter rains, leading to increased primary productivity and vegetative growth. This would increase the growth of both native and non-native plant growth. Giant kangaroo rats feed on both native and non-native seed-producing plants, so under this scenario, high winter precipitation would benefit the species. Carrying this assumption forward, all categories for winter precipitation were increased under scenario 1. Under scenarios 2 and 3, intense droughts are projected to increase in both duration and intensity. This would decrease overall primary productivity, and the species would be assumed to respond negatively. Therefore, future winter precipitation was lowered by one level under both of the remaining future scenarios.

Summer precipitation is also difficult to predict, and similar assumptions were necessary. Under scenario 1, all summer precipitation is likely to increase, decreasing the overall suitability of habitat during the summer. Plants would still senesce in the summer months, but increased precipitation would spoil food stores, leading to decreased health and death for individual giant kangaroo rats. Under future scenarios 2 and 3, summer precipitation would decrease, meaning summers would be hotter and dryer. Because giant kangaroo rats are already adapted for hot, dry summers, it is not likely that they would be severely, negatively impacted by these changes during the summer months. Habitat suitability models confirm, that under RCP 8.5 emission scenarios, the suitable range of the giant kangaroo rat is expected to remain similar or even expand (Widick and Bean 2019 p. 7-9).

Habitat connectivity among giant kangaroo rat populations has been decreasing throughout recent history. This trend is projected to increase into the foreseeable future. Under scenarios 1 and 2, we assumed if trends stayed the same, connectivity would decrease all categories for all populations by one level, for areas which are not already under protection. Under scenario 3, we assumed that aggressive land retirement under SGMA and efforts from conservation organization could increase habitat connectivity by one level.

Land protection was changed only for Scenario 3, where we assumed protections would increase under aggressive restoration and protection efforts.

We made changes to demographic factors in relation to expected changes to habitat factors. Although we used frequency of occupancy in our current condition estimates, it was not appropriate to project this metric into the future as it is not possible to project future occupancy with any degree of accuracy. Therefore, we relied on population trend to project demographics into the future. We did this using information based on past trends and responses of the species to changes in the environment.

Under scenario 1, we assumed that most categories would be lowered by one level. Winter precipitation would remain the same, while summer precipitation would increase, inversely lowering the condition of this category. Habitat connectivity and land protection would be lowered by one level because development would continue at current rates, further fragmenting habitat and reducing connectivity.

Under scenario 2, we also assumed this condition category would decrease by one level, due to continued habitat loss degradation. Under hot and dry conditions, we assumed that winter precipitation would be less, and droughts would become more intense, longer, and more frequent. Summer precipitation would become less frequent, meaning conditions for this category would improve. Habitat connectivity and land protection would each be lowered by one level, as we do not expect current rates of land protection to change under this scenario.

Within scenario 3 we assumed that winter precipitation would be lowered by one level, as droughts would increase in severity and frequency. However, we assumed that both habitat connectivity and land protection would increase by one level due to increased habitat restoration, which would increase both habitat connectivity and land protection categories.

Conditions throughout the range of the giant kangaroo rat are projected to change under all climate change scenarios (Table 12). There are uncertainties associated with all of our projections; these are the best estimates of future changes based on the best available data. The species is projected to decline in scenario 1 and 2, where climate becomes more unstable and humans continue to alter natural habitats. However, scenario 3 shows moderate increases to habitat and population trends. Within this scenario, changes to climate are mitigated by restoration of habitat throughout the range.

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Geographic Unit	Scenario 1 (Warm and Wet)	Scenario 2 (Hot and Dry)	Scenario 3 (Hot and Dry with Restoration)
Panoche	Low	Moderate	Moderate
Kettleman Hills	Low	Low	Moderate
San Juan Creek Valley	Low	Low	Moderate
Cuyama Valley	Low	Low	Low
Western Kern County	Low	Low	Moderate
Carrizo Plain Natural Area	Low	Moderate	High

Table 12. Summary of the overall condition scores predicted for the giant kangaroo rat geographic units under three future scenarios. Analysis units can be in overall low, moderate, or high condition. We give descriptions of these categories in **Factors influencing viability**.

CHAPTER 5: SPECIES VIABILITY

We have considered what the giant kangaroo rat needs for viability (Chapter 2) and evaluated the species' current condition in relation to those needs (Chapter 3). We also forecast how the species' condition might change in the future under three different scenarios (Chapter 4). In this chapter, we synthesize the results from our historical, current, and future analyses and discuss the potential consequences for the future viability of the giant kangaroo rat. We assess the viability of the species by evaluating the ability of the species to maintain a sufficient number and distribution of healthy populations to withstand environmental stochasticity (resiliency), catastrophes (redundancy), and changes in its environment (representation) into the future.

Resiliency

Resiliency is the ability of populations to tolerate natural, annual variation (stochasticity) in their environment and to recovery from periodic disturbance.

Throughout the latter half of the 20th century, large portions of the giant kangaroo rats' habitat were converted to agriculture and urban areas. Populations decreased rapidly in response to habitat loss and fragmentation. While there is little data on habitat condition and population trends prior to land conversion, evidence suggests historical populations had high resiliency, being abundant throughout their historical range.

Because there is no accurate, historical baseline to which we can compare, our analysis of the giant kangaroo rat's current condition and resiliency is limited to current geographic units which are fragmented, isolated, and increasingly small habitat patches throughout the range. Best estimates suggest giant kangaroo rats exist on less than five percent of their historical range. The recovery plan identifies six geographic units throughout the range of the species where the species continues to persist. Based on the relevant factors evaluated in our analysis, only one of these units (Carrizo Plain Natural Area) is currently in high condition. It is important to note that populations of giant kangaroo rat on the Carrizo plain are on the largest, continuous habitat with species-specific management in place. Once habitat is protected, connectivity can be increased, and populations might no longer be isolated from one another. In this case, many of the negative effects of demographic and environmental stochasticity can be mitigated and populations are more likely to be stable. Currently, only one geographic unit (Carrizo Plain Natural Area) is well equipped to withstand stochastic variation, leaving the other five vulnerable to the effects of continued land conversion and climate change. This reduces the overall resiliency of the species.

Our predictions of future condition varied under our three condition scenarios. Under climate change scenarios and current land management trends, resiliency is likely to decrease in the future for two of our scenarios within all geographic units (Table 12). However, if land is converted and managed for the species, it is possible future conditions could improve for the species (Scenario 3).

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Redundancy

Redundancy is the ability of a species to withstand catastrophic events. Redundancy is measured by the duplication and distribution of populations across the range of the species.

Historically, populations of giant kangaroo rat were spread along a narrow strip of gently sloping habitat on the western plains of the San Joaquin Valley. The exact abundance of populations throughout the range is unknown, but they are believed to have been relatively common (Grinnell 1922, 1932). Throughout the range of the species, most of its historical habitat has been converted to agriculture or urban areas. Where the species does exist, abundance fluctuates or remains uncertain. Today, the largest populations of giant kangaroo rat exist in both the extreme northern and southern part of the range; in the Panoche and Carrizo Plain respectively. These populations represent unique genetic lineages, and together increase the redundancy of the species. Should either one be lost, redundancy would be dramatically reduced.

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Because they are genetically distinct from one another, they are not a genetic replacement for one another.

Under future scenarios, many of the geographic units could exist in low conditions. Should this happen, or should populations become locally extirpated, redundant variation throughout the range might no longer be possible. Land protections and restorations can mitigate the effects to populations from climatic change, and in scenario three, many of the populations are in higher conditions then they are currently. This mean that extirpation would be less likely, even under climate change scenarios with increased stochastic events.

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Representation

Representation is the ability of a species to adapt catastrophic events, or to changing physical (climate, habitat) and biological (diseases, predators) conditions.

A species' representation is measured by assessing the genetic, morphological, behavioral, and ecological diversity within and among populations across its range. The more representation, or diversity, a species has, the more likely it is to persist in changing environments. Historically, the giant kangaroo rat was distributed over a long, narrow strip on the western slopes of the San Joaquin Valley. Within the range, giant kangaroo rats occupied a variety of grassland, desert, scrub and upland habitats. Precipitation varies among these habitats, being more mesic in the northern, and western (coastal) portions of the former range. Genetic diversity appears to remain high throughout much of the range of the giant kangaroo rat. However, it is uncertain how much genetic diversity has already been lost, however.

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Gene flow is not possible across the range of the species, and current populations appear to be isolated from one another. Precincts are not as abundant or dense as they once were, and populations continue to fluctuate throughout climatic events. However, populations still exist in a variety of habitats throughout the range, showing a moderate amount of representation. Giant kangaroo rat populations have persisted throughout their range during the most recent cycles of drought (2012-2016) and heavy rainfall events (2018-2019). However, population numbers are currently low throughout the range, possibly due to the prolonged stress from extreme weather events.

Under future scenarios, representation is likely to decrease under scenario 1 and 2, due to declining conditions across the range. As conditions decline, extirpation becomes more likely, reducing the ability of a species to withstand stochastic events. Under scenario 3, representation is likely to increase across the range, should land protection be increased.

Synopsis of Viability

Viability is the ability of a species to sustain populations over time. Species which exhibit high resiliency, redundancy, and representation are more viable than those which do not.

The giant kangaroo rat is currently endangered. Habitat loss and broad-scale rodenticide application were the main stressors responsible for the decline of the species. Since the time of listing, populations have increased in some areas, while diminishing in others. Abundances have fluctuated annually, and with climatic events. Currently, three of the geographic units are in low condition, two are in moderate condition, and one is in high condition. Populations are still distributed throughout the range and exist in the same breadth of habitats as they did historically, and show high genetic diversity and ability to rebound from climatic extremes, demonstrating redundancy and representation. However, habitat fragmentation and loss continue in many parts of the range, most notably the central and southern portions – where the most robust populations persist, threatening resiliency and the continued viability of the species.

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The central is highly fragmented. The populations are not robust.
The south is less fragmented, and more robust populations exists.

We forecasted the future viability of the species by predicting the responses of our geographic unit conditions under three future scenarios 50 years into the future. Under two scenarios, all but one unit (the Carrizo Plain) are at risk of population declines in the future, and would be at high risk of extirpation. This would represent a significant range contraction of the species throughout the range, and viability would be drastically reduced. Land protection and management in scenario 3 improves the condition of the species and increases viability. It is important to note that the Carrizo plain is the largest, contiguous habitat for the species, aspects which help to buffer against the effects of future threats. Should the Carrizo plain continue to be threatened by cannabis operations, oil development, or other human activities, this habitat could also be lost.

The viability of the giant kangaroo rat within the remaining habitat is evidence of the species' resiliency, and is largely due to large-scale habitat protections. Species-specific land management has been demonstrated to improve the habitat and abundance of the species locally. In order for the species to persist in all portions of the range, habitat protections and land management might be needed to protect the species in perpetuity.

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