Species Status Assessment for the Blunt-nosed leopard lizard (*Gambelia sila*) Version 1.0



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EXECUTIVE SUMMARY

This report summarizes a Species Status Assessment (SSA) completed for the blunt-nosed leopard lizard (*Gambelia sila;* listed and generally referred to by the Service as *G. silus*). To assess the species' viability, we used the three conservation biology principles of resiliency, redundancy, and representation (together, the 3 Rs). This species currently occurs in a fraction of its known historical range, in populations largely fragmented by agriculture and development. In this SSA we analyzed the current and future condition at the population level to assess population resiliency, and the representation and redundancy of the species as a whole to assess current and future viability. We identified 24 populations that were assessed in this analysis—19 populations from a recent genetic study, two of which are hybrids between the closely related long-nosed leopard lizard, and 5 populations that represent known occurrences from the California Natural Diversity Database but do not necessarily have recent observations.

Our analysis of the past, current, and future factors influencing viability in the blunt-nosed leopard lizard revealed that there are several factors that contribute to the current condition and pose a risk to future viability of the species. The primary threat at the time of listing was conversion of natural lands to agriculture, which continues to threaten the species in unprotected habitat. Other current threats include development (including oil, gas, solar, housing, and commercial), habitat modification by non-native plants, above- or below-average precipitation, and pesticide use. Ongoing conservation and management actions or factors positively influencing resiliency include grazing and land protection.

Resiliency of populations was measured by assessing habitat factors (habitat size, patchy habitat, and precipitation), and demographic factors (effective population size and connectivity). We analyzed the current condition of blunt-nosed leopard lizard populations relative to these factors, then translated this into an overall condition score for each population. We assessed the spread of population resiliency scores across the range of the species and relative to genetic clusters to evaluate species representation and redundancy. Under current conditions, there are five populations in high condition, ten populations in moderate condition, and nine populations in low condition.

The rates at which future threats may act throughout the species' range, and the long-term efficacy of current management actions, are unknown. We used the best available science to predict how future conditions could influence the resiliency, redundancy, representation, and overall condition of the blunt-nosed leopard lizard. In order to assess future condition, we developed three future plausible scenarios. The future scenarios use different combinations of climate change impacts and restoration efforts, and are evaluated on a time frame of approximately 60 years (through 2080) to align with climate projections and modelling for the area. The following is a description of the three future scenarios, the status of the species when analyzed under each scenario, and a summary of the assumptions we made under each scenario:

Scenario 1: This scenario assumes that there will be warm and wet conditions (using global climate model CNRM-CM5 and lower emission scenario RCP 4.5). We assume under this global climate and emission scenario that increased precipitation and frequency of extreme weather

events will lower habitat suitability for the species. A published habitat model using these climatic conditions predicts a range contraction for the species associated with increased herbaceous vegetation. However, we assumed that populations on protected lands with habitat management plans will have grazing or other management activities that will counteract the increases in vegetation in some cases. In addition to the potential range contraction, we expect an increase in drought years. Drought years are associated with decreased reproduction because adults do not come aboveground in some populations when there is little rainfall, presumably because of decreases in prey availability or other factors. Development and land conversion continues in this scenario at current rates, which continues to negatively impact blunt-nosed leopard lizard populations on unprotected lands by decreasing the size and connectivity of suitable habitat.

Under the conditions described in this scenario, we projected that the species would have zero populations in high condition, 12 populations in moderate condition, seven populations in low condition, and 5 populations that will be either in low condition or extirpated. Management on protected lands is particularly important on the edges of the species range where a potential range contraction is projected under these climatic conditions. As population resiliency is lowered across the species range, redundancy and representation are also reduced for the species. In particular, the prediction that populations may become extirpated in the northeastern part of the species range and that connectivity will continue to decline decreases representation.

Scenario 2: This scenario assumes that there will be hot and dry conditions (using global climate model MIROC-ESM and higher emission scenario RCP 8.5). We assume under this emission and global circulation scenario that decreased precipitation and increased extreme weather events will influence habitat for the species. We again assumed that increased drought years will limit reproduction for the species. Although we expect an increase in fallowed agriculture lands, we do not expect this to contribute to habitat for the species without specific recovery actions. Although the climatic changes in this scenario tend to point towards a possible expansion in suitable habitat for the species, it is unlikely that the species will expand into any new areas without restoration and/or other recovery actions. Instead, we project in this scenario that development continues at its current rate, reducing habitat size and connectivity for populations in unprotected areas.

Under the conditions described in this scenario, we projected that the species would have 1 population in high condition, eleven populations in moderate condition, seven populations in low condition, and five populations that will be either in low condition or extirpated. This scenario has similar decreases to representation and redundancy as Scenario 1.

Scenario 3: In this scenario, we make the same climate assumptions as in Scenario 2: hot and dry conditions and increased droughts. However, in this scenario we assume that there will be aggressive restoration of fallowed agricultural lands, particularly in the central portion of the species range. We assume that development will continue in the San Joaquin Valley, reducing habitat size and connectivity for some populations, but that restoration will increase the condition for these two factors in some locations.

Under the conditions described in this scenario, we projected that the species would have 1 population in high condition, 14 populations in moderate condition, five populations in low condition, and four populations that will be either in low condition or extirpated. This is the most optimistic of our future scenarios. Although there is only 1 population that remains in high condition, the restoration actions maintain moderate condition populations across much of the species range. Reductions in population resiliency in the northwestern part of the species range threaten to lower representation for the species because of genetic differentiation of blunt-nosed leopard lizards in that area. A decrease in redundancy in this scenario (as with the others) depends on the potential for some populations to become extirpated under continued threats.

The projected conditions under all scenarios rely on continuation of management activities in protected lands. The importance of habitat management is especially important under the warm and wet climate projection, but we emphasize that management is important under all potential climate projections. The main difference between outcomes of the scenarios depends on the implementation of strategic restoration of fallowed agricultural lands. The current emphasis on strategic land restoration and recovery for upland species in the San Joaquin Valley increases the likelihood of implementation of the restoration projections associated with Scenario 3.

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Chapter 1. Introduction

This report summarizes the results of a Species Status Assessment (SSA) conducted by the U. S. Fish and Wildlife Service (Service) for the blunt-nosed leopard lizard (*Gambelia sila*). The blunt-nosed leopard lizard is a large lizard that is endemic to the San Joaquin Valley of California (Stejneger 1893, p. 170; Smith 1946, p. 164).

We used the SSA framework to present a synthesis of our current understanding of the species' ecology and the factors that influence it, to evaluate the current status, and to predict the future status of its resources and condition as a means of assessing the species' viability. The purpose of this SSA report is to evaluate the condition of the blunt-nosed leopard lizard as part of a status review for the species.

Federal History

The blunt-nosed leopard lizard was listed as endangered under the Endangered Species Preservation Act in 1967, at which time it was not subject to the current listing processes.

The recovery plan for the species has undergone multiple iterations. A recovery plan was first approved in 1980, and was revised five years later (Service 1980; Service 1985). Currently, the species recovery strategy is described in the Recovery Plan for Upland Species of the San Joaquin Valley, California, along with 33 additional species of plants and animals that occur in the region (Service 1998).

The downlisting and delisting criteria for the blunt-nosed leopard lizard (Service 1998, p. 182) are described below.

Downlisting Criteria

1) Protection of five or more areas, each about 5,997 acres or more of contiguous, occupied habitat, including one each in the following locations:
   A) Valley floor in Merced or Madera Counties;
   B) Valley floor in Tulare or Kern Counties;
   C) Foothills of the Ciervo-Panoche Natural Area;
   D) Foothills of western Kern County; and
   E) Foothills of the Carrizo Plain Natural Area.
2) Management Plan approved and implemented for all protected areas identified as important to the continued survival of the blunt-nosed leopard lizard. Management plans will include survival of the species as an objective and range-wide population monitoring.
3) Each protected area has a mean density of two or more blunt-nosed leopard lizards per hectare (one per acre) through one precipitation cycle. A precipitation cycle is defined as a period when annual rainfall includes average to 35 percent above-average through greater than 35 percent below-average and back to average or greater.

Delisting Criteria

Delisting will be considered when, in addition to the criteria for downlisting, all of the following conditions have been met:

1) Protection of three additional areas with about 5,997 acres or more of contiguous, occupied habitat including one each in the following locations:

A) On the Valley floor;

B) Along the western Valley edge in Kings or Fresno Counties; and

C) In the Upper Cuyama Valley of eastern San Luis Obispo and eastern Santa Barbara Counties.

2) Management plan approved and implemented for all protected areas identified as important to the continued survival of the blunt-nosed leopard lizard. Management plans will include survival of the species as an objective and range-wide population monitoring.

3) Each protected area has a mean density of two or more blunt-nosed leopard lizards per hectare (one per acre) through one precipitation cycle.

There has been one status review published on the species (Service 2010).

The Species Status Assessment Framework

This report is a summary of the SSA analysis, which entails three iterative assessment stages (Figure 1):

1. **Species Ecology.** An SSA begins with a compilation of the best available biological information on the species (taxonomy, life history, and habitat) and its ecological needs at the individual, population, and species levels based on how environmental factors are understood to act on the species and its habitat.

2. **Current Species Condition.** An SSA describes the current condition of the species habitat and demographics and the probable explanations for past and ongoing changes in abundance and distribution within the species ecological settings (i.e. areas representative of the geographic, genetic, or life history variation across the species range).

3. **Future Species Condition.** An SSA forecasts the species response to probable future scenarios of environmental conditions and conservation efforts. As a result, the SSA characterizes species ability to sustain populations in the wild over time (viability) based on the best scientific understanding of current and future abundance and distribution within the species ecological settings.

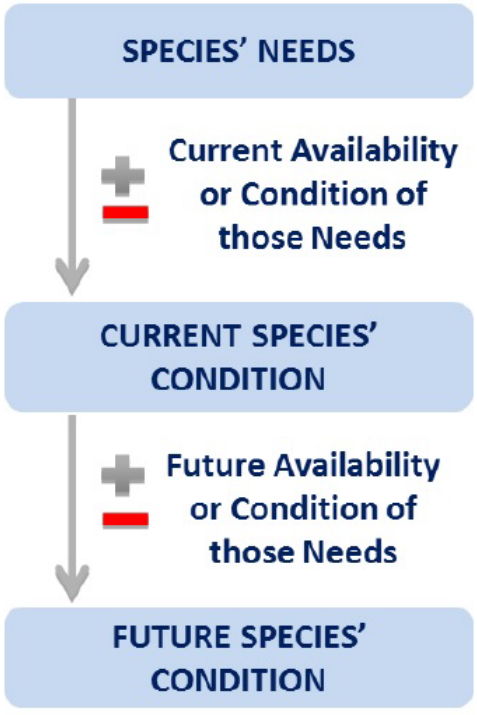


Figure 1. The Species Status Assessment framework

Throughout the assessment, the SSA uses the conservation biology principles of resiliency,

redundancy, and representation (collectively known as the "3Rs") as a lens to evaluate the current and future condition of the species. Resiliency describes the ability of the species to withstand stochastic disturbance events, an ability that is associated with population size, growth rate, and habitat quality. Redundancy describes the ability of a species to withstand catastrophic events, an ability that is related to the number, distribution, and resilience of populations. Representation describes the ability of a species to adapt to changing environmental conditions, which is related to the breadth of genetic and ecological diversity within and among populations. Together, the 3Rs—and their core autecological parameters of abundance, distribution, and diversity—comprise the key characteristics that contribute to a species' ability to sustain populations in the wild over time. When combined across populations, they measure the health of the species as a whole.

Summary of New Information

In addition to the information in our files and in conjunction with prior federal actions for this species (*e.g.*, the Recovery Plan and Status Review), we collected information for this analysis from a variety of sources. We conducted a literature search for reports and peer-reviewed publications; searched for occurrence information through the California Natural Diversity Database (CNDDB); solicited information and consulted with partner agencies and species experts; and mapped protected lands using publicly available data including the USGS Protected Areas database, California Protected Areas Databases (CPAD) and California Conservation Easement Database (CCED). The Service also hosted a workshop with over 20 experts familiar with the San Joaquin region and the species found within the region to discuss threats and species condition (Service *in litt*. 2019).

Our literature review and data solicitation resulted in new information on: genetics (summarized in Chapter 2); ecology, including information from telemetry studies and monitoring that provided information about demographics and survival (summarized in Chapter 3); and threats and conservation measures (summarized in Chapter 4).

Uncertainties and Assumptions

This report incorporates the best available information through reports, peer-reviewed literature, and communication with species experts. When information is not available at the species level, we sometimes use surrogate species, but are always careful to make this clear throughout the report.

Because the species' historical range covers a broad area throughout the San Joaquin Valley, and because current surveys and research tends to be restricted to discrete plots within land management units (*e.g.*, survey grids within National Wildlife Refuges, Ecological Reserves, etc.), we generally assume that these findings carryover more broadly into other areas of contiguous habitat.

Additional uncertainties and assumptions are highlighted in Chapter 4 (Historical and Current Condition) and Chapter 5 (Future Condition).

Chapter 2. Background

In this section, we provide background about the blunt-nosed leopard lizard, including taxonomic history and genetic information, a description of the species and how to distinguish it from similar species, and the historical and current range. The references cited within this section provide additional information pertaining to these topics.

Taxonomy and Genetics

The blunt-nosed leopard lizard was first described and named by Stejneger (1890, p. 105) as *Crotaphytus silus,* from a specimen collected in Fresno, California. The species was subsequently relegated to a subspecies of the long-nosed leopard lizard (*C. wislizenii*), and listed as *C. w. silus* by Cope (1900, p. 257). Smith (1946, pp. 158-166) distinguished leopard lizards (genus *Gambelia*) from the genus *Crotaphytus*, but tentatively retained the subspecific status *G. w. silus* pending further study. This generic split was not universally agreed upon and the status, both generic and specific, of the lizards remained controversial until Montanucci (1970, entire) presented an argument for specific status based upon the study of hybrids between the long-nosed and blunt-nosed leopard lizards (referred to at this time as *C. silus*). Montanucci *et al*. (1975, entire) again separated the genera *Gambelia* and *Crotaphytus*, resulting in the name *G. sila* (Jennings 1987, p. 11). The spelling *sila* replaced *silus* (Frost and Collins 1988, p. 73) to agree in gender with the genus *Gambelia*, giving the blunt-nosed leopard lizard the taxonomic status used today (Table 1). We listed the species as *G. silus* and have not updated the nomenclature in the Federal Register.

Table 1. Taxonomic status of the blunt-nosed leopard lizard

Class	Order	Suborder	Family	Genus	Species
Reptilia	Squamata	Iguania	Crotaphytidae	Gambelia	sila

At the northern end of the blunt-nosed leopard lizard range, historical specimens from Madera Ranch (private property; contemporary samples not available due to access permission) had the most divergent haplotype using mitochondrial sequences (Richmond *et al.* 2017, pp. 3624-3625). At the southern end of the range, a putative hybrid zone was recognized well before genetic studies but subsequently supported through multiple genetic studies. Montanucci (1970, entire) proposed evidence of hybridization between the blunt-nosed leopard lizard and long-nosed leopard lizard in the Cuyama River drainage system using morphological, biological, behavioral, and ecological differences. Genetic work is consistent with historical hybridization between the two species in the Cuyama River Valley, although mitochondrial and nuclear genome boundaries show some discrepancy (Grimes *et al.* 2014, p. 40; Richmond *et al.* 2017, pp. 3621-3630). Analysis of nuclear DNA (SNPs and microsatellites) indicate that the species boundary is about 50 km (31 miles) north of the Cuyama River Valley proper (Richmond *et al*. 2017, pp. 3621, 3630), while the mitochondrial boundary is in the upper Cuyama Badlands to the south (Grimes *et al*. 2014, p. 40; Richmond *et al*. 2017, pp. 3621, 3630). Although leopard lizards in the putative hybrid zone are generally morphological intermediates, genetic analysis suggests that blunt-nosed leopard lizard mitochondrial DNA (mtDNA) may have introgressed further south than morphology suggests and may extend into areas where lizards more closely resemble long-nosed leopard lizards (Richmond *et al*. 2017, p. 3630). Population genetics are discussed further in *Species Needs: Representation* below.

Species Description

The blunt-nosed leopard lizard is a relatively large lizard with a long, regenerative tail; long, powerful hind limbs; and a short, blunt snout (Smith 1946, p. 164; Stebbins 1985, p. 124; Figure 2). Males are typically larger than females. Males range in size from 87 to 120 millimeters (3.4 to 4.7 inches) snout-vent length (SVL) and weigh between 31.8 and 60.0 grams (01.1 to 2.1 ounces). Females range from 86 to 116 millimeters (3.4 to 4.6 inches) SVL; non-gravid females weigh 20.6 to 37 grams (0.7 to 1.0 ounces), and gravid females weigh up to 62 g (2.2 ounces) (Germano and Williams 2005, p. 5; Tennant *et al*. 2018, p. 16; Tollestrup 1982, p. 11; Uptain *et al*. 1985, pp. i, 22).



Figure 2. Blunt nosed leopard lizards. Adults with breeding coloration (left) and a gravid female (right) Photo credits: Michael Westphal (left) and Thomas Leeman, USFWS (right).

While the ventral surface is uniformly white to yellow (Smith 1946, p. 164), the species exhibits extensive variation in color and pattern on the back. Background color ranges from yellowish or light gray-brown to dark brown depending on the surrounding soil color and vegetation association (Montanucci 1965, pp. 272-273). Background color can also change based on temperature, with cooler lizards tending to be darker in color (Germano 2019, p. 430). The color pattern on the back consists of longitudinal rows of dark spots interrupted by a series of seven to ten white, cream-colored, or yellow transverse bands that are broader and more distinct than in other leopard lizards (Smith 1946, p. 164). Similar colored bands or rows of transverse spots produce a banded appearance to the tail (Smith 1946, p. 164).

Blunt-nosed leopard lizard appearance varies based on age, sex, and season. Hatchling and juvenile blunt-nosed leopard lizards have varying amounts of yellow coloration on the undersides of their hind limbs and tail, which was most common in individuals between 55 and 85 mm SVL (Figure 3; Germano and Williams 2007, p. 48). Juveniles also have blood-red spots on the back that darken with age (Montanucci 1965, p. 272). These spots become brown when sexual maturity is reached, although a few adults retain reddish centers to the spots (Montanucci 1967, p. 124). With increasing age, crossbands may fade and the spots may become smaller and more numerous (Smith 1946, p. 164), particularly in males (Montanucci 1967, p. 124). Males are distinguished from females by their enlarged postanal scales, femoral pores (visible pores on the underside of the thigh), temporal and mandibular muscles (muscles on the skull that close the jaws), and tail base (Montanucci 1965,

p. 271; Figure 3). Both males and females develop breeding coloration soon after emerging each year, and many retain this coloration throughout the active season (Germano and Williams 2007, p. 49). Males in many populations develop a salmon to bright rusty-red nuptial (associated with courtship or mating) color during the breeding season that spreads over the entire undersides of the body and limbs, and may be maintained indefinitely (Montanucci 1965, p. 272). Most, but not all, males develop breeding coloration, although the intensity varies within the season and across males (Germano and Williams 2007, pp. 48-49). Females in breeding coloration have bright red-orange markings on the sides of the head and body and the undersides of the thighs and tail (Montanucci 1965, p. 272), with individual coloration varying throughout the active season (Germano and Williams 2007, p. 49). Gravid females were more likely to display full breeding coloration, although non-gravid and gravid females were equally likely to show some level of coloration (Germano and Williams 2007, p. 50). The smallest males and females with breeding coloration were in the 85 to 89 mm SVL size class, with the proportion of individuals displaying breeding coloration increasing with size class (Germano and Williams 2007, p. 49).

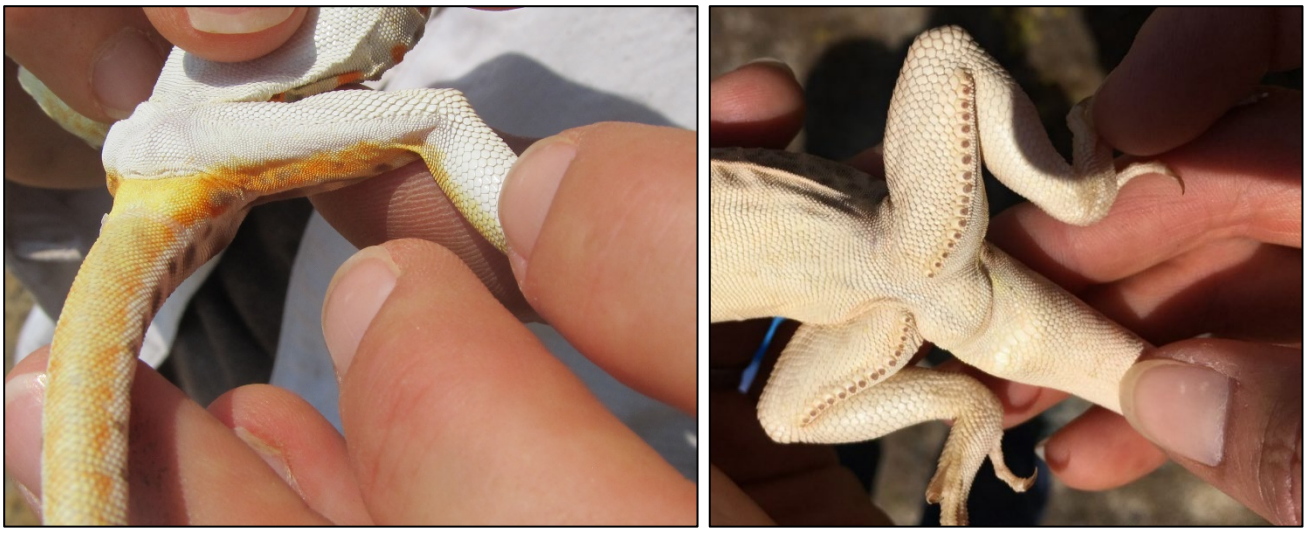


Figure 3. Blunt-nosed leopard lizard appearance varies based on age, sex, and season. Juveniles have yellow coloration on the undersides of their hind limbs and tail (left); male blunt-nosed leopard lizards have enlarged postanal scales and femoral pores. Photo credits: USFWS.

Leopard lizards (genus *Gambelia*) can be distinguished from collared lizards (genus *Crotaphytus*) by their narrower head and differences in scalation (detailed in Smith 1946, p. 158). The blunt-nosed leopard lizard can be distinguished from the long-nosed leopard lizard by its color pattern, truncated snout, and short, broad triangular head (Stejneger 1890, p. 105; Smith 1946, p. 164; Montanucci 1970, p. 108). Additionally, the blunt-nosed leopard lizard has dark blotches on the throat instead of the parallel streaks of the long-nosed leopard lizard (Montanucci 1970, pp. 109-110, 119).

Range and Distribution

Historical Distribution

The blunt-nosed leopard lizard is endemic to the San Joaquin Valley of central California (Stejneger 1893, p. 170; Montanucci 1965, p. 271). The historical distribution is described in the recovery plan as follows: “Although the boundaries of its original distribution are uncertain, blunt-nosed leopard

lizards probably occurred from Stanislaus County in the north, southward to the Tehachapi Mountains in Kern County. Except where their range extends into the Carrizo Plain and Cuyama Valley west of the southwestern end of the San Joaquin Valley, the foothills of the Sierra Nevada and Coast Range Mountains, respectively, define the eastern and western boundaries of its distribution" (Service 1998, p. 114; Figure 4). Construction of a utilization polygon based on blunt-nosed leopard lizard occurrences yielded an estimated historical distribution in the San Joaquin Valley covering 21,106 km^2 (Germano *et al*. 2011, pp. 140-141).

Current Distribution

The current distribution of the blunt-nosed leopard lizard is greatly fragmented, and has been restricted to less than 15% of its historical range (Germano and Williams 1992, pp. 38, 41). This fraction of the historical distribution is in scattered parcels of undeveloped land on the San Joaquin Valley floor, and in the foothills of the Coast Range. Current distribution extends north into Merced County and south into Santa Barbara and Ventura Counties. This distribution reflects a climatic niche contraction and associated range contraction correlated with dense invasive vegetation (Stewart *et al.* 2019, pp. 7-9). To document this contraction, historical locations in Stanislaus County were extensively surveyed without positive detections, and these absences were linked to vegetation shift towards higher vegetation biomass (Stewart *et al*. 2019, pp. 8-9). We discuss this potential range contraction further in *Non-native Plants*.

Pure blunt-nosed leopard lizards are not thought to be found above 800 meters (2,600 feet) in elevation, although the blunt-nosed/long-nosed leopard lizard hybrid zone extends above 900 meters (2,950 feet) and possibly higher (Montanucci 1970, p. 118). Sampling in the putative hybrid zone in Cuyama Valley revealed continued uncertainty in the species southern boundary based on different genomic analyses, indicating that further genetic work may be necessary to clearly define geographic limits of blunt-nosed leopard lizard parental and hybrid forms (Richmond *et al*. 2017, entire; see *Taxonomy and Genetics* above).

The blunt-nosed leopard lizard has 323 occurrences in CNDDB, of which only 65 have detections within the past 20 years (CNDDB 2019; Figure 4). Individual observations or populations located within one-quarter mile of each other constitute a single occurrence in CNDDB, with some grouping multiple observations based on proximity. Therefore, CNDDB occurrences are not akin to unique populations. Lack of recent detections at many of these occurrences does not necessarily mean that the species is not present: CNDDB is a positive detection database (i.e., it does not include information about species' absences); repeat surveys may or may not have been conducted at these locations; and, not all observations are included in the CNDDB database.

Sampling from all known extant populations for a recent genetic study included samples from 17 pure blunt-nosed leopard lizard populations and 6 sites in a putative hybrid zone (Richmond *et al*. 2017, p. 3620) (Figure 4). Known extant populations include: Little Panoche Valley, Panoche Plateau, Silver Creek Ranch, Kettleman Hills, Pixley National Wildlife Refuge, Allensworth Ecological Reserve, Semitropic Ecological Reserve, Antelope Plain, Buttonwillow Ecological Reserve, Lokern, Buena Vista, Elkhorn Plain, Carrizo Plain, Bakersfield, Comanche Point, and Wheeler Ridge, plus the hybrid zone in the Cuyama watershed (Richmond *et al*. 2017, pp. 3630-3621). Additionally, a documented population at the northern part of the range in Madera Valley is on private property last surveyed in the late 1980s (Williams 1990, pp. 11-14). At least one

individual was seen on this property as recently as 2012 (Tomlinson pers. comm. 2019) and it is presumed to be extant. The species has also been documented as recently as 2006 in the Firebaugh Essential Habitat Area in Madera County (CNDDB 2019).

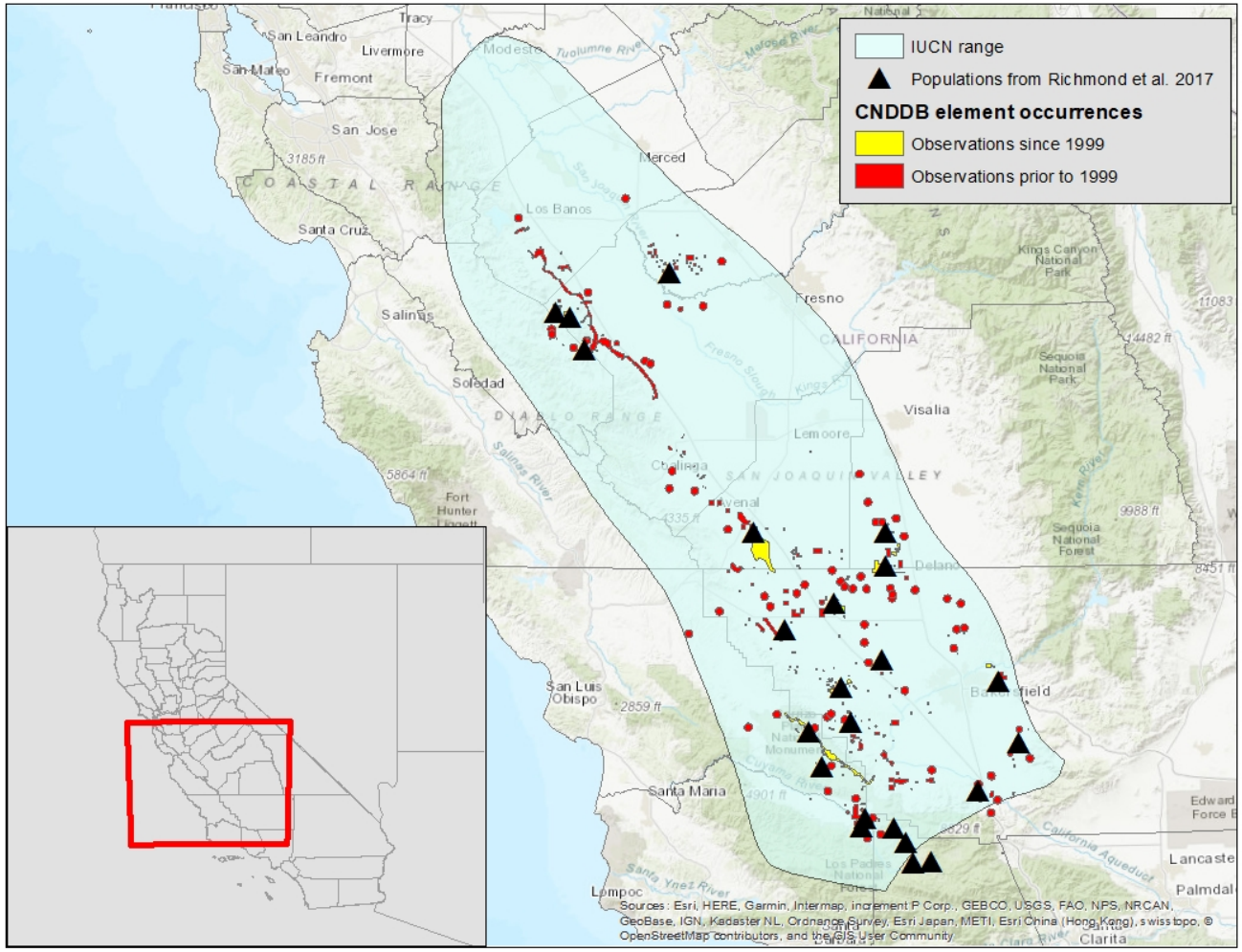


Figure 4. Blunt-nosed leopard lizard historical range and contemporary populations, including hybrids. Historical range (data from IUCN Red List, version 3, May 2017) is represented as a polygon around the presumed extent of the range, although not all habitat within the polygon was suitable habitat for the species. The hybrid zone in the Cuyama watershed extends further south than the IUCN shapefile. Figure also includes all populations included in genetic sampling in Richmond et al. 2017, and all element occurrences from the California Natural Diversity Database version 10/2018. CNDDB occurrences are symbolized based on whether observations have been updated in the database within the previous 20 years. Please Note: The CNDDB occurrences shown on this map represent the known locations of the species listed here as of the date of this version. There may be additional occurrences or additional species within this area which have not yet been surveyed and/or mapped. Lack of information in the CNDDB about a species or an area can never be used as proof that no special status species occur in an area.

Chapter 3. Species Ecology and Needs

In this chapter, we provide biological information about the blunt-nosed leopard lizard, including habitat needs and life history traits such as demographic and reproductive parameters, activity patterns, and behavioral space use. The references cited within this section provide additional information pertaining to the species.

Species' Ecology

Life History

In this section, we describe demographics associated with the species' life stages and generalized timeline of activity (Table 2).The blunt-nosed leopard lizard life cycle consists of eggs, hatchlings, juveniles, small adults, and adults (Figure 5). We distinguish hatchlings (40-57 mm SVL), juveniles (58-82 mm SVL), small adults (83-97 mm SVL), and adults (≥98 mm SVL) based on size, following classification in Germano and Williams (2005, p. 2). Although it is usually possible to distinguish between individuals emerging from their first winter dormancy from those after two or more dormancies, variation in growth rates can lead to some overlap in size between ages (Tollestrup 1982, pp. 8-11). We note that some papers distinguish yearlings from 20+ month adults (Williams *et al.* 1993, p. 7; Germano *et al.* 1994, p. 12), distinguish juveniles from adults based on sexual maturity rather than size (Tollestrup 1982, p. 3), or fail to elucidate criteria for distinction.

Table 2. Gantt chart for one year in the life cycle of the blunt-nosed leopard lizard, including egg, hatchling, juvenile, small adult, and adult life stages.

Life Stage	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Eggs						In chamber underground						
							Hatch					
Hatchlings (40-57 mm SVL)							Active above ground/Foraging					
											Brumation	
Juveniles (58-82 SVL)				Active season (Above ground/foraging)								
											Brumation	
Small adults (83-97 mm SVL)					Breeding							
					Active season (Above ground/foraging)							
									Brumation			
Adults (≥98 mm SVL)					Breeding							
					Active season (Above ground/foraging)							
									Brumation			

Breeding activity begins soon after emergence from dormancy. Breeding generally lasts from the end of April through the beginning of June, and in some years and/or populations, gravid females are observed into August (Montanucci 1967, p. 121; Tollestrup 1982, p. 6). During this period, adults are often observed in pairs and occupying the same burrow systems (Montanucci 1965, p. 278). Females often achieve postnuptial coloration a week after copulation, which may deter

additional copulation attempts or serve as a releasing stimulus for eggs (Montanucci 1965, p. 279). However, males may mate with several females (Montanucci 1965, pp. 278-279).

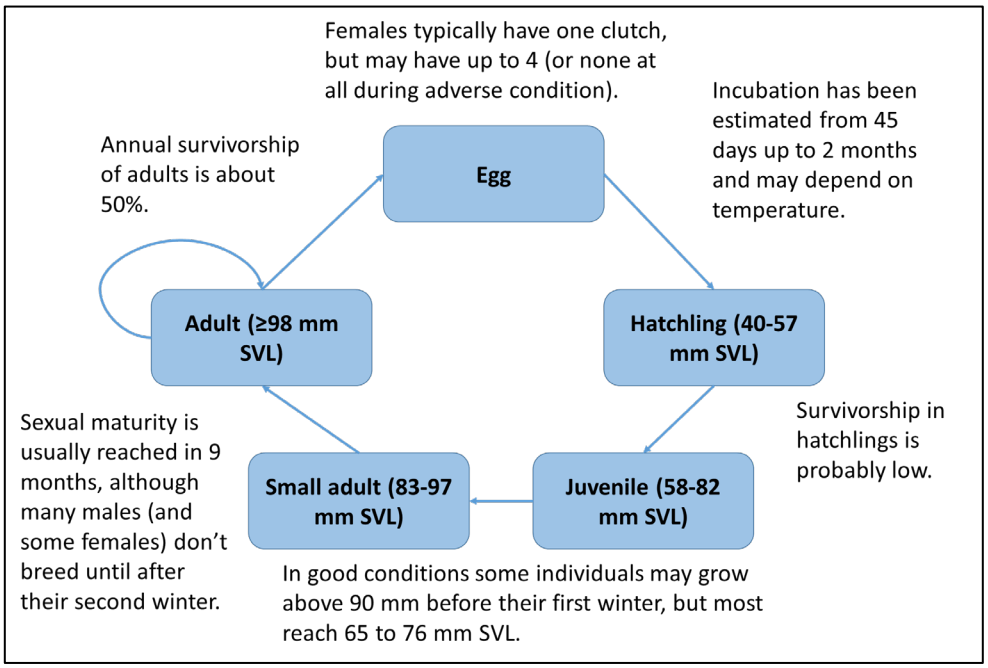


Figure 5. The life cycle of the blunt-nosed leopard lizard includes eggs, hatchlings, juveniles, and adults.

Females typically produce one clutch of eggs per year (Tollestrup 1982, p. 7), although in some locations and/or years, two or more clutches may be common; under favorable environmental conditions, some females may produce up to four clutches (Germano and Williams 2005, p. 10). Under adverse conditions, egg laying may be delayed (Tollestrup 1982, p. 6) or reproduction may not occur at all (Germano *et al.* 1994, p. 15). One to six eggs (Germano and Williams 1992, p. 40; Germano and Williams 2005, p. 10) averaging 15.6 by 25.8 millimeters (0.6 by 1.0 inch) are laid in June and July (Montanucci 1967, p. 120), with larger females laying more eggs (Montanucci 1965, p. 279; Tollestrup 1982, p. 6). Clutch size varies across sites and years. At one site, mean clutch size varied from 3.1 to 3.8 eggs across 6 years, averaging 3.4 eggs per clutch across the entire period (Germano and Williams 2005, p. 10). In another study, mean clutch size at three sites averaged over 3 years was 2.5 eggs (Tennant *et al*. 2018, pp. 20-22). Eggs are laid in a chamber either excavated specifically for a nest or already existing within the burrow system, and the chamber is plugged from the outside by pushing earth into it after egg laying (presumably to maintain appropriate humidity and to protect the eggs (Montanucci 1965, p. 279; Montanucci 1967, pp. 19-20). Incubation length may vary based on temperature or other factors, and was estimated to be four weeks (Tollestrup 1982, p. 6) to 57 days (Montanucci 1965, p. 279). The incubation period is similar for long-nosed leopard lizards, ranging from 43 to 61 days across a three-year study (Parker and Pianka 1976, p. 102). The relationship between incubation temperature and length was inversely correlated in an experimental study on another member of the Crotaphytid family, the collared lizard (*Crotaphytus collaris*) (Santoyo-Brito *et al.* 2017, p. 199).

Blunt-nosed leopard lizard growth rate may vary between sites and/or years (Tennant et al. 2018, p. 55). Montanucci (1965, p. 279) found that blunt-nosed leopard lizards usually reach 65 to 76

millimeters (2.6 to 3.0 inches) SVL (Montanucci 1965, p. 279) before brumation, but some individuals may grow above 90 mm (3.5 inches) SVL before going below ground for the winter in favorable environmental conditions (Germano and Williams 2005, p. 15). In a three year study at Lokern Ecological Reserve, hatchlings/juveniles grew quickly and had usually already progressed to the adult size class when recaptured in the spring. In contrast, large adults at Semitropic Ecological Reserve during the same time period were usually in their second spring season (Tennant *et al*. 2018, p. 55). Males generally grow faster than females (Tollestrup 1982, p. 8).

Sexual maturity is usually reached in about nine months for both sexes (*i.e.* after emerging aboveground after one winter), as determined by oviductal eggs and/or breeding colors (Tollestrup 1982, pp. 3, 7-8). Most females reproduce following their first dormancy at about 9 months, although some wait until after their second dormancy to reproduce at about 21 months (Tollestrup 1982, p. 11). Although males are likely capable of producing sperm after their first dormancy, they often do not reproduce until after their second dormancy, likely because of size and the ability to hold territories (Tollestrup 1982, p. 11).

Snapshots of data based upon surface activity do not give an accurate estimate of the population age structure because the adults may cease activity aboveground around or before hatchlings emerge. The best estimate of the relative proportions of 20+ month old adults to individuals hatched the previous summer may be made from data gathered in May (Service 1998, p. 116), and from hatchlings to smaller adults in August (Montanucci 1965, p. 277), based on aboveground surface activity of these groups (see *Activity* below). Population structure is often characterized by the distribution of SVLs of blunt-nosed leopard lizards throughout the active season. Population structure may vary across sites and/or years (Germano and Williams 2005, p. 5; Tennant et al. 2018, p. 5).

Habitat

Blunt-nosed leopard lizards inhabit open, patchy vegetated areas of low relief on the San Joaquin Valley floor and in the surrounding foothills (Montanucci 1965, p. 273). Vegetation communities associated with blunt-nosed leopard lizard occupancy include alkali sink scrub, saltbush (*Atriplex* spp.) scrub, Ephedra scrub, and grasslands (Montanucci 1965, p. 273; Service 1998, p. 118; Figure 6). Grasslands inhabited by blunt-nosed leopard-lizards may have historically been scrub habitat; Germano *et al*. (2011) summarize arguments that the region is best characterized and managed as a desert rather than as perennial or annual grasslands. Shrubs are resilient to aboveground damage, a phenomenon that Lortie *et al*. (2017, p. 3) termed the "Groot effect". However, they may be less adapted to fires, which have likely converted some scrublands to grasslands that blunt-nosed leopard lizards still use. Indeed, Germano and Rathbun (2016, p. 432) and Germano (2019, pp. 429-432) describe habitat use in an area largely devoid of shrubs following a 1997 fire. A 4,000 acre (1,619 hectare) fire in saltbush habitat in the western part of the San Joaquin Valley has had very little saltbush regeneration since that time (BLM 2009, p. 3-41).



Figure 6. Variation in habitat occupied by blunt-nosed leopard lizards. Northern Valley floor grasslands (top left), Panoche Plateau (top right), valley floor saltbrush (bottom left), and Elkhorn Plain (bottom right). Photo credits: Michael Westphal.

Habitat modeling identified environmental variables associated with blunt-nosed leopard lizard occupancy, including: hydroclimatic variables correlated with vegetation productivity, indicating a preference for low density herbaceous vegetation; slope, comprising areas of low topographic relief; and, soil variables, indicating lower clay content and more alkaline and moderately saline soils (Stewart *et al.* 2019, pp. 5-6). In agreement with these modeling results, blunt-nosed leopard lizards are generally absent from areas of steep slope or dense vegetation, or areas subject to seasonal flooding (Montanucci 1965, pp. 273-274). They generally do not occur on slopes greater than 30 degrees (Germano 2009, p. 121). Based on ecological descriptions of 14 sites with blunt-nosed leopard lizard populations, the presence of 15 to 30% bare ground is suggested as the optimum range of openness (Chesemore 1980, p. 23). They likely avoid dense or tall vegetation because it reduces their ability to detect or escape from predators (Warrick *et al.* 1998, p. 188). Indeed, several researchers noted that they were able to capture blunt-nosed leopard lizards by hand in areas with dense herbaceous cover (Montanucci 1965, p. 273; Germano and Williams 2005, p. 13).

Several papers demonstrate the importance of shrubs as a component of the blunt-nosed leopard lizard habitat for populations that have this resource. The use of shrubs for thermal facilitation and as shelter from predators has been demonstrated using both post-hoc analyses (Germano and Rathbun 2016, pp. 431-432) and a priori hypothesis testing (Westphal *et al.* 2018, entire). Blunt-nosed leopard lizards selected saltbush habitat relative to open habitat, but home range size was not predicted by shrub cover (Germano and Rathbun 2016, pp. 431-432). Blunt-nosed leopard lizard telemetry locations were associated with shrubs more frequently than predicted by shrub area relative to the home range size, with a shift towards shrub habitat during peak afternoon temperatures and when avoiding predators (Westphal *et al*. 2018, pp. 12156-12159). Within a larger dataset at the same study site, shrub cover increasingly predicted presence of blunt-nosed leopard lizard compared to available habitat (Lortie *et al*. 2020, p. 3). Preliminary data comparing microhabitat use of shrubbed vs. shrubless habitat demonstrates that blunt-nosed leopard lizards spend more time underground in burrows at a shrubless site (Gaudenti *et al. in litt*. 2020). Behaviors associated with cooling were also more common underneath shrubs than in the open (Westphal *et al*. 2018, pp. 12156-12157). These findings, combined with data demonstrating that shrub microclimates were significantly cooler compared to open areas (Filazzola *et al.* 2017, p. 56; Ivey *et al*. 2020, p. 5), further supports the importance of shrubs for thermal regulation. In other ecosystems such as the Sonoran Desert, artificial shading resulted in cooler, moister habitat (Smith *et al.* 1987, pp. 69-72). If this pattern holds true in habitat occupied by blunt-nosed leopard lizards, shading could aid in thermal facilitation for blunt-nosed leopard lizards. In areas without shrubs, blunt-nosed leopard lizards use other available habitat features in similar ways (*e.g.*, as perches, or to survey the landscape, Figure 7). Males use shrubs as perches more frequently than do females (Germano 2019, p. 436).



Figure 7. Blunt-nosed leopard lizards use habitat features such as cow patties and minor topographical changes for thermal facilitation and to survey the environment, similar to ways in which they might use shrubs. Photos taken at Pixley National Wildlife Refuge. Photo credits: Stephanie Herrera.

Blunt-nosed leopard lizards are generally found in large areas of contiguous habitat. In isolated potential habitat patches ranging from 19 to 4,415 hectares (47 to 10,910 acres), habitat patch size predicted blunt-nosed leopard lizard occupancy (Bailey and Germano 2015, p. 25). The smallest occupied patch was 238 hectares (588 acres), and patches of 500 hectares (1236 acres) had a 90.7% chance of occupancy (Bailey and Germano 2015, pp. 25-26).

Blunt-nosed leopard lizards use burrows for seasonal brumation [period of dormancy in poikilothermic (having a body temperature that varies with the temperature of its surroundings) vertebrates]. Burrows are also used during the active season, as shelter overnight or during the day from predators and temperature extremes, and for nesting (Montanucci 1965, pp. 273-274; Montanucci 1967, pp. 119-120; Westphal *et al*. 2018, p. 12157). Individuals have burrows that are used consistently (i.e., a 'home burrow', Montanucci 1965 p. 281), but telemetry data demonstrates that multiple burrows are frequently used by one individual (Westphal *et al*. 2018, supplemental online material). Burrows are usually occupied or abandoned kangaroo rat tunnels (*Dipodomys* spp.), or other rodent/small mammal burrows, including abandoned ground squirrel (*Spermophilus beecheyi*) tunnels; they can also use abandoned badger (*Taxidea taxus*) dens, gopher burrows (*Thomomys bottae*), or kit fox burrows (Montanucci 1965, pp. 273-274; Tennant *in litt*. 2020). There is also some evidence that blunt-nosed leopard lizards can dig their own burrows throughout the active season and for egg-laying. In areas with low mammal burrow density, the lizards construct shallow, simple tunnels in banks of soil or under exposed rocks (Montanucci 1965, p. 273; Germano pers. comm. 2019). Germano (2019, p. 435) found several telemetered blunt-nosed leopard lizards in lizard-made burrows at the end of the season; individuals found in burrows later in the season had completely plugged burrows, while those found in burrows earlier in the season had unplugged burrows (although these individuals may not yet have fully started their winter torpor). The closely related long-nosed leopard lizard frequently construct their own burrows for egg-laying (*e.g.*, Parker and Pianka 1976, p. 101).

Adults often retreat to their burrow if frightened (Montanucci 1965, p. 281; Warrick *et al*. 1998, p. 188), while juveniles may also seek temporary safety using structural features of the habitat such as vegetation or rock piles (Montanucci 1965, p. 274). Home burrows that have been experimentally vacated by removal are rapidly reoccupied (Montanucci 1965, p. 281).

Foraging

Blunt-nosed leopard lizards use both active foraging and a sit-and-wait strategy to feed (Tollestrup 1982, p. 2), and observations of the species' diet suggest that they feed opportunistically on whatever is available in the size range they can capture and swallow (Montanucci 1967, p. 122; Germano *et al.* 2007, p. 321). Individuals forage in varying directions from their home burrow. Montanucci found a maximum foraging distance of 42 m (138 feet) (Montanucci 1965, p. 281), but more recent telemetry data has found larger movements (see *Home Range Behavior and Movements* below). They feed primarily on insects (97% of their diet). Insect species consumed are primarily orthopterans (grasshoppers, locusts, and crickets) and coleopterans (beetles), but also include hymenopterans (bees and wasps), dipterans (flies), and hemipterans (true bugs) (Montanucci 1965, p. 276; Germano *et al*. 2007, p. 319), and likely vary based on local availability. The diet may also include other lizards (Montanucci 1965, p 276; Germano *et al*. 2007, p. 319) and small mammals such as mice (Jessen pers. comm. in Montanucci 1965, p. 276). Lizard species taken depend largely on the size and behavior of the prey (Montanucci 1965, p. 276). Although diet may include young of its own species, differences in surface activity based on size and age limit cannibalism of hatchlings (Montanucci 1965, pp. 266-277). Plant material is occasionally eaten or, perhaps, unintentionally consumed with animal prey (Montanucci 1965, p. 276).

Diet varies both seasonally and regionally (Montanucci 1965, p. 276; Germano *et al*. 2007, pp. 319-320), with the dominant food sources changing based on availability. For example, cicadas may make up a significant portion of the diet early in the summer, whereas locusts may predominate the diet when they appear in large swarms later in the year (Montanucci 1965, p. 276).

Activity and Thermoregulation

Blunt-nosed leopard lizards demonstrate diurnal (during the day) daily activity as well as seasonal brumation. Seasonal above ground activity is correlated with weather conditions (primarily temperature) (Montanucci 1965, p. 275). Based on a climate profile using occurrences over the last 100 years, blunt-nosed leopard lizards use areas with a mean annual temperature of 16.6 degrees Celsius (62 degrees Fahrenheit) (Lortie *et al.* 2018, p. 6). Montanucci (1965, p. 275) documented that small individuals were actively foraging at 22.2 degrees Celsius (72 degrees Fahrenheit) and that most individuals took cover at 41.1 degrees Celsius (106 degrees Fahrenheit). Telemetry studies demonstrate that most surface activity occurs when air temperatures are between 26 and 41 degrees Celsius (79 to 106 degrees Fahrenheit) and can occur up to 45 degrees Celsius (113 degrees Fahrenheit), albeit at this air temperature most individuals are in the shade (Germano 2019, pp. 431-435). Median preferred body temperature of individuals (measured at a field station using thermocouples inserted into the cloaca), was 34.1±1.2 degrees Celsius (93.4 degrees Fahrenheit), with a preferred body temperature range of

32.3±1.2 to 37.5±1.1 degrees Celsius (90.14 to 99.5 degrees Fahrenheit). Voluntary maximum body temperature in the field was 40.4±0.8 degrees Celsius (104.7 degrees Fahrenheit). Measurements of upper thermal tolerance in a temperature-controlled chamber found that individuals began panting at 41.4±0.2 degrees Celsius (106.5 degrees Fahrenheit); it was inferred from these data that the critical thermal maximum that could lead to loss of muscle control and death if exceeded is probably in the mid 40 degree Celsius range (Ivey *et al*. 2020, pp. 5-6). On hot days, blunt-nosed leopard lizards are most likely to be observed in the morning and late afternoon (Tollestrup 1976, p. 4); even on the hottest days they don't usually emerge until temperatures reach the minimum observed by Montanucci (1965, p. 275; Germano 2019, p. 438).

Lizard thermoregulation often includes behavioral adjustments, including moving between microhabitats. Ability of lizards to thermoregulate may vary based on habitat quality, such as thermal quality or ecological heterogeneity (Vickers *et al*. 2011, pp. 456-457; Basson *et al*. 2017, pp. 860-861). Blunt-nosed leopard lizard individuals can reduce their internal temperatures by retreating to the shade or beneath shrubs, which allows them to continue foraging or mating behaviors that would otherwise be precluded if they retreated to burrows (Germano 2019, p. 438; Ivey *et al*. 2020, pp. 5-6), or by retreating into burrows. Field measurements of body temperatures taken throughout the active season (using radiotransmitters) demonstrated that individual body temperatures did not vary across each month, indicating that blunt-nosed leopard lizards thermoregulate to keep their body temperatures consistent. Accordingly, individuals increased burrow use and time spent under shrubs and decreased time spent in the open throughout the active season (Ivey *et al*. 2020, p. 5-6). Ivey *et al*. (2020, pp. 4-6) used data from biophysical models placed in different thermal environments to show that blunt-nosed leopard lizards on the Elkhorn Plain in 2018 were restricted from continually basking in an open environment for 8 to 9 hours per day during the hottest part of the active season, and restricted to burrows for 5 hours per day. Burrow temperatures during this same period did not exceed blunt-nosed leopard lizard preferred body temperatures (Ivey *et al*. 2020, p. 6).

Earlier research found similar temperature values in the field in comparison to field station thermal gradient ranges presented above. Cloacal temperatures of seven individual blunt-nosed leopard lizards captured in the field ranged from 37 to 41 degrees Celsius (98.6 and 105.8 degrees Fahrenheit), giving a mean activity range or optimum of 38.7 degrees Celsius (101 degrees Fahrenheit) (Cowles and Bogert 1944, pp. 279-280). On the Elkhorn Plain, cloacal temperatures were related to air temperature: active adults aboveground averaged 38.6 degrees C (101.5 degrees F) in full sun and 36.8 degrees C (98.2 degrees F) in the shade, and belowground were 34.7 degrees C (94.5 degrees F) (Germano 2019, p. 433).

Activity cycles may vary between years and populations (*e.g.*, Germano *et al*. 1994, p. 15; Williams *et al*. 1993, pp. 90-91). Adults are capable of remaining below ground for two winters in poor conditions such as drought (Germano *et al*. 1994, p. 16), although individuals following their first winter may not have enough fat reserves to stay below ground (Williams *et al*. 1993, p. 90). Smaller lizards tend to have a wider activity range than adults: smaller, juvenile lizards emerge from hibernation earlier, remain active later in the year, and are active earlier and later in the day relative to adults (Montanucci 1965, pp. 275-276). Adults are active above ground in the

spring months from about April through August, with the amount of activity decreasing over time so that by the end of July almost all sightings are of smaller adults and hatchling leopard lizards (Germano and Williams 2005, p. 5). Hatchlings are usually first seen in July or August (Germano and Williams 2005, p. 5). Adults generally retreat to their burrows to brumate around when hatchlings emerge, but hatchlings are active until mid-October or November, depending on weather (Germano and Williams 2005, p. 5). The proportion of each sex that is active changes, as males tend to cease surface activity sooner than females (Montanucci 1967, pp. 120-121).

Survival

Estimated survivorship from blunt-nosed leopard lizard populations suggests low but variable survivorship of hatchlings to the following year (15 and 30 percent over two years, Germano and Williams 2005, pp. 7-9; 6.3 to 40 percent over two years across three sites, Tennant *et al*. 2018, p. 31). These estimates overlap but are generally higher than estimated survivorship reported for long-nosed leopard lizards in the same life stages (~5 to 6 percent) (Parker and Pianka 1976, p. 107). Adult survivorship was about 50 percent (Germano and Williams 2005, pp. 8-9), similar to survivorship estimates from a population of long-nosed leopard lizards (Parker and Pianka 1976, p. 107). Mortality rates found using radio telemetry indicate that predation is not a significant factor reducing populations. In a home range study, 22 percent of adults were killed or presumed killed by predators annually; this number dropped to 18 percent if only confirmed predation events were counted (Germano 2018, pp. 278-279). Maximum longevity is probably 8 to 9 years (Service 1998, p. 116), although studies across multiple sites found that few adults are seen across more than two years (Germano and Williams 2005, pp. 7-9; Tennant *et al*. 2018, pp. 30-31). In the latter study, survivorship of 2-year olds (7.1 to 35.7 percent) was similar to that of hatchlings (Tennant *et al*. 2018, pp. 30-31).

Sex Ratios

Sex ratios are likely even, based on over 1000 individuals caught (including hatchlings) over 6 years of study in foothill habitat (Germano and Williams 2005, pp. 14-15) and earlier studies in valley habitat (Montanucci 1965, p. 271). However, sex ratio may vary across populations, age class, or years (Table 3). For example, males outnumber females by 2:1 in foothill areas (Montanucci 1965, p. 271) and by 3:1 in another population (Mullen 1981 in Service 1985, p. 116). Sex ratio may also vary by season: Uptain *et al*. (1985) found that, although 63 percent of the hatchlings in a population on Pixley National Wildlife Refuge were male, the male:female ratio varied seasonally from 2:1 in the spring, to 1:1 in the summer, and 2:3 in the fall.

Although Tennant *et al*. (2018, pp. 15-23) also found that the adult sex ratio was generally 1:1 across two study sites, they found that hatchling sex ratios were male-biased in the Lokern Ecological Reserve. Over 3 years of study, 85 percent of hatchlings/juveniles captured at Lokern Ecological Reserve were males, compared to an adult sex ratio of 1.4:1 M:F (Tennant *et al.* 2018, pp. 15-16). Other studies have also shown a male-biased hatchling sex ratio varying between about 1.5:1 and 2.5:1 male:female (Williams et at. 1993, pp. 49-53; Germano and Williams 1994 in Service 1998, p. 117; Endangered Species Recovery Program unpubl. data in Service 1998, p. 117).

Table 3. Sex ratios of adult, juvenile, and hatchling blunt-nosed leopard lizards at three sites.

		Adults			Juvenile			Hatchlings			Source
Site	Year	Males	Females	M:F	Males	Females	M:F	Males	Females	M:F	
Lokern	2015	15	13	1.15				15	1	15.00	Tennant *et al*. 2018
Lokern	2016	13	6	2.17				12	2	6.00	Tennant *et al*. 2018
Lokern	2017	9	5	1.80				12	4	3.00	Tennant *et al*. 2018
Pixley	1984	56	17	3.29	44	31	1.42			1:1.7	Uptain *et al*. 1985
Pixley	2015	3	13	0.23				22	11	2.00	Tennant *et al*. 2018
Pixley	2016	18	29	0.62				23	19	1.21	Tennant *et al*. 2018
Pixley	2017	17	22	0.77				31	34	0.91	Tennant *et al*. 2018
Semitropic	2015	11	12	0.92				2	3	0.67	Tennant *et al*. 2018
Semitropic	2016	10	18	0.56				3	4	0.75	Tennant *et al*. 2018
Semitropic	2017	12	9	1.33				2	3	0.67	Tennant *et al*. 2018

The mechanism for sex determination in blunt-nosed leopard lizards is not known. In some reptiles, sex of embryos is determined by environmental factors including temperature (temperature-dependent sex determination, TSD). Despite the commonly held belief that reptile sex determination is a dichotomous process involving either genetic sex determination (GSD) or environmental sex determination (ESD) (e.g., Janzen and Paukstis 1991, entire), recent evidence suggests that sex determination in at least some species may be more flexible than originally thought. For example, in collared lizards (*Crotaphytus collaris*), hatchling sex ratios significantly varied based on incubation temperature, with the percentage of female hatchlings increasing and then decreasing around a certain temperature threshold (Santoyo-Brito *et al*. 2017, pp. 199-200). Although collared lizards have microchromosomes that determine sex, evidence suggests that temperature can override GSD (Santoyo-Brito *et al.* 2017, pp. 199-200; Wiggins *et al.* 2018, pp. 5-6). While Santoyo-Brito *et al*. (2017) used constant temperatures in their experiment, other evidence suggests that temperature fluctuations may play a role in sex determination. In another species in the suborder Iguania, a combination of field and experimental studies demonstrated an interaction between mean nest temperatures and temperature fluctuations in sex determination of hatchling jacky dragons (*Amphibolurus muricatus*; (Warner and Shine 2011, pp. 257-262). Outside of lizards, experiments in turtles with TSD demonstrates evolutionary potential of painted turtle (*Chrysemys picta*) to persist despite anthropogenic climate change through a combination of microevolution and phenotypic plasticity (Refsnider and Janzen 2016, pp. 63-66).

Home Range Behavior and Movements

Blunt-nosed leopard lizards exhibit home range behavior, although home range sizes were found to vary based on factors including habitat type, sex, year, or location. Male home range averages varied from 1.9 to 9.3 hectares (8.4 to 23.0 acres) and female home range averages were 1.2 to 5.8 hectares (4.7 to 14.3 acres) from radio telemetry studies (Warrick *et al.* 1998, pp. 186-187; Germano and Rathbun 2016, p. 431; Tennant *et al.* 2018, p. 12156), although the home range analysis varied by study (Table 4). Maximum home ranges for both sexes were over 30 ha (74 acres) (Germano and Rathbun 2016, p. 431). Core home range (areas delineating 50% of

telemetry locations) averages did not significantly differ based on sex, ranging from 0.37 to 0.56 hectares (0.91 to 1.4 acres) across two sites (Warrick *et al*. 1998, pp. 186-187). Both male and female home ranges often overlap with several other individuals (Warrick *et al.* 1998, pp. 186-187; Germano and Rathbun 2016, p. 431; Westphal *et al.* 2018, p. 12156). Additionally, both males and females tagged in successive years had high overlap in individual home ranges across years (Germano and Rathbun, p. 431).

Although dispersal distance is not known, there is some information available about movements within a season. At one site, average distance moved from one day to the next was 100 m (328 feet) for males and 65 m (213 feet) for females (Germano and Rathbun 2016, p. 432). Mean and greatest distance moved between consecutive days varied by sex and site in Tennant *et al* (2018, pp. 42-44). Movements of hatchling long-nosed leopard lizards were about 100 m (328 feet) in the short-term and about twice that over a 9 to 22 month period (Parker and Pianka 1976, p. 108). Juvenile long-nosed leopard lizard males moved 806 m (2644 feet) and 1186 m (3891) over 14 days and 20 months, respectively (Parker and Pianka 1976, p. 107).

Table 4. Blunt-nosed leopard lizard home range size from studies in various locations. Home ranges are estimated using minimum convex polygons (MCPs), a home range estimator that draws the smallest possible convex polygon around included data points.

Site	Period	Mean MCP: Males	n	Mean MCP: Females	n	Source	Data Collection	Analysis Method
Lokern Natural Area	2003	7.93±1.37	13	4.48±0.88	12	Germano and Rathbun 2016[1]	Radio Telemetry	100% MCP
Lokern Natural Area	2004	9.36±1.63	17	5.75±2.11	14	Germano and Rathbun 2016	Radio Telemetry	100% MCP
Elkhorn Plain	2016	5.14±2.15	not specified	1.87±0.53	not specified	Westphal *et al*. 2018[2]	Radio Telemetry	95% MCP
Naval Petroleum Reserves 10B site	1982	5.64±1.28	4	1.92±0.88	4	Warrick *et al.* 1998[3]	Radio Telemetry	MCP (% not specified)
Naval Petroleum Reserves 8B site	1984	3.43±0.51	7	2.42	1	Warrick *et al.* 1998[3]	Radio Telemetry	MCP (% not specified)
Pixley National Wildlife Refuge	1976	0.21±0.25	10	0.1±0.11	7	Tollestrup 1983	Observations of marked individuals	MCP (% not specified)
Pixley National Wildlife Refuge	2015-2016	1.89±0.39	11	1.22±0.32	8	Tennant *et al* 2018	Radio Telemetry	95% MCP
Semitropic Ecological Reserve	2015-2016	5.58±0.6	11	7.19±1.37	13	Tennant *et al* 2018	Radio Telemetry	95% MCP

[1]Paper also includes LoCoH kernels

[2]Additional home range data available online but not presented in paper

[3]Also include core home ranges using 50% isopleth

There is also some evidence that females may make long-distance movements associated with egg laying. At Semitropic Ecological Reserve, a radio-tagged female moved 1150 m (3773 feet) to lay eggs in a burrow and then returned to her normal home range area (Tennant *et al*. 2018, p. 57). Other females moved long distances associated with egg laying but did not return, and still others did not make long distance movements at all (Tennant *et al*. 2018, p. 57), showing the flexibility of this behavior.

Blunt-nosed Leopard Lizard Needs

In this section, we summarize the life history information available for the species and translate these data into needs at the individual, population, and species levels. For individual blunt-nosed leopard lizards, we summarize the general habitat resources or conditions that eggs, hatchlings, juveniles, and adults need to complete each stage of their life cycle. Next, we describe the habitat and demographic conditions that resilient populations require. Finally, we describe what the species needs for viability in the context of the 3Rs.

Individual and Population Needs

Individual blunt-nosed leopard lizard needs vary somewhat by life stage. Hatchling, juvenile, and adult blunt-nosed leopard lizards need patchy habitat with low relief, as described above in *Habitat*. Although shrubs are described as important for the species in many populations and are often associated with high quality habitat (*e.g.*, Westphal *et al*. 2018, 12156-12159; Germano and Rathbun 2016, pp. 431-432), we do not include them as a "need" because of persistent populations in areas without this resource (Westphal *et al*. 2018, p. 12159). All age classes need abundant burrows for shelter and brumation (Montanucci 1965, pp. 273-274; Montanucci 1967, pp. 119-120; Westphal *et al*. 2018, p. 12157), with burrows being especially important for adult females during egg-laying and for individuals for brumation. Both burrows and patchy habitat are related to appropriate thermal environment for individuals. Additionally, all age classes need sufficient numbers of prey, although the prey type may vary seasonally and across population sites (Montanucci 1965, p. 276; Germano *et al*. 2007, pp. 319-320).

Blunt-nosed leopard lizard populations for the most part need the same habitat features as individuals, although in larger quantities. We describe habitat and demographic needs of blunt-nosed leopard lizards below in relation to population resiliency.

Resiliency

Resiliency describes the ability of the species to withstand stochastic disturbance events, an ability that is associated with habitat quality and demographic characteristics of the populations.

For the purposes of this SSA, we broadly define a population of blunt-nosed leopard lizards as a group of animals in the same general space and with the potential to breed. For convenience, we refer to populations using land management units or geographic landmarks following Richmond *et al*. (2017, p. 3622). Habitat and demographic needs associated with resiliency are shown in Figure 8.

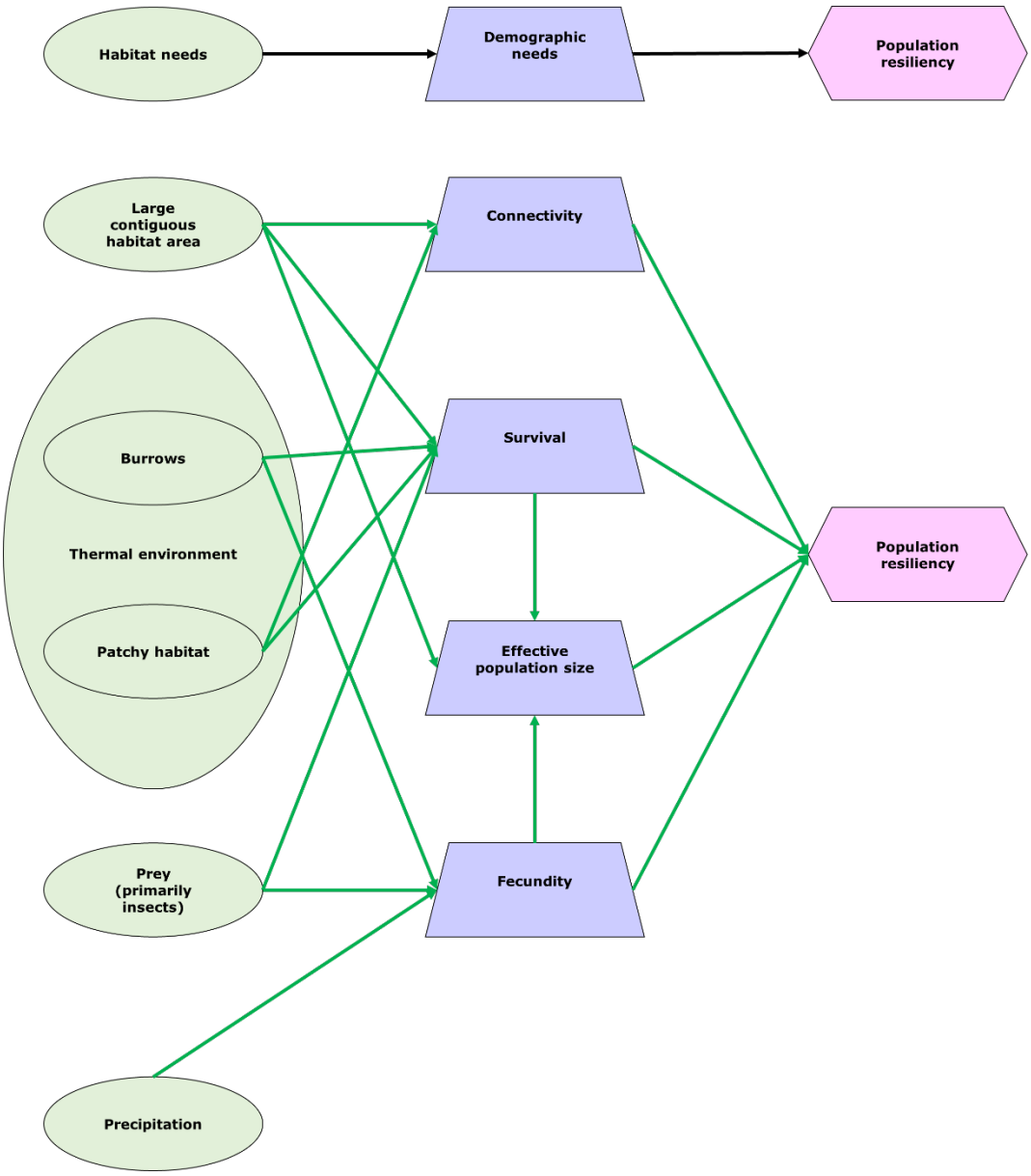


Figure 8. Blunt-nosed leopard lizard population habitat and demographic needs. Green arrows represent positive relationships.

Resilient populations need large areas of contiguous habitat (Bailey and Germano 2015, p. 25) containing the same habitat resources as needed by individuals. Although little is known about patch dynamics, habitat patch size was positively related to probability of occupancy for the species, possibly due to the wide-ranging nature of individuals or the amount of habitat needed to support a resilient population based on home range size and density estimates (Bailey and Germano 2015, pp. 25-27). The different temporal activity of the varying age classes highlights the importance of prey sources throughout the active period. Appropriate amounts of precipitation are important to support vegetation and prey within the species habitat, although droughts or excess precipitation could actually threaten the species (see discussion in *Factors Influencing Viability* below).

Demographic indicators that might suggest population resiliency are related to effective population size, fecundity, survival, and connectivity. We refer to effective population size according to the definition in a review by Frankham (2005, p. 95): the size of an idealized population that would give rise to the same variance of gene frequency, or rate of inbreeding, as the actual population under consideration. Briefly, effective population size is calculated using an equation that incorporates heterozygosity, a measure of genetic diversity. Effective population size in wildlife is often much lower than census population size (Frankham 1995, entire). The ratio between effective population size and census population size varies based on factors such as unequal sex ratios, variance in family size, and population fluctuations. Of these factors, population fluctuations based on limited reproduction in drought years could be a contributing factor for blunt-nosed leopard lizards. Populations need sufficient numbers of juveniles and adults to be able to withstand drought conditions that limit reproduction. Because few adults are seen across more than two years (Germano and Williams 2005, pp. 7-9; Tennant *et al*. 2018, pp. 30-31) despite expected survivorship of up to 9 years, evidence of breeding is important, as is the ability of females to lay multiple clutches in good years.

Connectivity within and between populations is important to maintain (or in some cases, reestablish) gene flow. Although blunt-nosed leopard lizards probably occurred in connected populations (within major subpopulations) throughout the historical range (Richmond *et al*. 2017, p. 3628), anthropogenic habitat fragmentation has greatly reduced the potential for gene flow between populations in the current landscape. In isolated populations or genetic clusters, maintaining sufficient numbers of adults in a population to guard against loss of alleles (*e.g.*, from demographic bottlenecks) is important. Attempting to reestablish connectivity between fragmented areas, when possible, will also add to population resilience.

Species Needs

In order to adapt to changing environmental conditions, the species needs to maintain its ecological and genetic diversity (representation) in resilient populations distributed throughout the species range (redundancy).

Redundancy

Redundancy contributes to the ability of a species to withstand catastrophic events by spreading risk among multiple populations and/or across a large area. Thus, redundancy is related to the number, distribution, and resilience of populations. When evaluating redundancy it is important to identify potential natural or anthropogenic catastrophic events that could occur within the range of the species and that could lead to population extirpations. For the blunt-nosed leopard lizard, potential catastrophic events include a prolonged drought or large-scale flood events.

Measures of redundancy for the blunt-nosed leopard lizard include the total number of resilient populations (based on the analysis of resiliency described above) combined with the overall distribution of these populations across the range of the species. Surveys in 2014 after three years of drought identified neonate presence in areas that could be potential climate change refugia for the species. Blunt-nosed leopard lizard neonates in the Panoche Valley region, Carrizo Plain National Monument, Tejon Ranch, and the eastern San Joaquin Valley (*e.g.*, Pixley National Wildlife Refuge) identify these locations as important breeding locations during drought

conditions, while surveys in the southwestern part of the range failed to observe neonates (Westphal *et al.* 2016, pp. 3-6). Redundancy for the species relies on having resilient populations in these areas that could be climate change refugia for the species.

Representation

Representation describes the ability of a species to adapt to changing environmental conditions, which is related to the breadth of genetic and ecological diversity within and among populations. For the blunt-nosed leopard lizard, we assessed species representation based on genetic diversity referencing a recent genetic analysis (Richmond *et al*. 2017, entire). The genetic study revealed historical population connectivity within clusters and deep primordial divisions between the clusters (Richmond *et al*. 2017, pp. 3624-2627). Maintaining multiple resilient populations within each of these genetic clusters is important for species viability. Although this could be also be seen as a sort of scaled redundancy, because of the emphasis on multiple populations, we include this under the representation heading according to the definitions of the 3Rs in the SSA framework.

Two regional clades were supported by mtDNA (northern vs. southern), while nuclear DNA revealed 5 major clusters, with populations distributed throughout each of the clusters (Figure 9). The northern regional clade only includes one of the genetic clusters, emphasizing a need to preserve multiple populations within this cluster to preserve genetic diversity in this clade. Clusters include: a "northern" cluster including sites from the Kettleman hills north; a "Valley floor" cluster in the center of the species current range; a "southwestern" cluster on the plains and foothills on both the east and west of the Temblor Range; a "southeastern" cluster along the southeastern edge of the San Joaquin Valley; and a "southern" cluster of blunt-nosed/long-nosed leopard lizard hybrids in the Cuyama River Watershed (Richmond *et al*. 2017, pp. 3621-3625). Within the northern cluster, microsatellite data recovered additional structure in the Panoche Hills region and the Madera Ranch samples grouped more closely with the Valley floor populations than the other northern locations, and, the southeastern cluster included a largely distinct Bakersfield population (Richmond *et al*. 2017, pp. 3621-324). Habitat fragmentation as well as primordial separation have contributed to population structure such that populations within these clusters are for the most part demographically independent, in that their dynamics are determined by birth and death rates within populations and clusters more than migrant exchange (Westphal *in litt*. 2019).

Representation depends on the distribution and connectivity between populations. Historical movement across the Temblor Range likely occurred in corridors in the Bitterwater Creek area in the southwestern genetic cluster (Westphal *in litt*. 2019). In the area surrounding the southeastern genetic cluster, Penrod *et al*. (2003) used landscape permeability analyses to determine least cost paths for movement for blunt-nosed leopard lizard and other San Joaquin Valley species that overlap historically important blunt-nosed leopard lizard dispersal areas. The Valley floor genetic cluster contains populations that are extremely isolated by fragmentation and development (see *Habitat Modification and Destruction* below). These populations have historical connectivity that is currently not possible because of the current habitat matrix (Westphal *in litt*. 2019).

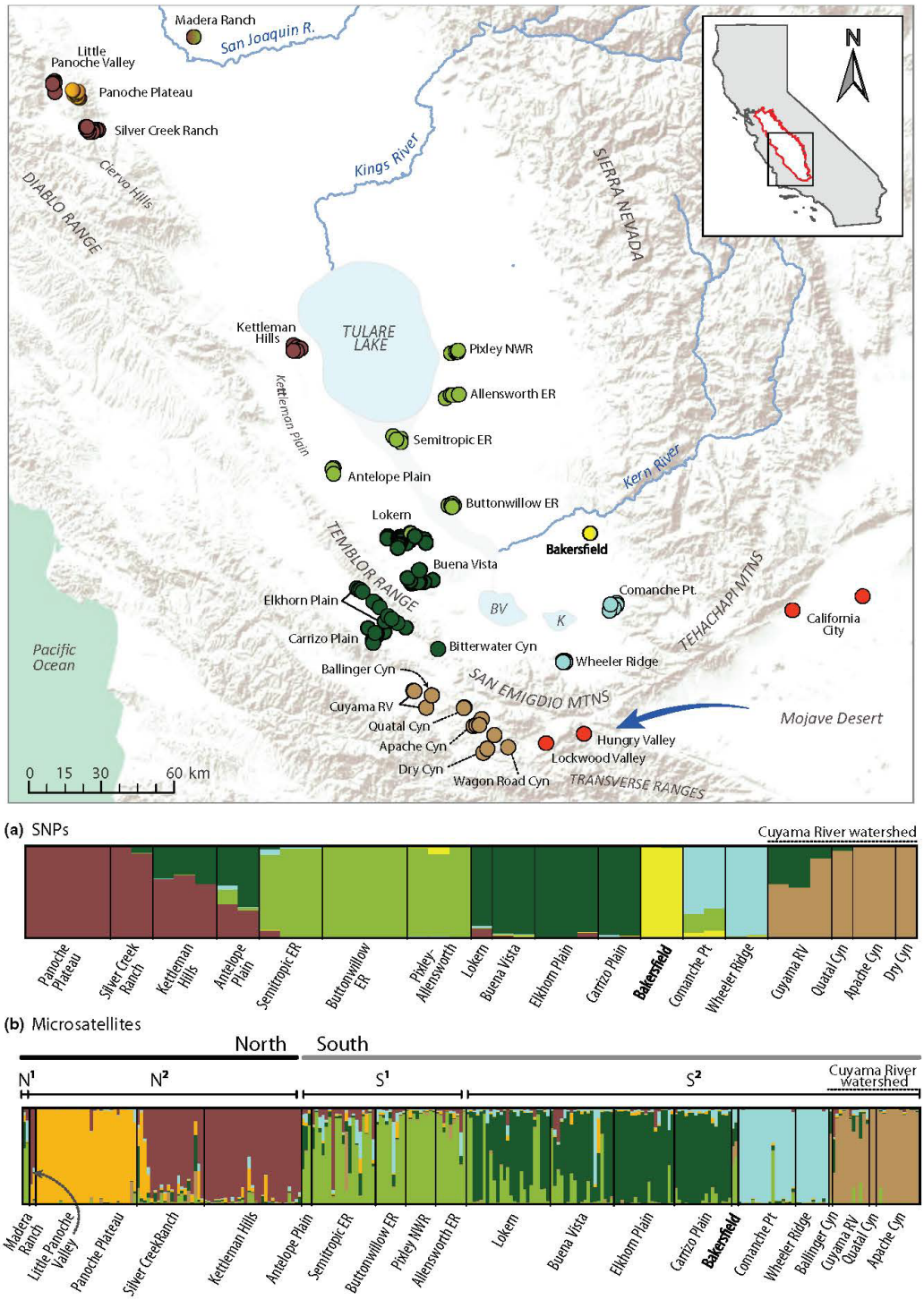


Figure 9. Map from the rangewide genetic study. Points represent samples, and colors represent cluster assignments at K=6, with the exception that orange dots represent mtDNA and nuclear genomes that are unambiguously G. wislenzii. Blue arrow indicates the entryway in the San Joaquin Desert for the ancestor to G. sila (but see caveats in journal article). Shaded gray bars distinguish North and South regional clades. Note that colors represent 6 cluster assignments, whereas text refers to the 5 clusters described in Richmond et al. 2017. Source: Richmond et al. (2017).

Although populations are largely demographically isolated in the current landscape, establishing dispersal corridors within and between genetic clusters would be an effective conservation strategy to add to the adaptive potential of the species. In particular, reestablishing corridors that were probably historically important for gene exchange would be beneficial (Westphal *in litt*. 2019). Genomic population structure indicate that sufficient numbers of blunt-nosed leopard lizards survived the extensive development and conversion to agriculture that led to the species' listing as endangered to maintain evidence of primordial structure (Westphal *in litt*. 2019). Maintaining resilient populations across these genetic clusters is important in preserving this structure and minimizing potential for genetic bottlenecks.

In addition to the use of genetic clusters to assess representation, we note the differences in habitat used by the species at both a regional and local level. Habitat types used by different populations range from non-native annual grasslands, grassland mixed with native forbs, saltbrush scrub, and Ephedra steppe. This variation in habitat type highlights the flexibility of the species as well as the potential for local adaptations that contribute towards fitness within populations in these habitats.

Summary of Species Ecology and Needs

Individual blunt-nosed leopard lizards need access to food and habitat in order to maintain resilient populations. Populations need to be resilient to be able to withstand periodic natural disturbances, such as drought. At the population level, survival of juveniles to the minimum size for reproduction is essential to drive population growth, as is survival of reproductive females. At the species level, connectivity maintains dispersal and gene flow between populations. Distribution of resilient populations across the genetic diversity of the species, as well as connectivity to allow for dispersal and gene flow, provides for adaptation to changing environmental conditions (representation). Distribution of resilient populations throughout the range of the species enables the species to withstand potential catastrophic events (redundancy). Having sufficient resiliency, representation and redundancy supports maintenance of the species in the wild over time (viability) (Table 5).

Table 5. Individual, population, and species needs for the blunt-nosed leopard lizard.

Level	Need	Function of Need	Association with 3 Rs
Individual	Insects	Provides caloric needs for hatchlings, juveniles, and adults	Resiliency
	Burrows	Provides refuge for shelter and seasonal brumation, and also house eggs	Resiliency
	Patchy habitat	Provides sites for foraging and thermoregulation	
Population	Large areas of contiguous habitat		Resiliency
	Abundance	Prevents inbreeding depression	Resiliency
	Survival	Promotes abundance; allows adults to become reproductively capable	
	Fecundity/recruitment	Drives population growth	Resiliency
	Connectivity between populations	Provides for dispersal; increases genetic diversity and allows for immigration following catastrophic events	Resiliency, Redundancy
Species	Multiple, connected, resilient populations	Improves species viability by spreading risk associated with catastrophic events	Redundancy
	Resilient populations throughout the 5 genetic clusters within the species' range	Maintains diversity and allows for adaptability to changing environmental conditions	Representation

Chapter 4. Historical and Current Condition

In this section, we summarize the historical and current condition of the blunt-nosed leopard lizard at the population and species levels. We examine historical and current population trends, consider factors (both positive and negative) influencing the species, and assess current population condition in the context of these factors. We summarize the historical and current condition by synthesizing this information in the context of the 3Rs to evaluate the species' viability.

Historical and Current Population Density

There are no current (or historical) population size estimates for the species, so in this section we focus on available data on population density. That being said, historical blunt-nosed leopard lizard population densities are not known. However, the evidence of high population densities in some locations and years provides evidence that blunt-nosed leopard lizards were probably historically abundant throughout the San Joaquin Valley.

Contemporary population density is not consistent between sites or within sites across years, with variable densities potentially associated with sex, habitat, home range size, and environmental factors. The highest documented densities of the species come from the Elkhorn Plain, with densities of 16 adults per hectare and 36 hatchlings per hectare, albeit not in the same year (Germano and Williams 2005, p. 9). More recently, Tennant *et al*. (2018, pp. 53-56) found densities of 0.16 to 1.16 adults and 0.1 to 1.2 hatchlings per hectare across various sites on State Ecological Reserves or National Wildlife Refuges. Opportunistic surveys in several other populations revealed blunt-nosed leopard lizard adults and hatchlings but at much lower densities than the censused locations (Tennant *et al*. 2018, p. 56). Surveys in Semitropic Ecological Reserve and Lokern Ecological Reserve were subjectively located in areas with the highest numbers of blunt-nosed leopard lizards but had lower densities than those in a long-term monitoring grid on Pixley National Wildlife Refuge (Tennant *et al*. 2018, pp. 53-56). This coincides with earlier reports that population densities in marginal habitat rarely exceed 0.5 blunt-nosed leopard lizards per hectare (0.2 per acre) (Mullen 1981, Le Fevre *in litt*. 1976, and Madrone Associates 1979 in Service 1998, p. 117).

Although the Pixley long-term monitoring site had higher densities than its study counterparts did, they were notably lower than some previous surveys at this site. Monitoring at a long-term site suggests that population densities fluctuate widely across years, which has been suggested to relate to precipitation. During a flood year, 1998, there were no blunt-nosed leopard lizards observed (Williams *in litt*. 2006), but surveys in the years before and after this event show oscillations in density. We note that monitoring at Pixley shows that population densities vary widely across different study plots, and that the long-term monitoring grid likely has a higher density of the species than the NWR as a whole. Monitoring in the 1980s and 1990s at 8 8-hectare plots had population density estimates that varied from 0.3 to 10.8 adults per hectare (Uptain *et al*. 1985, p. 17).

Oftentimes, blunt-nosed leopard lizards on private properties are not surveyed due to limited property access. Lack of access for monitoring or conservation-related work has led to challenges in

understanding population abundance and resiliency in some areas, including Madera Ranch (Service *in litt*. 2019; Westphal *in litt*. 2020).

Factors Influencing Viability

In this section, we consider the historical and current anthropogenic and environmental factors influencing blunt-nosed leopard lizard population resiliency (Figure 10), which in turn contribute to the overall viability of the species. We acknowledge that there are other factors that influence the blunt-nosed leopard lizard, but for the purposes of this SSA we focus on those factors that are generally thought to have population or species-level effects. Additional stressors to the blunt-nosed leopard lizard, including predation, parasitism, and waterfowl drums that can trap individuals, are summarized in the five-factor analysis of the 2010 status review (Service 2010, pp. 18-43) but are largely excluded from the analysis in this report because we deemed them more likely to affect individuals than populations.

We first discuss factors that are limiting blunt-nosed leopard lizard populations, including a description of the factor, the path through which it is thought to influence population resiliency, and the magnitude of its impact and/or specific populations that it may disproportionately affect (if known). We then discuss management actions that are currently underway or in consideration and how these actions stem from or may alleviate some limiting factors. Figure 10 is an influence diagram summarizing the pathways through which management actions and anthropogenic or environmental factors can influence blunt-nosed leopard lizard resiliency through their effects on habitat needs or demographic parameters.

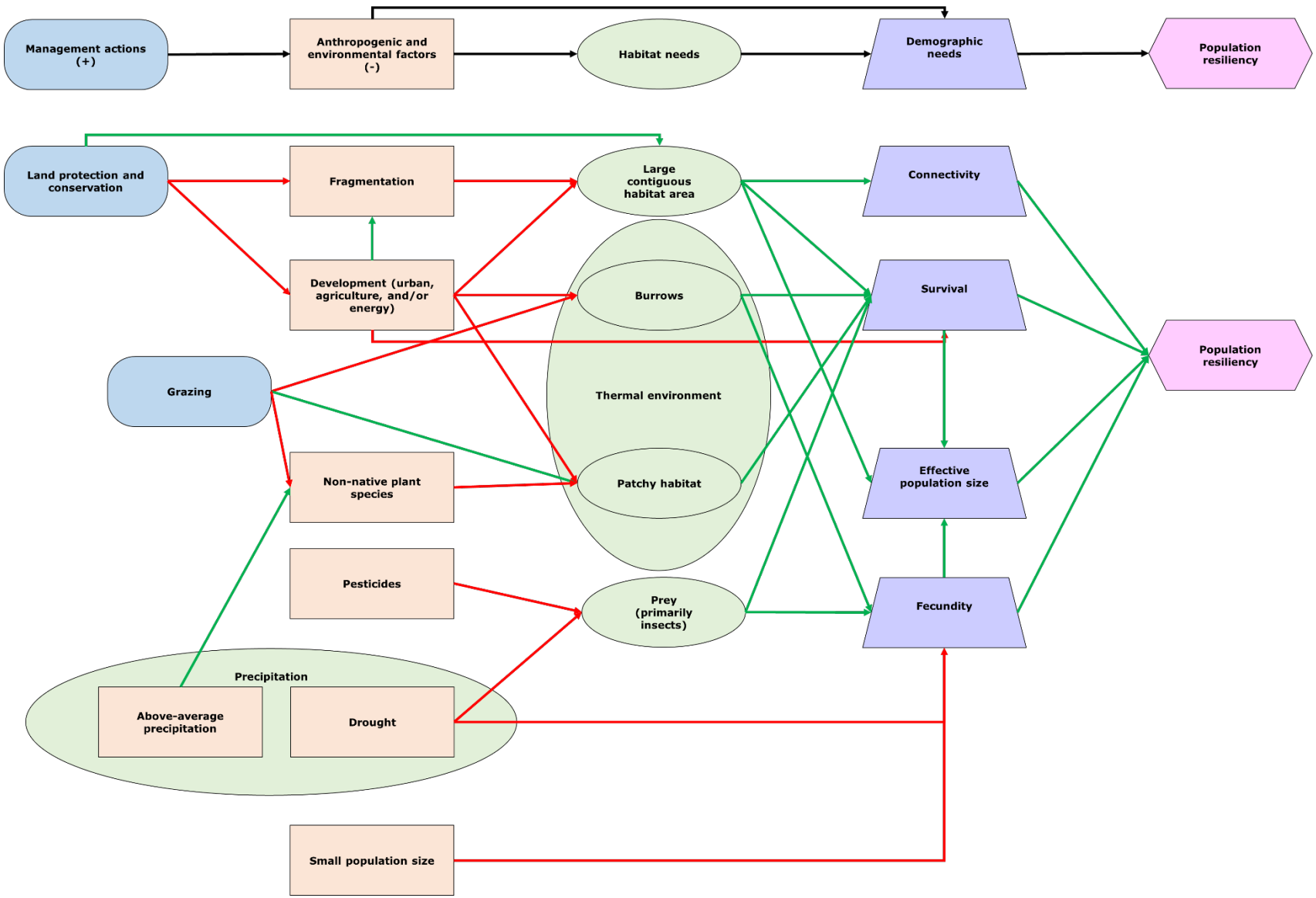


Figure 10. Influence diagram showing the pathways through which factors may influence habitat or demographic needs of the blunt-nosed leopard lizard. Green lines indicate positive relationships, and red lines indicate negative relationships.

Habitat Modification and Destruction

In this section, we consider any modification or destruction of habitat that would adversely affect the habitat needs of the blunt-nosed leopard lizard. Historically, habitat destruction via development and habitat modification (including agricultural cultivation and energy development) contributed to a dramatic decline in blunt-nosed leopard lizard populations that led to their present status as endangered. Estimates of habitat loss vary based on analyses and geographical boundaries, but all point to extensive reductions in available habitat. The 1998 recovery plan estimated that less than 5 percent (approximately 150,000 acres or 60,700 hectares) of habitat on the San Joaquin Valley floor remained uncultivated or developed (Service 1998, p. 1). Germano *et al*. (2011) used the distribution of precipitation, soils, plants, and animals including the blunt-nosed leopard lizard, to propose boundaries of the San Joaquin Desert. This analysis estimated that the approximate boundary of the San Joaquin Desert historically encompassed 28,493 km^2, of which 59% had a current land use classification as agricultural or urban (Germano *et al*. 2011, pp. 140-145).

It is important to highlight that habitat loss continued after the species was listed as endangered. As noted in the 1985 revised recovery plan, between 1977 and 1983 over 30,000 hectares (74,000 acres) of land in Habitat Units identified as "Essential" to the survival of the blunt-nosed leopard lizard in the 1980 recovery plan were destroyed (Service 1985, p. 10). From 1976 to 1979, the mean rate of loss of natural communities on the San Joaquin Valley floor exceeded 15,500 hectares (38,000 acres) per year by agricultural, urban, oil, gas, or other development (Service 1985, p. 9). Habitat modification and destruction contribute to declines in blunt-nosed leopard lizard resilience both directly and indirectly from sources including: displacement and habitat fragmentation; reduced feeding, breeding, and sheltering sites; reduced carrying capacity and prey populations for occupied sites; reduced connectivity between sites; and direct mortality.

The 2010 status review for the species summarizes Service-issued biological opinions authorizing take of approximately 21,000 acres (8,498 hectares) of blunt-nosed leopard lizard habitat (Service 2010, p. 19). This number only accounts for those projects that were reviewed under the Act; the estimates do not include any loss of habitat or adverse effects from habitat conversion that was not reported to the Service. However, permitted take of blunt-nosed leopard lizard individuals and habitat is often accompanied by protection of lands via conservation easements or other forms of land protection (see *Conservation and Management* below). Habitat Conservation Plans (HCPs) also result in permanent impacts or temporary disturbance of habitat, as well as land designated for conservation, which will be discussed in more detail in the *Habitat Conservation Plan* section below. Habitat modification and destruction via fragmentation and development, in addition to habitat modification via non-native invasive plant species, are all current threats to the species, and are discussed in more detail below.

Fragmentation

Habitat modification and destruction often leads to habitat fragmentation. Fragmentation can reduce population connectivity, which can limit gene flow within and between populations. Isolated populations could eventually be at risk of inbreeding depression or Allee effects (Courchamp *et al.* 2008). Fragmentation can also impact blunt-nosed leopard lizards by

increasing the potential for vehicle collisions. Individuals can be killed directly from automobile traffic and off-road vehicle use. Roads surround and often bisect remaining fragments of habitat, increasing the risks of mortality by vehicles. The blunt-nosed leopard lizard's preference for open areas, such as roads (Warrick *et al.* 1998, pp. 186-188), makes them especially vulnerable to mortality from vehicle strikes, which is supported by individual observations of roadkill blunt-nosed leopard lizards (Westphal *in litt*. 2020). At the border of Pixley National Wildlife Refuge, blunt-nosed leopard lizards were seen crossing a dirt road from the refuge into adjacent alfalfa fields (Lantz *in litt*. 2019), likely to forage in the croplands. Although these dirt roads are not a high traffic area, the potential for fatal collisions exists on stretches of habitat with different habitat factors needed by individuals on opposite sides (*e.g.*, food vs. burrows).

Agriculture

Agricultural development is a change in land use from its previous state (in this case natural habitat) to agricultural use. At the time of listing, the conversion of native habitat to agricultural use was considered the primary threat to the blunt-nosed leopard lizard (Service 2010, p. 18). Conversion of natural lands to agriculture was not halted by the listing of the blunt-nosed leopard lizard, and continues to threaten blunt-nosed leopard lizard habitat on private lands.

Agricultural development can influence blunt-nosed leopard lizard populations both directly and indirectly, including: direct mortality by crushing individuals or eggs in burrows; reducing feeding, breeding, and sheltering sites and opportunities; and reducing connectivity between sites through habitat fragmentation. In general, habitat conversion to agriculture does not require additional permits in areas zoned for agriculture (Cates 2017 pers. comm.). For example, in August 2006, about 1,300 acres of saltbush scrub and sink scrub habitat were disced for cultivation of melons along Interstate 5 north of the Kings – Kern County line near known blunt-nosed leopard lizard occurrences (Vance *in litt.* 2006). An analysis of land uses changes from 2008 to 2018 using the Cropland Data Layer (CDL) from the United State Department of Agriculture's National Agricultural Statistics Service revealed land use changes within the historical range of the blunt-nosed leopard lizard (USDA National Agricultural Statistics Service Cropland Data Layer 2019). Notably, many of the changes in the CDL (almost 1.5 million acres) were from one crop type to another crop type (*e.g.*, alfalfa to almonds), which is unlikely to have implications for the blunt-nosed leopard lizard. Over this same period, almost 500,000 acres of cropland were fallowed, although the future land use of these fallowed areas is uncertain. Over 400,000 acres of other land use types were converted to crops, although it is unclear how much of that habitat would have been suitable for the blunt-nosed leopard lizard. Stewart *et al*. (2019, p. 8) used land use maps overlaid on historical blunt-nosed leopard lizard occurrences to demonstrate that 105 occurrences had been converted to agriculture and urban development (Figure 11). Of these, 45 were lost after the species received federal protection beginning in 1967, including 8 occurrence locations converted to agriculture between 2007 and 2016. Several of the occurrences that were lost were adjacent to protected lands.

Although agricultural conversion has been a powerful influence shaping land use of the San Joaquin Valley, there is also some evidence of an increase in fallowed agricultural lands (at least

in drought years) (Melton *et al.* 2015, pp. 3-7), which may have potential for strategic restoration (see *Restoration* below).

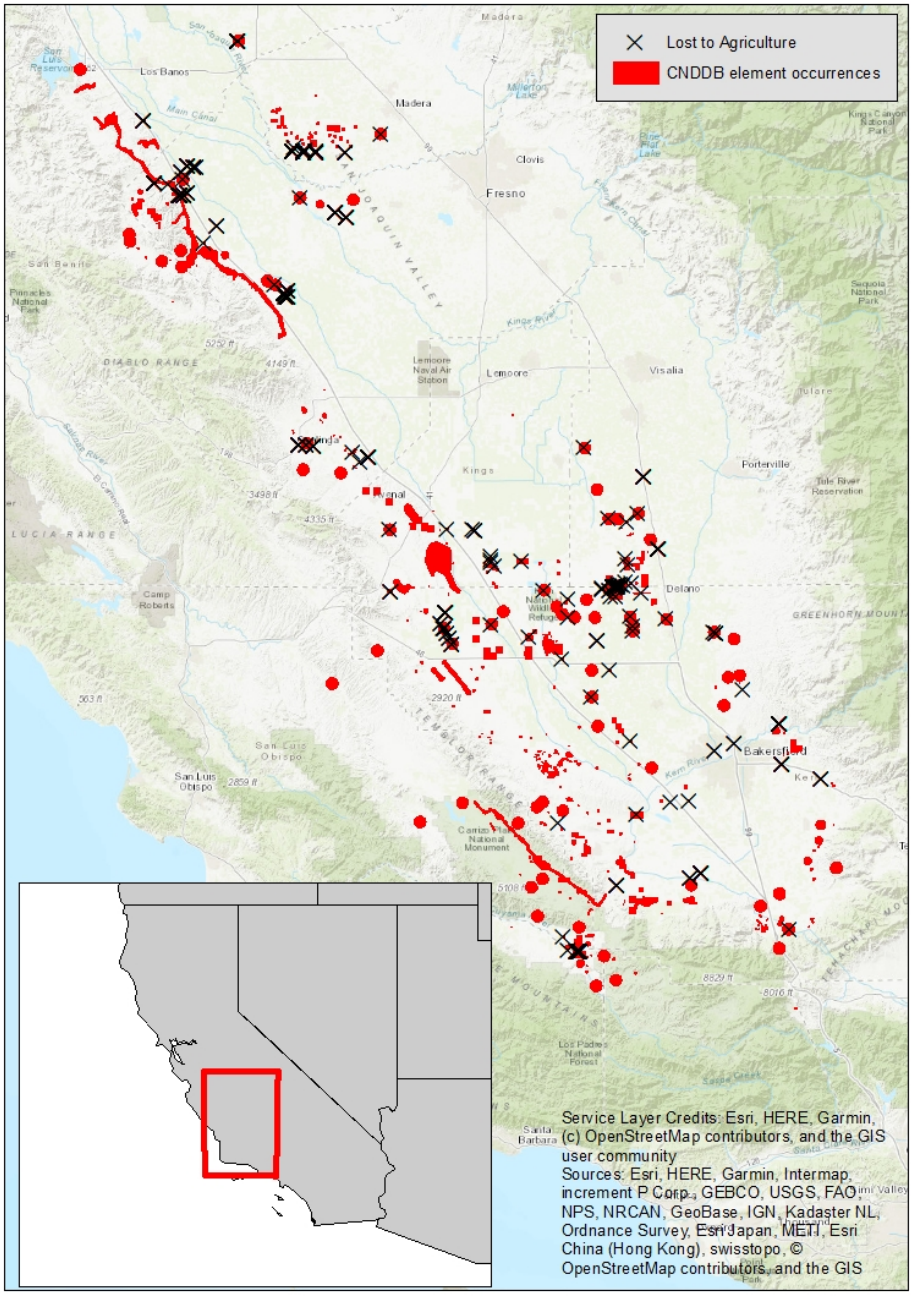


Figure 11. Blunt-nosed leopard lizard element occurrences (CNDDD) and occurrences putatively lose to agriculture and urban development (data from Stewart et al. 2019). For description of methods for extirpated populations, see Stewart et al. (2019). Note that the authors thinned occurrence data (from CNDDB as well as other sources), while we present the raw CNDDB occurrences.

Oil and Gas Development

Oil and natural gas exploration activities threaten blunt-nosed leopard lizard habitat, especially in western Kern, Kings, and Fresno Counties (Service 2010, p. 21). Oil and gas development can cause direct mortality to individual lizards, or indirectly affect the species through habitat modification. Direct mortality can occur from facility construction (*e.g.* well pads, wells, storage tanks, sumps, pipelines), associated roads and vehicular traffic, or oil leakage (from pumps and pipes or during transport). All of these activities can cause blunt-nosed leopard individuals to be crushed, buried, drowned, or trapped, and depending on the scale can have population-level effects (discussed in Service 2010, p. 21). Individuals that initially survive construction, but are displaced, may ultimately be unable to survive in adjacent habitat if it is unsuitable, there are insufficient corridors, or if habitat is already saturated. Oil and gas exploration can also have non-lethal effects on individuals including harassment from noise or vibration, and degradation of habitat.

In some areas, blunt-nosed leopard lizards persist in areas with oil fields and/or recolonize oil fields that have been abandoned. The species likely occurs in areas with lightly to moderately developed oil fields but is unlikely to be found in densely developed parts (Germano *in litt*. 2019). However, population densities may be reduced during periods of activity or because of habitat degradation, or individuals may be forced into areas with little or no petroleum-related activity (Kato and O'Farrell 1986 in Service 1998, p. 119). A study comparing home range sizes and movements of radio-tagged lizards in an oil field verses a control site did not lead to subjective differences, but analyses of these data are still pending (Germano and Saslaw 2016, entire; Germano *in litt*. 2019).

Solar Development

Although solar energy development is an important source of renewable energy, it was also listed as an emerging threat to blunt-nosed leopard lizards and their habitat in the 2010 status review (Service 2010, p. 18). To our knowledge there have not been specific studies focusing on the impacts of solar projects on blunt-nosed leopard lizard demographics, but it seems likely that solar projects could have direct or indirect impacts on the species. Solar development projects can destroy, fragment, or impact blunt-nosed leopard lizard habitat by altering landscape topography and vegetation, and, reducing habitat quality through interception of solar energy normally reaching the ground surface, affecting ambient air temperatures through habitat shading, and altering soil moisture. Solar energy development can cause direct morality during construction by crushing individuals through vehicle strikes or in burrows.

The terrain, climate, insolation, and land use of the San Joaquin Valley combine to offer high potential for solar energy development (Phillips and Cypher 2015, pp. 13-16). Based on a number of factors including climate and land prices, over 120 solar facilities were in operation or planned stages by 2015 (Pearce *et al.* 2016, p. 1). In the Western San Joaquin Valley, approximately 259 km^2 (100 mi^2) of utility-scale solar energy projects were proposed or under construction in 2013 (Butterfield *et al.* 2013, p. 2). However, in recent years there has been a shift in size and location of proposed solar projects towards smaller projects on lands that would provide lower conservation benefit for the species (Sloan *in litt*. 2019). Spatial analyses are

useful for modeling areas where there could be conflict or to help minimize conflict between solar development and rare species. A recent analysis identified over 8400 km^2 of land with moderate to high potential for solar development but no or low-quality habitat for rare species, including the blunt-nosed leopard lizard (Phillips and Cypher 2019, pp. 31-37). Low-impact solar energy development sites could actually provide conservation value for rare species, as it could create protected linkages between occupied areas and provide better habitat than existing land use (e.g., agriculture) (Butterfield *et al*. 2013, p. 7; Phillips and Cypher 2019, p. 38). Additionally, mitigation from solar projects can add to conservation for the species. For example, Silver Creek Ranch in San Benito County was protected as part of mitigation for the Panoche Valley Solar Farm (Butterfield *et al*. 2013, p. 8).

Housing/Commercial Development

Housing/commercial development can influence blunt-nosed leopard lizards both directly and indirectly. As with energy development, there is potential for take associated with the physical development of land through direct mortality or crushing the lizards. There is also the potential for indirect effects such as lowering habitat quality (*e.g.*, reducing the number of burrows, altering vegetation, reducing prey availability, etc.). Habitat Conservation Plans (HCPs), discussed below, describe anticipated effects of development and the ways in which those impacts will be minimized or mitigated.

Non-native Plants

The southern San Joaquin Valley of California, as with much of western North America, has been drastically altered by the invasion of non-native plant species. Non-native plants began altering grasslands when European settlers reached the Americas, bringing with them changes to plant composition and grazing patterns (Biswell 1956, pp. 21-22; Heady 1977, pp. 497-499). More specifically, non-native grass species are frequently observed within blunt-nosed leopard lizard habitat (Germano *et al*. 2001, pp. 552-554). The timing of germination for introduced grasses is often earlier than most native species, which effectively gives the non-native species a competitive advantage over native plant species (e.g., Dyer *et al.* 2000, pp. 525-526). Additionally, an overabundance of residual dry matter (RDM) from the previous year's non-native grass production can obstruct native seedlings, compounding the problem. Dense growth of these grasses, and associated RDM, can impede blunt-nosed leopard lizard cursorial (adapted for running) flight from predators or other movements. Blunt-nosed leopard lizard scat was negatively correlated with RDM in one year of a two-year study, indicating that the species was using areas with less RDM. Scat was associated with lower RDM in a year with high plant productivity, but this relationship was not found during a drought year (Filazzola *et al*. 2017, p. 57).

Non-native grasses can contribute to feedback cycles between grasses and the size, intensity, and frequency of fire (Brooks *et al*. 2004, entire). Indeed, wildfires in the San Joaquin Desert have likely contributed to habitat dominated by non-native grasses in some areas (Germano *et al*. 2012, p. 671). In another feedback cycle involving non-native grasses, native shrubs within blunt-nosed leopard lizard habitat may actually facilitate invasions by non-native annual grasses. In a study from 2015 to 2018 at the Carrizo Plain National Monument, native shrubs enhanced

abundance of both native and non-native annual plants, with stronger facilitation of exotic annuals (Lucero *et al*. 2019, pp. 79-81).

At the northern range limit of the species, dense exotic vegetation corresponds with a climatic niche contraction and associated range contraction of the blunt-nosed leopard lizard (Stewart *et al*. 2019, pp. 8-9). Historical occurrences where blunt-nosed leopard lizards had not been detected since 1960 had significantly higher actual evapotranspiration (a proxy for vegetation biomass) than modern occurrences, indicating that habitat modification by exotic plants may be responsible for the range contraction (Stewart *et al*. 2019, pp. 9-11).

Above- or Below-Average Precipitation

Fluctuations are characteristic of population dynamics in many animal and plant species in the San Joaquin Valley (Service 1998; Service 2019) and elsewhere, and are often associated with changes in resource availability. Blunt-nosed leopard lizard population instability is often associated with above- or below-average annual precipitation. Above-average precipitation is associated with decreases in survival of the species, while below-average precipitation is associated with decreases in reproduction. A preliminary Population Viability Analysis (PVA) based on historical data collected from the Elkhorn Plain aims to use precipitation as a predictor variable to model fecundity and population persistence over time (Tennant *et al*. 2018, p. 59; Sinervo *in litt*. 2019).

Long-term monitoring studies demonstrate population declines after consecutive years of above-average precipitation (*e.g.*, Germano and Williams 2005, pp. 10-11). Although the correlations between blunt-nosed leopard lizard abundance and precipitation in that study were not significant, a general consensus among experts exists that high rainfall is associated with a decrease in abundance. The likely pathway through which this affects the species is via increases in annual plant biomass, which may lead to decreases in hatchling or juvenile survival (Germano and Williams 2005, p. 13). Modeling demonstrated that high precipitation and the resulting increase in vegetation biomass are the most limiting variables for the species (Stewart *et al*. 2019, p. 8). Above-average precipitation can also threaten populations by flooding burrows. Flooding can also lead to changes in local topography, vegetation composition and structure, and prey base composition. Populations at risk from flooding are predominantly those on the Valley floor, including, but not limited to, Semitropic Ecological Reserve, Pixley National Wildlife Refuge, Kern National Wildlife Refuge, and Allensworth Ecological Reserve.

Drought within the current decade represents the most severe California drought in the last 1200 years (Griffin and Anchukaitis 2014, pp. 9018-9020). An analysis of winners and losers of long-term drought in California declared the blunt-nosed leopard lizard a loser based in decreases in abundance (Prugh *et al.* 2018, p. 821). More specifically, monitoring studies of blunt-nosed leopard populations during drought years have demonstrated negative effects on reproduction (Germano *et al.* 1994, pp. 13-15; Germano and Williams 2005, p. 5) and associated population declines (Germano and Williams 2005, pp. 7-8). This link between drought and blunt-nosed leopard lizard reproduction is suggested to relate to a decrease in prey abundance in years with low rainfall (Germano *et al*. 1994, pp. 15-16) or to other habitat changes such as soil moisture, soil temperature, or NDVI (Westphal *et al*. 2016, p. 6). Adults of the species may not emerge

above ground at all during drought years (*e.g.*, Germano *et al*. 1994, p. 16), which has obvious implications for reproduction. Surveys during the third year of an ongoing drought failed to detect hatchling blunt-nosed leopard lizards in the majority of sites across the range of the species (Westphal *et al*. 2016, pp. 3-5). Evidence of reproduction in some populations during this period highlight the importance of these populations as climate change refugia (Westphal *et al*. 2016, p. 6). In particular, reproduction in populations in the Panoche Valley region and Carrizo Plain National Monument in the coast ranges, the Tejon Ranch region in the southern Sierra Nevada foothills, and the eastern San Joaquin Valley (*e.g*., Pixley National Wildlife Refuge) (Westphal *et al*. 2016, pp. 4-6), highlight the importance of these populations for species viability and maintaining connectivity between populations.

Pesticide Use

The use of pesticides, specifically insecticides, may affect the blunt-nosed leopard lizard directly or indirectly (Montanucci 1965, p. 278). Because droughts already reduce the number of available insect prey, use of malathion or other insecticides during drought years may have a particularly strong effect. Insecticide use in the fall after hatchlings have emerged may also have strong impacts on populations because prey availability tends to be lower at this time of year, and because hatchlings need to grow as much as possible before going belowground for the winter.

The insecticide malathion has been used to control the sugar beet leafhopper (*Circulifer tenellus*), which spreads the plant pathogen curly-top virus (*Curtovirus* sp.) (Redak *et al.* 2009, abstract). California Department of Food and Agriculture (CDFA) began treatment using malathion in 1969, and sprays up to three times per year (fall, winter, spring; winter treatments were only conducted three times from 2005-2018). Up to 100,000 acres of rangeland and idle agricultural land are treated each year on the west side of the San Joaquin Valley from Merced to San Luis Obispo Counties (Figure 12), and CDFA notes that even larger areas may require treatment in drought years (CDFA 2007; CDFA 2008). Insecticides also drift outside of application areas. Windborne drift of non-volatilized pesticides such as malathion can be lethal to invertebrates at distances up to 200 m (656 ft.) from application (Newhart 2006, p. 5).

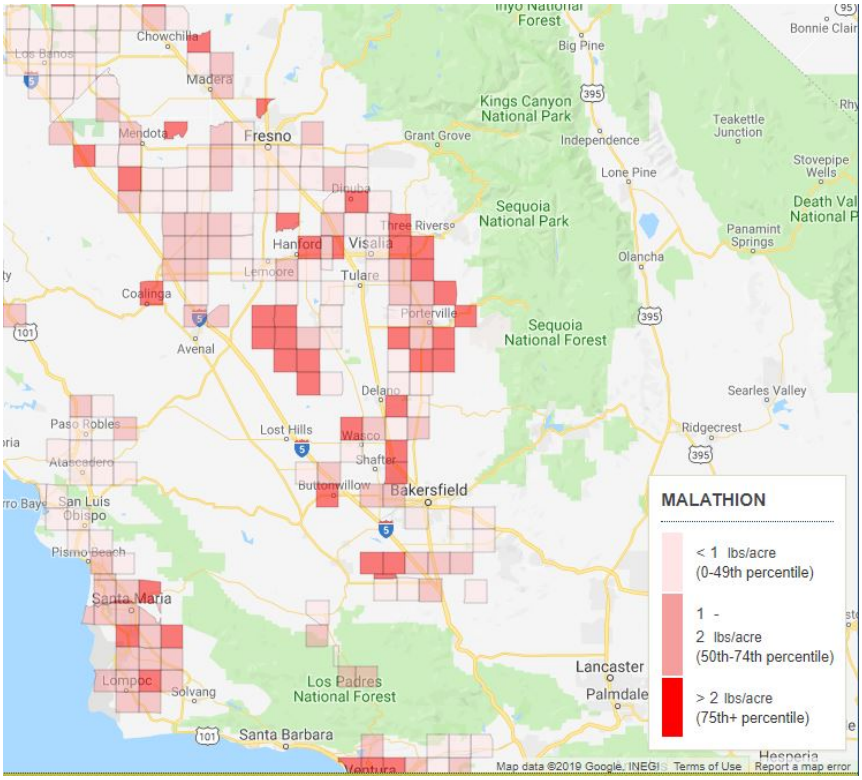


Figure 12. Malathion use in 2017 across blunt-nosed leopard lizard habitat. Data shows application rates (pounds/acre) averaged over townships. Data from the California Environmental Health Tracking Pro.

In a 2001 biological opinion, the Service authorized the renewal of a five-year pesticide use permit to CDFA for use of malathion which included measures to protect the blunt-nosed leopard lizard (Service 2001). The permit was again extended in a 2009 amendment (Service 2009). The biological opinion designated ten blunt-nosed leopard lizard conservation areas; of these, malathion application would not to be conducted in seven. The measures allowed the aerial application of malathion in some blunt-nosed leopard lizard conservation areas prior to April 15 and after October 15 in an effort to avoid the primary blunt-nosed leopard lizard activity period. In accordance with these opinions, from 2000 through 2009, over 65,000 acres per year were treated on average, in Kern, King, and Fresno Counties (CDFA 2009, p. 92).

Although the Recovery Plan cites a study that says acute administration was relatively non-toxic to another lizard in the Iguanidae family (Hall and Clark Jr. 1982 in Service 1998, p. 120), the National Pesticide Information Center lists malathion as moderately toxic to birds (the closest taxa reported; (Gervais *et al.* 2009). The most important effects of malathion on the blunt-nosed leopard lizard may be those associated with the reduction of insect prey populations. Although aerial application of malathion likely reduces the availability of food for lizards in the spring (Germano *et al*. 2007, p. 321), Redak *et al*. (2009, abstract) found that malathion treatment had little impact on arthropod abundance, and suggest that affects to the blunt-nosed leopard lizard would be minimal. These data suggest that arthropod communities may recover quickly after spray periods. Germano *et al*. (2007, p. 321) recommended research on effects of malathion to

the prey base of blunt-nosed leopard lizards but to our knowledge no detailed studies have been conducted to date that rigorously examine this question.

Conservation and Management

Grazing

Grazing is a common management tool to combat dense growth of invasive non-native grasses. Because of the prevalence of non-native annual grasses in the San Joaquin Valley, appropriate levels of grazing are critical in maintaining sufficiently open habitat for blunt-nosed leopard lizards. Although grazing is mostly considered a positive management tool for the species, it can have negative influences depending on the intensity. Anecdotal evidence of overgrazing in the Bitterwater Creek corridor was suggested as a potential correlate of low abundance during sampling at that site in 2016 (Westphal *in litt*. 2019), although we do not have information about grazing levels or abundance trends at this site. Determining appropriate grazing levels is made more difficult because terms to define grazing, including "light", "moderate", and "heavy", are often undefined or variable, as is the more controversial term "overgrazing" (Fleischner 1994, p. 630).

In the southern San Joaquin Valley, habitat is generally managed so that less than 1000 lb/acre (1,140 kg/ha) residual dry matter (RDM) remain at the end of a growing season, and preferably less than 500 lb/acre (570 kg/ha) RDM (Bartolome *et al.* 2014, p. 40). Moderate levels of grazing may be beneficial by lowering vegetation height and density, and reducing fuels for fires (Chesemore 1980, p. 30; Germano *et al.* 2001, pp. 556-557). Blunt-nosed leopard lizard abundance increased in treatment plots grazed by cattle compared to control plots, although this trend was not statistically significant (Germano *et al.* 2012, pp. 675-676). Blunt-nosed leopard lizards were also more abundant on grazed plots relative to an ungrazed exclosure on the Pixley National Wildlife Refuge (Clark 1989, p. 2). Conversely, livestock grazing can negatively affect blunt-nosed leopard lizard habitat through removal of herbaceous vegetation and shrub cover, destruction of rodent burrows used by lizards for shelter, and associated soil erosion if the stocking rate is too high or if animals are left on the range for too long after annual plants have died.

It is important to note that native and non-native plant species may respond differently to grazing. Grazing can actually increase the establishment and spread of non-native invasive species (Vavra *et al*. 2007, entire). In one study on the Carrizo Plain National Monument, non-native annual grasses sometimes compensated in growth and reproduction compared to native species following simulated herbivory (*i.e*., clipping and mulch removal). The authors suggested that livestock grazing may actually be counterproductive to restoration efforts in some cases, perhaps because of adaptations by invasive plants relative to native grassland species (Kimball and Schiffman 2003, pp. 1681, 1684-1687). Grazing management in blunt-nosed leopard lizard habitat should ideally balance with biodiversity or other conservation efforts in their habitat.

Land protection and conservation

Protected Lands

We assessed the proportion of land owned by Federal, State, or other protected entities (*e.g.*, NGOs, Districts) verses land that is privately owned. We compared land protection within species historical range and within habitat mapped as suitable in Stewart *et al*. (2019) (Table 6). We note that some of the protected areas do not have suitable habitat and/or blunt-nosed leopard lizard occupancy. For example, Mendota Wildlife Area is 11,800 acres but is mostly floodplain or flatlands, with limited alkali scrub (CDFW 2019).

Table 6. Blunt-nosed leopard lizard habitat acreage and land protections. We assessed the percent of protected habitat to the total IUCN range acreage and suitable habitat acreage (from Stewart et al. 2019).

County	IUCN Range (Acres)	Suitable Habitat (Acres)	Percent Suitable within IUCN Range	Percent Protected within Range	Percent Protected Suitable Habitat
Fresno	1865885	171054	9	24	69
Kern	2318023	778677	34	16	24
Kings	890581	157663	18	3	7
Madera	360333	31049	9	0	0
Merced	948728	80861	9	27	56
Monterey	203883	0	0	12	NA
San Benito	563996	18873	3	37	55
San Joaquin	2555	0	0	11	NA
San Luis Obispo	666484	287763	43	52	70
Santa Barbara	411426	52299	13	75	18
Santa Clara	73229	0	0	29	NA
Stanislaus	541605	0	0	12	NA
Tulare	397271	22262	6	8	48
Ventura	100613	5598	6	91	85

The CPAD and CCED map existing land protections in California, and are a useful visual tool to assess contiguous blocks of land that support blunt-nosed leopard lizard populations, as well as potential land acquisitions that could help promote corridors between populations and genetic clusters. We mapped CPAD, CCED, and USGS PAD relative to blunt-nosed leopard lizard populations (Figure 13). Because large blocks of contiguous land are important for the resilience of blunt-nosed leopard lizard populations, conserving connected parcels of land is important for the health of the species.

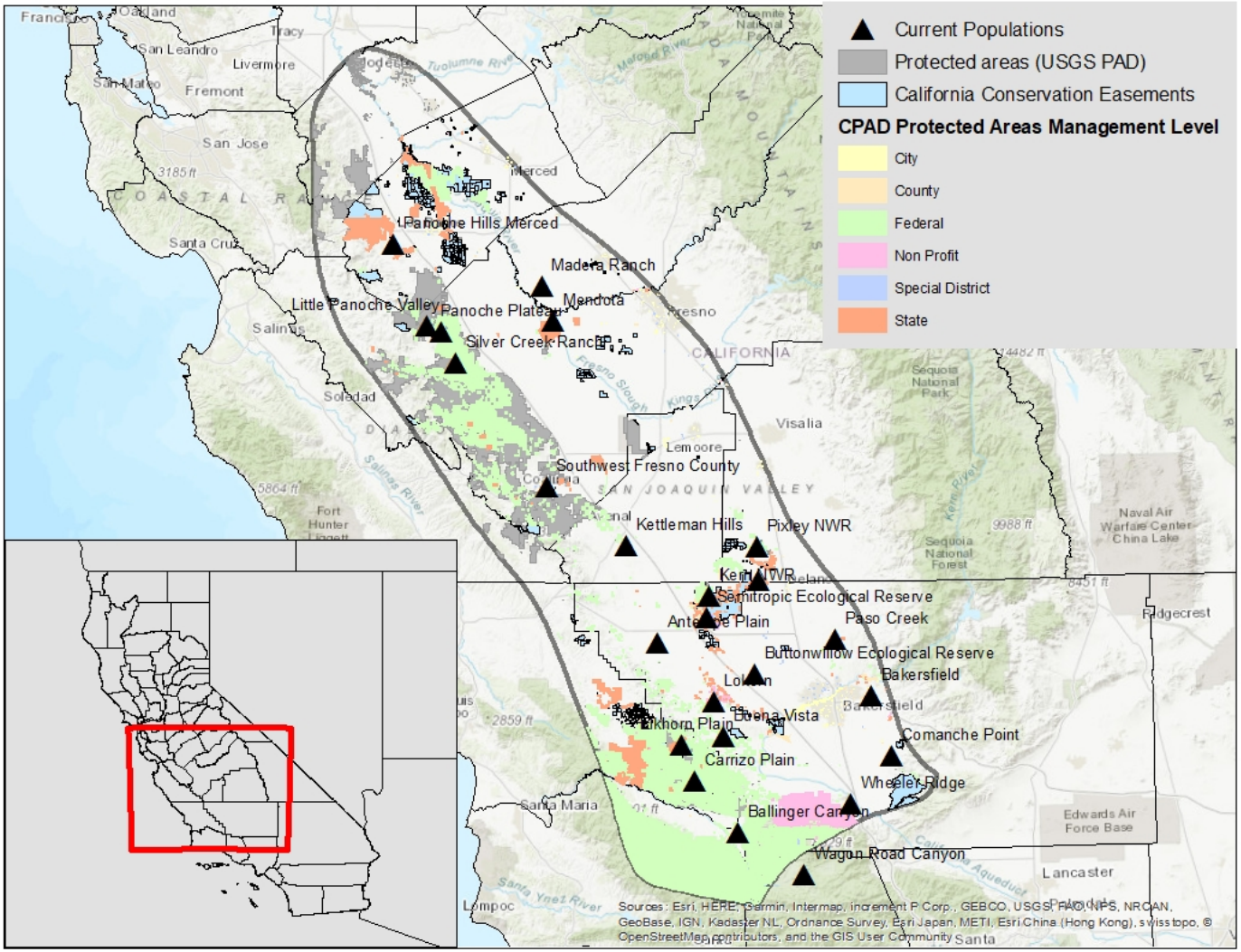


Figure 13. Protected lands within the historical range of blunt-nosed leopard lizard populations. General locations for populations are from Richmond et al. (2017); protected lands are from the California Conservation Easement Database, California Protected Areas Database, and USGS Protected Areas Database.

Central Valley Project Conservation Program (CVPCP) and Habitat Restoration Program (HRP)

The Central Valley Project (CVP) is a large multi-purpose water conveyance network designed to supply water and provide flood protection throughout a 644 km (400 mile) section of central California (Bureau of Reclamation 2019) The Conservation Program (CVPCP) and CVP Improvement Act Habitat Restoration Program (HRP) are dual projects designed to protect and restore habitats impacted by the CVP. The blunt-nosed leopard lizard is listed as a high priority species for these projects, with emphasis on efforts to: determine habitat management and compatible land uses, conduct presence/absence surveys, and protect key habitat areas (Bureau of Reclamation 2017, p. 1). Notable projects under the two programs include land acquisition and habitat restoration. The history of the CVPCP and HRP is discussed further in Service 2010 (pp. 24-33), including discussion of the Land Retirement Program and a list of lands acquired through the Bureau of Reclamation. Much of this land is mapped in the CPAD and CCED (see previous section).

Regulatory mechanisms that provide conservation benefits

In addition to being listed as a federally endangered species, the blunt-nosed leopard lizard was listed as endangered (and fully protected) species by the State of California in 1971. There are several State and Federal laws and regulations that are pertinent to listed species, each of which may contribute in varying degrees to the conservation of listed and non-listed species. These laws have reduced or eliminated the threat of wholesale habitat destruction, although the extent to which they prevent the conversion of natural lands to agriculture is less clear. Here we provide details on protection of blunt-nosed leopard lizards through the Endangered Species Act (Act); additional information relating to state and federal protections is included in the status review (Service 2010, pp. 34-38).

The Endangered Species Act of 1973, as amended (Act), is the primary Federal law providing protection for the blunt-nosed leopard lizard. 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.

Although habitat destruction and modification continues to occur in blunt-nosed leopard lizard habitat throughout its range (as described above in *Habitat Modification and Destruction*), the status of the blunt-nosed leopard lizard as a species listed under the Act can reduce the severity of the effects of habitat loss. 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). 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 mitigation or conservation bank (bank) is a property or suite of properties (i.e., umbrella bank, phased bank, etc.), providing habitat or other conservation values that are conserved and managed in perpetuity, and provides ecological functions and services for specified listed species or resources. Mitigation and conservation banks function to offset adverse impacts 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 to offset adverse impacts their projects will likely have on listed species. The money from the initial investment and bank credit sales is then used to permanently protect and manage the land for those species and resources.

There is currently one active conservation bank and one inactive conservation bank for the blunt-nosed leopard lizard. The Kern Water Bank, currently active, and the Coles Levee Ecosystem Preserve, inactive, are both in Kern County, and there are a handful of proposed banks in development. More information about these and other 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/.

Permittee-Responsible Mitigation

Permittee-responsible mitigation, also sometimes referred to as turn-key mitigation, includes activities or projects undertaken by a permittee (or authorized agent) to provide compensatory mitigation to offset impacts from a single project. The permittee retains full responsibility for this mitigation. Ideally, permittee-responsible mitigation projects are established in advance of

the project-related impacts they are offsetting; however, this typically does not occur due to multiple factors.

Habitat compensation through permittee-responsible mitigation for the blunt-nosed leopard lizard has occurred throughout the species range for a number of projects, primarily with regard to energy development or infrastructure projects. For example, the Panoche Valley Solar Farm, LLC reduced impacts of the solar farm on listed species, including the blunt-nosed leopard lizard, through acquisition and protection in perpetuity of over 25,000 acres of conservation lands (Panoche Valley Solar, LLC 2017).

Habitat Conservation Plans

Habitat Conservation Plans (HCPs) are planning documents required as part of an application for an incidental take permit. They describe the anticipated effects of the proposed taking; how those impacts will be minimized, or mitigated; and how the HCP is to be funded. HCPs can apply to both listed and non-listed species, including those that are candidates or have been proposed for listing. Regional HCPs develop large-scale conservation strategies within a specific region that are designed to conserve functional ecological systems, and the covered species that depend on them. Such HCPs aim to avoid a fragmented conservation landscape by working with local land use authorities and a designated implementing entity to conserve, enhance, and manage a preserve system. Project-level HCPs are designed to fully offset the impacts associated with the permitted activity by contributing to a larger conservation design.

Being included as a covered species under an HCP can result in habitat being set aside and managed for the species as mitigation for impacts associated with covered activities, such as planned urban development, within the HCP permit area. In addition to mitigation, avoidance, minimization, and other conservation measures (e.g. monitoring, seasonal work windows, habitat management, etc.) are implemented. HCPs can also utilize banks, in-lieu fee programs, or other mechanisms to preserve habitat in perpetuity and contribute to a regional conservation strategy.

Currently, there are 13 current Habitat Conservation Plans (HCPs) that include the blunt-nosed leopard lizard as a covered species, and 1 HCP that is not currently valid, although this number includes some HCPs that are expired or pending an amendment (Table 7). Implications of being included as a covered species vary depending on the plan, but in general assures 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, and that measures will be implemented to avoid or minimize take of the covered species. Other conservation measures such as monitoring, seasonal work windows, and habitat creation and/or enhancement are often included. Habitat that is set aside is relative to the amount of permanent and temporary impacts of the project, and may be within the area the HCP covers or in adjacent habitat, as agreed upon and permitted by the Service. Specifics for each HCP are included within each agreement. More information about HCPs that include the blunt-nosed leopard lizard as a covered species can be found at: https://ecos.fws.gov/ecp0/profile/speciesProfile?spcode=C001, and additional information about the HCPs through 2010 is provided in an appendix in Service (2010, pp. 74-77).

Table 7. HCPs that include the blunt-nosed leopard lizard as a covered species

Plan Name	Stage	Permit Issued	Permit Term (Years)	Total Area Covered (acres)	Habitat Protection (acres)	Compensation Area Location	Authorized Impacts to BNLL Habitat (acres)
ARCO Coles Levee (ARCO Western Energy)	Not currently valid[1]	1996	30	120320	990	Coles Levee Ecosystem Preserve	270 (P)
California Dept. of Corrections Delano Prison	Implementing	1990	50	635	384/514	On-site/ Allensworth ER	287 (P); 348 (T)
California Dept. of Corrections Statewide Electrified Fence Project	Implementing	2002	50	2937	282/800	Allensworth ER	Take of 2 individuals
Chevron Pipeline	Implementing	1996	50	25.5	28	Lokern Area	25.5 (T)
Coalinga Cogeneration	Expired, new HCP in planning stage	1991	20	50.12	179	On-site	49.6 (P); 27.6 (T)
EnviroCycle, Inc.	Implementing	1993	50	20			20 (P)
Granite Construction, Phase 1	Expired	1993	20	54	162	Semitropic Ridge ER	54 (P)
Kern County Waste Facilities (amendment in progress)	Implementing	1997	50	1500	755	Coles Levee Ecosystem Preserve and permittee responsible	251 (P)
Kern Water Bank	Implementing	1997	75	19900	4263	On-site	12081 (P); 291 (T)
Metropolitan Bakersfield	Expired, amendment in progress	1994	20	262000	3:1 compensation	Off-site	15200 (P)

Plan Name	Stage	Permit Issued	Permit Term (Years)	Total Area Covered (acres)	Habitat Protection (acres)	Compensation Area Location	Authorized Impacts to BNLL Habitat (acres)
PXP (formerly Nuevo-Torch)	Implementing	1999	30	21800	840	Lokern Area	850 (P)
PG&E San Joaquin Valley Operations & Maintenance HCP	Implementing	2007	30	276350	360	Future conservation easement	9 (P); 690 (T)
Seneca and Enron Oil and Gas	Implementing	1998	30	650			650 (P)
Wright Solar	Implementing	2015	40	5186	2449		1.2 (P); 1.9 (T)

[1]Permittee surrendered the permit prior to the expiration date

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.

The Service does not define minimum qualifications required to perform blunt-nosed leopard lizard visual surveys, but a standard protocol can be found at: https://www.fws.gov/sacramento/es/Permits/, where minimum qualifications and survey protocols for other listed species can also be found. The protocol was developed by the Central and South Coast Regions of the California Department of Fish and Wildlife (CDFW), with input from the Service, the Bureau of Land Management, and various species experts, and includes CDFW qualifications for surveyors. Monitoring data using this standard protocol (or previous versions thereof) has confirmed blunt-nosed leopard lizard presence at sites throughout the species range. Recently, Statham *et al*. (2019; entire) described the utility of scat detection dogs as a noninvasive sampling method to monitor blunt-nosed leopard lizards without direct contact (when combined with genetic analyses). However, the authors caution that additional work is needed before scat detection dogs can replace visual surveyors in a regulatory context.

Research performed by biologists with recovery permits has resulted in a number of reports and peer-reviewed papers used as sources throughout this document, and contributes to our knowledge of blunt-nosed leopard lizard ecology, habitat use, movements, and genetics.

Analysis of Current Condition

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 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. That being said, we do refer to "suitable habitat" when analyzing

current and future condition of the populations with regard to some categories (i.e., habitat size and connectivity; see below).

We analyzed the current condition of blunt-nosed leopard lizards at the population level, and also assessed population conditions relative to the genetic clusters (Richmond *et al*. 2017, pp. 3621-3625) to assess species representation. Currently extant populations in our analysis include: 17 populations identified in Richmond *et al*. (2017, p. 3622); five additional populations from CNDDB to more accurately assess the geographic spread of the species across the historical range; and two hybrid populations, for a total of 24 populations (Figure 14). One of the current populations from Richmond *et al*. (2017), the Comanche Point population on Tejon Ranch property, was not included in prior Service documents, but was found to have a sustained population in recent sampling (Westphal *in litt* 2019). Richmond *et al*. (2017, pp. 3621, 3625) sampled at six sites within the putative hybrid zone, which we have consolidated into two populations for analysis of condition with this area. The additional populations in our analysis that are not part of the genetic study (Richmond *et al*. 2017) are areas that have historically supported blunt-nosed leopard lizard populations but have not had CNDDB observations updated within the last 20 years (CNDDB 2019). We chose these populations based on CNDDB occurrences in relation to distance from the populations identified in Richmond *et al*. (2017) to more fully capture condition across the range of the species.

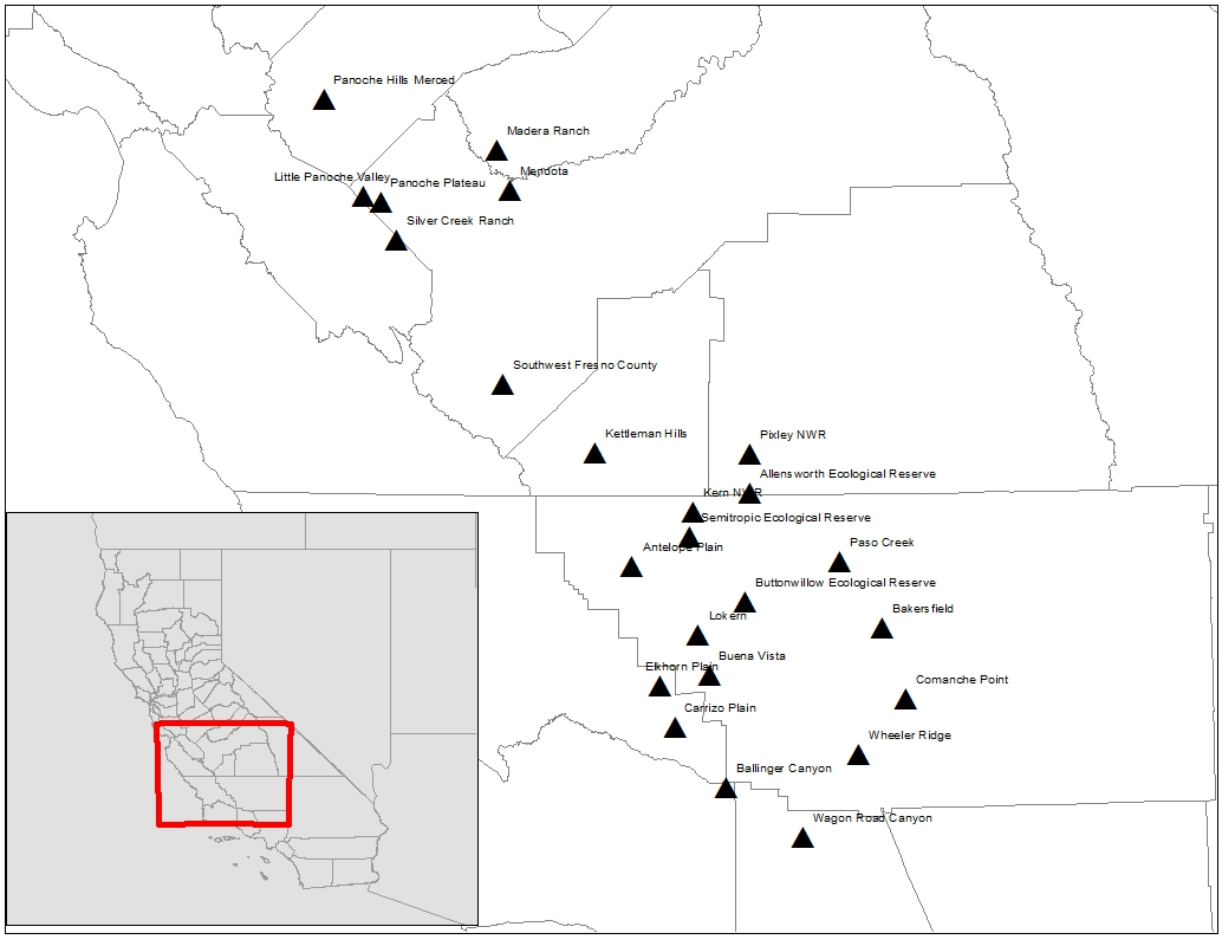


Figure 14. Blunt-nosed leopard lizards used in SSA analysis.

For a blunt-nosed leopard lizard population to be considered in high condition, it should have the needs listed in Chapter 3 of this SSA. At the individual and population levels, we identified habitat needs: large areas of contiguous habitat, burrows and patchy habitat (which are both components of thermal environment), and prey; and demographic needs: connectivity, survival, abundance, and fecundity (Figure 8 in Chapter 3). Although we originally sought to include all of these variables in our analysis of current condition, we omitted some factors after consultation with species experts and/or based on data availability. Although we do not include thermal environment explicitly in our analysis of current condition, we acknowledge that individuals would not survive in temperatures exceeding the critical thermal maximum. While experts agreed that burrows are necessary for blunt-nosed leopard lizards, there is not currently available data on the number of burrows that comprise high quality habitat at the population level. Further, evidence that blunt-nosed leopard lizards can dig their own burrows during the active season, for egg-laying, and for brumation makes it less practical to include this habitat component in a condition table. Similarly, although all experts agreed that sufficient numbers of prey are necessary to sustain hatchling, juvenile and adult blunt-nosed leopard lizards, we did not directly include this habitat component as a category in the analysis. This was because of the flexibility of the species to eat a wide variety of available prey, combined with a lack of information on

necessary (and available) prey abundances. Instead, prey abundance is indirectly included through the precipitation category. The demographic needs of survival and fecundity are not directly assessed because there is a lack of available data to assign categorical definitions or to quantify these measures for the different populations. However, both of these demographic needs are indirectly assessed through habitat parameters in the table. Survival is related to habitat components, particularly patchy habitat, while fecundity is addressed through our inclusion of precipitation in the table, because drought years are associated with low reproductive success. Therefore, our analysis of condition included condition assessments for the following habitat and demographic categories: habitat size, patchiness, precipitation, effective population size, and connectivity. We use quantitative or qualitative assessments to classify habitat and demographic categories into high, moderate, and low conditions in a Condition Category Table (Table 9). 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 5 of this document).

Habitat size quantifies the population need for large areas of contiguous habitat. We define a high quality habitat patch as having at least 500 hectares (1236 acres) of contiguous suitable habitat, because patches of at least this size had a 91% probability of occurrence of blunt-nosed leopard lizards (Bailey and Germano 2015, p. 25). We defined moderate habitat as those patches with at least 238 hectares (588 acres) of suitable habitat because this was the minimum occupied patch in Bailey and Germano 2015 (p. 25), and patches smaller than this were defined as low quality. We emphasize that smaller habitat patches still have the possibility of being occupied by blunt-nosed leopard lizards. We specify that this habitat needs to be suitable for the species (as assessed more directly in other categories and described in *Habitat* above) to facilitate movement within and between sites. To assess population condition in relation to habitat size, we compared population locations with modeled habitat suitability (Stewart *et al*. 2019, p. 7), assessing the amount of suitable habitat that intersected a 500 hectare polygon around points for each of our populations. We also calibrated these assessments through discussions with species experts. For example, although the habitat suitability model shows greater than 500 ha of suitable habitat near the Bakersfield population, we assigned this population “low” for the habitat size category because of comments about habitat in Westphal *in lit.* 2019.

We used the percentage of bare ground as a simplified way to assess the need for patchy habitat. Patchy habitat was identified as important for thermal regulation, and both low and high levels of bare ground are correlated with threats to the species. In particular, non-native annual grasses can threaten survival of blunt-nosed leopard lizards because they are less able to move to escape predators. Conversely, too much bare ground can also make individuals vulnerable to predation. Including a patchy habitat category in the table indirectly assesses the threat of above-average precipitation because of the relationship between rainfall and grass cover, and relates to the demographic need of survival. To categorize patchy habitat for each population, we used a raster file with “Peak growing season bare ground cover estimated over five annual growing seasons” from a NASA Web-Enabled Landsat Data (WELD) 5-Year Land Cover Land Use Change dataset (Hansen *et al*. 2015). We created 500-hectare polygons in ArcMap that we centered on each of the populations in our analysis, and averaged the bare ground percentage over each of the

polygons. High condition was categorized as 15 to 30 percent bare ground (Chesemore 1980, p. 23), which we assumed to be scattered throughout the 500-hectare area. We assumed that areas with very little bare ground or excessive bare ground would provide low condition habitat for the species. Although shrub cover is not directly assessed though our analysis of patchy habitat, we acknowledge that shrubs would be part of a preferred vegetation community interspersed with the designated bare ground percentages.

We also included precipitation as a habitat factor that can influence blunt-nosed leopard lizard population condition. Specifically, we extracted winter precipitation from PRISM interpolated weather surfaces (4-km resolution) from October through April (similar to Westphal *et al*. 2016, p. 3) for each of the past 30 years (1998-2018). We considered excluding years within the current decade because the recent drought was especially severe (Griffin and Anchukaitis 2014, pp. 9018-9020). However, we decided to include those years in our analysis because evidence of limited reproduction in the majority of populations in at least one year of this drought (Westphal *et al*. 2016, pp. 3-5) was likely pivotal in leading to the current condition of those populations. Likewise, evidence of reproduction in some populations during drought demonstrates the importance of maintaining resilient populations in these areas (as well as habitat connecting these populations to other areas). We centered our winter precipitation analysis on waypoints for populations provided in Richmond *et al*. 2017 (p. 3622) or CNDDB. To assess the current condition in relation to winter precipitation, we quantified the number of years with at least 92 mm of winter rain. The number of drought years was significantly correlated with mean winter precipitation (Table 8; Figure 15), but we chose to focus on drought years because of documented link between droughts and reproduction. Drought years are associated with decreased reproduction (Germano *et al.* 1994, pp. 13-15; Germano and Williams 2005, p. 5), which may relate to a decrease in prey abundance (Germano *et al*. 1994, pp. 15-16) or to other habitat changes (Westphal *et al*. 2016, p. 6). Although excess precipitation is also considered a threat to blunt-nosed leopard lizard populations because it can reduce survival, we did not attempt to categorize precipitation based on years that were above average. Modeling demonstrated high precipitation, and associated vegetation biomass, to be the most limiting environmental variables for the species (Stewart *et al*. 2019, p. 8); for the most part this analysis demonstrated the association between the species and the San Joaquin Valley rather than categorizing habitat quality within the species' range. Further, ongoing population viability analyses focus on the relationship between precipitation and fecundity, but use data collected mainly from one locality (Tennant *et al*. 2018, p. 59). A range-wide understanding of how the species responds to high precipitation and at what levels would be a valuable addition to the condition category table.

Table 8. Estimated regression parameters, standard errors, z*-values and* P*-values for the Poisson GLMM comparing mean winter precipitation and number of drought years.*

	Estimate	Standard Error	z value	P-value
Intercept	6.29	0.74	8.55	<0.001
Mean Winter Precipitation	-0.03	0.00	-6.62	<0001

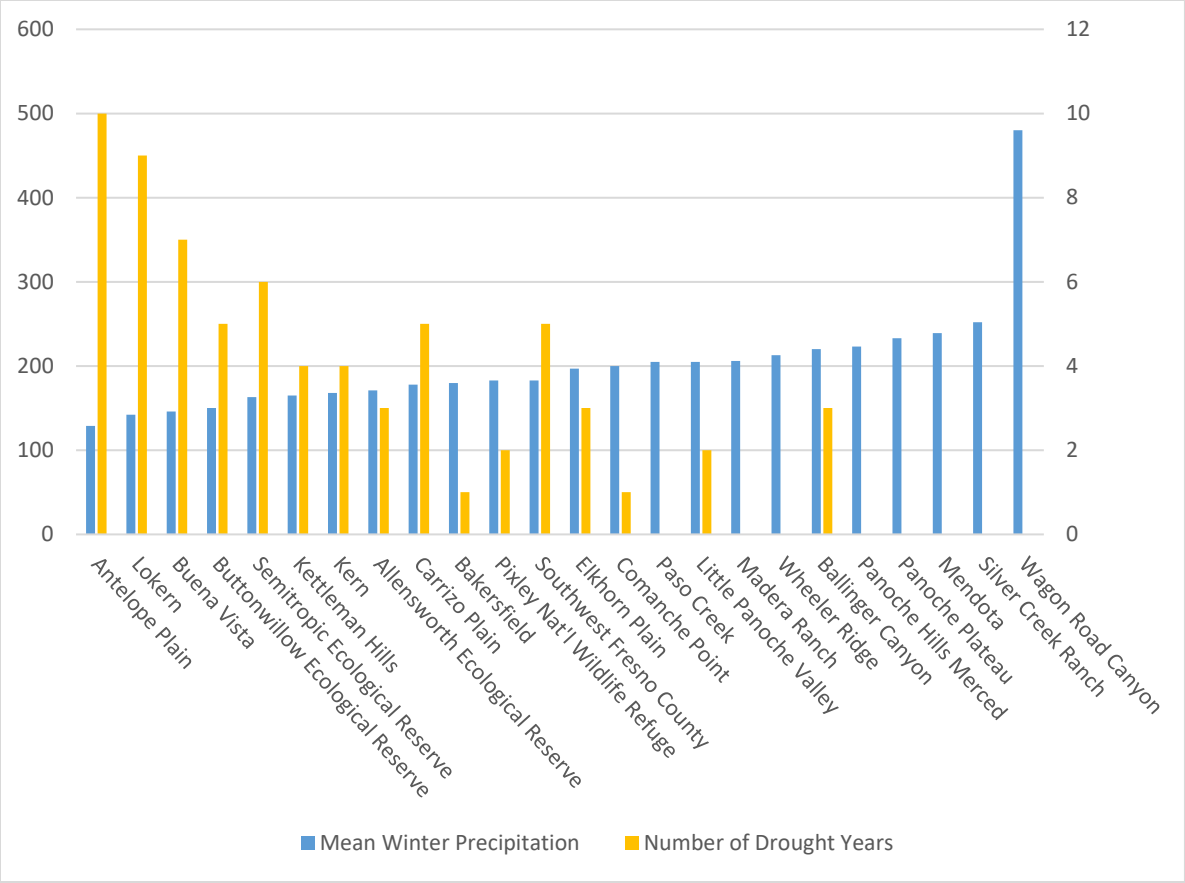


Figure 15. Mean winter precipitation from 1988 through 2018 and the number of drought years (defined as years with less than 92 mm winter precipitation) at locations centered on blunt-nosed leopard lizard population analysis units.

We chose 92 mm as a cutoff to reference drought years because this number was highlighted in Stewart *et al*. 2019 (SOM). To categorize precipitation in relation to drought years, we compared the number of drought years from our analysis to hatchling survey data in Westphal *et al*. (2016, p. 4). All surveyed populations that had neonates detected in 2014 had two or fewer drought years in the last 30-year period, thus we categorized at least 28 of the last 30 years with at least 92 mm of rain as high condition. We assumed that populations with that amount of rainfall in at least 25 of the last 30 years were in moderate condition, while populations with more drought years than that were assumed to be in low condition. We acknowledge that the assumptions that went into categorization of condition related to precipitation averages do not take into consideration timing of rain, population-specific changes in habitat in relation to rainfall, variation across the range, or other more or less nuanced responses. Indeed, in some years and populations, demographics may actually be better than in a non-drought year because of changes to other habitat features.

The demographic needs of the species are presented in two categories in our analysis of current condition: effective population size and connectivity. Frankham *et al*. (2014, entire) recommends that populations expected to persist for at least 5 generations or to retain evolutionary potential into perpetuity have at least 100 or 1000 individuals, respectively. However, we modified these numbers based on discussion with species experts and based on our analysis units, giving us

cutoffs of 50 and 250 for moderate and high condition. Lastly, connectivity is represented in the category table based on potential connectivity to other populations or to large areas of land that could have blunt-nosed leopard lizards. The potential for stochastic variation in population size necessitates that populations be connected to other occupied areas or to environmentally diverse habitats to maintain resiliency. Corridors between populations can facilitate gene flow, which is an important element related to both representation and resiliency. We defined a population to have high connectivity if the population is connected to at least one other population. Populations on at least 2,428 hectares were categorized as having moderate connectivity, even if they were not connected to other populations, because this habitat size was identified as an important target in the Recovery Plan (Service 1998, p. 182). We assumed that populations with access to large areas of suitable habitat would have occupancy in environmentally diverse areas. We defined isolated populations as having low connectivity. This category takes into account multiple threats to the species, including fragmentation and development. In general, we assumed that suitable habitat within the range of the species that have recent observations were contiguously occupied, although a range-wide survey would be necessary to validate this assumption and is beyond the scope of this analysis. As with habitat size, we assessed connectivity by comparing population locations with modeled habitat suitability (Stewart *et al*. 2019, p. 7), and calibrated these assessments through discussions with species experts. For example, although Wheeler Ridge is connected to other populations through suitable habitat, we modified the category condition to low because of descriptions of the surrounding habitat in Westphal (*in litt* 2019).

The criteria presented in our condition category table (Table 9) were used to determine the overall current condition of each blunt-nosed leopard lizard population (Table 10). The habitat and demographic factors (habitat size, patchy habitat, winter precipitation, effective population size, and connectivity) included in Table 9 were not weighted equally in this analysis. Specifically, in our literature review and in discussions with species' experts, we decided that habitat size was the most important habitat factor affecting resiliency. Habitat size takes into account the most pressing current threat to the species, habitat destruction and modification. Moreover, available habitat can change in predictable ways and be useful in estimating future conditions (see *Chapter 5. Future Condition*). We therefore weighted habitat size as being equally as important as the other two habitat categories combined.

Relative weights were assigned to each factor to maintain these relationships: 2x for habitat size, and 1x for all other categories. Each analysis unit was given a 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, assuming that the population was in low condition for that category. We next translated the overall condition score into an overall current condition category of low, moderate, or high. A complex with all low, all moderate, or all high ratings for the factors would have overall conditions scores of 6, 12, or 18, respectively. We took the difference between the lowest and highest possible overall condition scores and divided this into three equal intervals representing the breadth of possible scores. A score of 10 or less means the complex is in overall

low condition, a score greater than 14 means the complex is in overall high condition, and scores between 10 and 14 mean that the complex is in moderate condition. To be conservative, we rounded down, such that if a population had a score of 14 or 10, they were given a condition or moderate or low, respectively. For the five populations not included in the genetic study but included in our analysis based on CNDDB occurrences, we assigned the overall condition as low even if the analysis gave a score that would fall into a higher condition.

Table 9. Habitat and demographic factors used to assess blunt-nosed leopard lizard population resiliency. Habitat Size and Effective Population Size were both given double weight relative to other categories when analyzing overall population condition.

Condition	Habitat size	Patchy habitat	Precipitation	Effective population size (N_e)	Connectivity
High	500 ha (1236 acres) or more of protected contiguous suitable habitat	15 to 30 percent bare ground in scattered areas	At least 28 years have greater than 92 mm of winter rain in the last 30 years	N_e > 250 adults	Population is connected to at least one other population through contiguously suitable habitat
Moderate	238 ha (588 acres) to 500 ha (1236 acres) of protected suitable habitat	5 to 15 percent or 30 to 40 percent bare ground in scattered areas	At least 25 years have greater than 92 mm of winter rain in the last 30 years	50< N_e < 250 adults	Population is located within 2,428 hectares (5,997 acres) or greater of contiguously suitable habitat
Low	Protected suitable habitat less than 238 hectares (588 ha)	Limited patchy habitat	24 or less years have greater than 92 mm of winter rain in the last 20 years	N_e < 50 adults	Population is isolated

Current Condition Uncertainty

As discussed above, we did not include all habitat and demographic needs in our condition category table. Although it appears that blunt-nosed leopard lizards are capable of digging their own burrows at sites with low mammal density, it is unclear if the species can dig burrows that are deep enough to maintain optimal thermal environments in the future. Burrow requirements and availability is a topic that may warrant additional research.

Also as discussed above in our analysis of current condition, we had to make a number of assumptions, both in defining condition categories and in assessing condition relative to these categories. The sample size in Bailey and Germano (2016) is limited, but was the best available information to categorize habitat size conditions for the species. Re-analysis using additional populations may yield different results that could change both the categories and condition for this factor. We also made general assumptions that habitat classified as suitable was occupied, although this would need to be verified using range-wide surveys. This led to assumptions in both the habitat size and connectivity categories. Because we used the habitat suitability model from Stewart *et al*. (2019) that did not show suitable habitat below Ballinger Canyon, we were

unable to assess the amount of suitable habitat in this region and left it as unknown for this analysis. Although there are several papers demonstrating the relationship between drought and reproduction in blunt-nosed leopard lizards, we again had to make assumptions when defining the conditions in the precipitation category. Blunt-nosed leopard lizard responses to rainfall may vary across the landscape, but because we lack data on how this potential variation may play out across the range, we assume uniform response to drought. It is likely that populations may respond differently to individual drought years based on combinations of other factors including vegetation. For example, Pixley NWR was one of the populations with neonates in Westphal *et al*. 2016 that helped make the case for our cut-off of two or fewer droughts to describe high condition, but 2014 (the survey year from that paper) was a drought year (<92 mm winter rain, as defined in the SSA) at Pixley, indicating that it is clearly not a 1-to-1 link between drought and reproduction in a given year. However, without information regarding reproduction and the interaction between precipitation, RDM, and vegetation across the past 30 years for most sites, we think that using precipitation data as described makes the most sense for our analysis. Regarding effective population size, we did not attempt to categorize this factor for populations that lack genetic data. For these populations, we left the effective population size condition as unknown.

Our condition analyses (current condition, this chapter, and future condition in Chapter 5) attempts to identify the condition of populations in the context of the threats affecting their viability. The following is a brief crosswalk examining the relationship between the threats to the blunt-nosed leopard lizard and categories used to assess current condition. The threat of habitat modification and destruction (including agriculture and various types of development) is assessed using the habitat size and connectivity categories. Although a precipitation category could in theory assess the threats of both above- and below-average precipitation, we lack quantitative information on the upper thresholds of rainfall that threaten the species, so instead we assess these two extremes in precipitation separately. Below-average precipitation is assessed using the winter precipitation category, which attempts to quantify the number of drought years experienced by a population. The patchy habitat category assesses the threat of above-average precipitation (which reduces bare ground) as well as the threat of habitat modification by non-native plants. Although we also consider pesticide use to be a threat that may rise to a population-level threat, we do not carry this threat forward in the analysis because of uncertainty about its magnitude. Additional information about this threat could make it relevant to include more directly in our analysis in the future.

Current Condition

Of the 24 populations that we analyzed for current condition, 5 are in high condition, 10 are in moderate condition, and 9 are in low condition (Table 10). These populations are distributed throughout the genetic clusters identified in Richmond *et al*. (2017) (Figure 16). Both the "northern" and "southwestern" clusters have 2 populations in high condition as well as at least 2 additional populations. The "southern" cluster within the hybrid zone of the species has populations in low and moderate condition, although there is more uncertainty regarding these populations and habitat in this area. The "Valley floor" and "southeastern" clusters both have populations in low and moderate condition, although the "Valley floor" cluster contains three

times as many populations. We did not attempt to assign the Madera, Mendota, Bakersfield, or Paso Creek populations within genetic clusters. Uncertainties or ambiguities in the genetic analysis led Madera and Bakersfield to have greater affinity to genetic clusters that were further from them spatially or varied based on genetic data type (Richmond *et al*. 2017, p. 3624), and Mendota and Paso Creek individuals were not part of the genetic analysis.

The distribution of populations throughout the species historical range, including high condition populations at both the north and southern edges of the range, indicate that the species exhibits redundancy. Similarly, the distribution of populations throughout genetic clusters infers that the species currently exhibits representation and may have the ability to adapt to changing environmental and biological conditions.

Table 10. Current condition table rating blunt-nosed leopard lizard populations as high, moderate, or low in habitat and demographic categories. The overall ranking is a measure of the current resiliency of the populations.

Population unit	Habitat size[1]	Patchy habitat[2]	Precipitation[3]	Effective population size (N_e)[4]	Connectivity[1]	Overall[5]
Panoche Hills Merced	High	High	High	Unknown	Low	Low
Madera Ranch	High	Moderate	High	Unknown	Low	Moderate
Mendota	High	High	High	Unknown	High	Low
Little Panoche Valley	High	Moderate	High	Unknown	Moderate	Moderate
Panoche Plateau	Low	Moderate	High	Moderate	Low	Low
Silver Creek Ranch	High	Moderate	High	Moderate	Moderate	High
Southwest Fresno County	Low	Moderate	Moderate	Unknown	Low	Low
Kettleman Hills	High	High	Moderate	Moderate	Moderate	High
Pixley National Wildlife Refuge	High	High	High	Unknown	Moderate	High
Allensworth Ecological Reserve	Low	Low	Moderate	Unknown	Low	Low
Kern National Wildlife Refuge	High	High	Moderate	Unknown	Moderate	Low
Semitropic Ecological Reserve	High	Moderate	Low	Moderate	Moderate	Moderate
Antelope Plain	High	Moderate	Low	Unknown	High	Moderate
Paso Creek	High	Moderate	High	Unknown	High	Low
Buttonwillow Ecological Reserve	High	Moderate	Moderate	Unknown	Low	Moderate
Bakersfield	Low	Moderate	High	Unknown	Low	Low
Lokern	High	Low	Low	Moderate	High	Moderate
Buena Vista	High	Low	Low	Moderate	High	Moderate
Elkhorn Plain	High	Moderate	Moderate	Moderate	High	High
Carrizo Plain	High	Moderate	Moderate	Moderate	High	High
Comanche Point	High	Moderate	High	Low	Moderate	Moderate
Wheeler Ridge	High	Moderate	High	Unknown	Low	Moderate
Ballinger Canyon	High	Moderate	Moderate	Unknown	Moderate	Moderate
Wagon Road Canyon	Unknown	Moderate	High	Unknown	Unknown	Low

[1]Data from Stewart *et al*. 2019 habitat suitability model.

[2]Bare ground data from NASA WELD dataset.

[3]Data from Prism Climate Group 2019

[4]Data from Richmond in litt. 2019. Populations marked as unknown do not have estimated effective population sizes.

[5]Populations without recent observations were given an overall condition of low independent of scoring across categories.

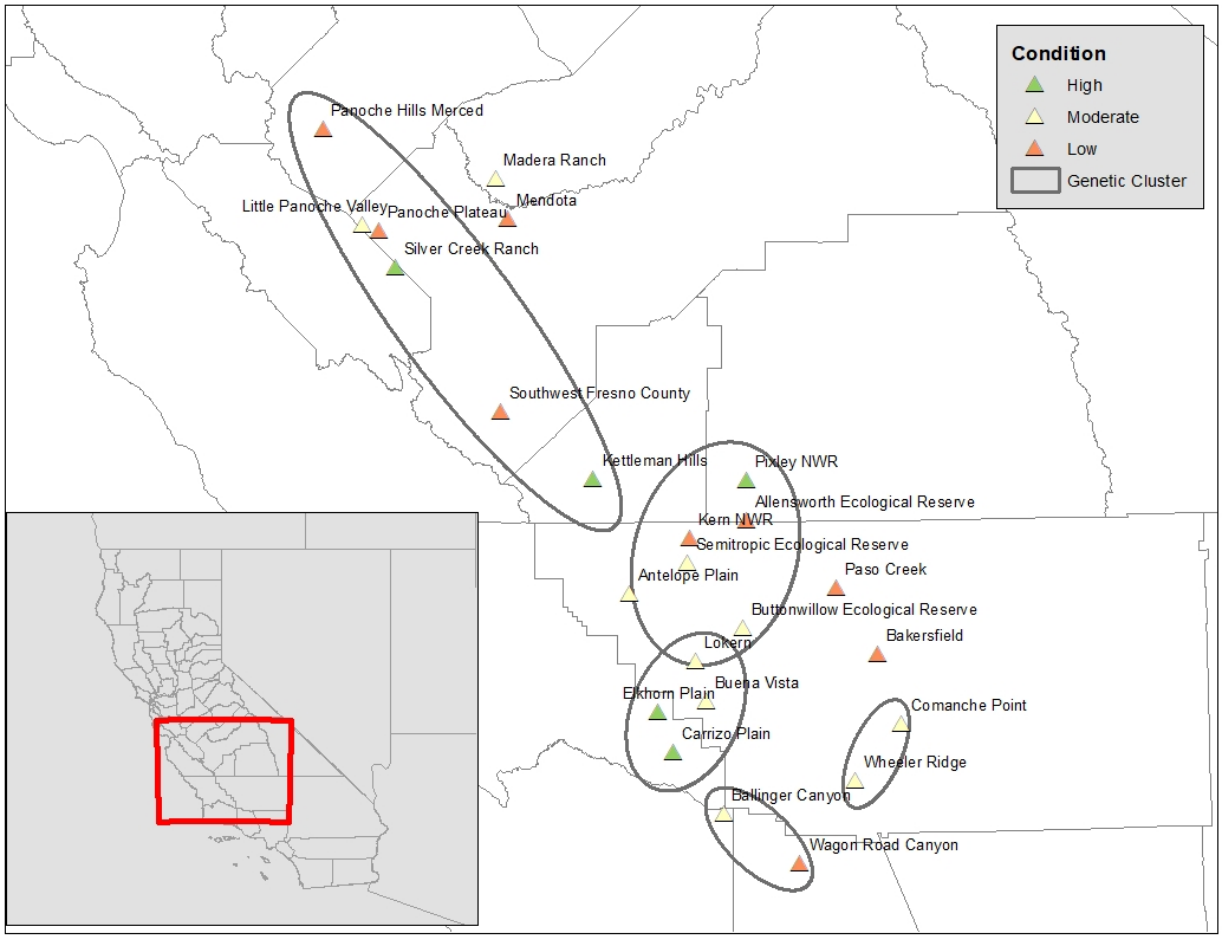


Figure 16. Current condition of blunt-nosed leopard lizard populations, loosely grouped into genetic clusters.

Current Condition Relative to Recovery Criteria

The Recovery Plan has downlisting and delisting criteria related to three main components: population density, protected habitat, and habitat management plans. These factors are discussed briefly below; criteria are partially met for the species.

Population Density

The Recovery Plan calls for a mean density of two or more lizards per hectare (one per acre) across large areas of contiguous occupied habitat throughout one precipitation cycle (period when annual rainfall includes average to 35 percent above-average through greater than 35 percent below average and back to average or greater) (Service 1998, p. 182). This number was derived based on the assumption that metapopulations would be potentially viable with populations of 5,000 or more individuals during average years (Service 1998, p. 193). Based on currently available data, population densities are generally lower than this average, even in areas subjectively located based on habitat quality. Therefore, this criterion is not met.

Occupied Protected Habitat

For downlisting, the Recovery Plan calls for protection of five or more areas, each about 5,997 acres or more of contiguous, occupied habitat, including one each on: Valley floor in Merced or Madera Counties; Valley floor in Tulare or Kern Counties; Foothills of the Ciervo-Panoche Natural Area; Foothills of western Kern County; and Foothills of the Carrizo Plain Natural Area. For delisting, the same amount of protection is called for in three additional areas: one on the Valley floor; one along the western Valley edge in Kings or Fresno Counties; and one in the Upper Cuyama Valley of eastern San Luis Obispo and eastern Santa Barbara Counties.

This criterion is partially met. Protected occupied habitat of sufficient size occurs in: the Foothills of the Ciervo-Panoche Natural Area (BLM lands), the Valley floor in Kern County (Semitropic Ecological Reserve), the Foothills of the Carrizo Plain Natural Area (Carrizo Plain National Monument), the western Valley edge in Fresno County (the Panoche Valley Preserve, managed by the Center for Natural Lands Management), and in the Upper Cuyama Valley (Los Padres National Forest lands). To our knowledge, there is not protection of contiguous, occupied habitat of the required size on the Valley floor in Merced or Madera Counties, the Foothills of western Kern County, or an additional area of the Valley floor. Smaller parcels of protected lands within these areas exist in a mosaic across the landscape. Additional land protections are discussed in more detail in the most recent Status Review (Service 2010 pp. 5-6) and shown in Figure 13.

Management Plans

The Recovery Plan calls for a management plan that has been approved and implemented for all protected areas identified as important to the continued survival of blunt-nosed leopard lizard. Management plans should include survival of the species as an objective and range-wide population monitoring. This downlisting criterion for the approval and implementation of management plans in all protected areas is partly achieved, with approved and implemented management plans in some but not all areas.

To date, we are aware of management plans for: Kern National Wildlife Refuge (NWR); Pixley NWR; the Center for Natural Lands Management (CNLM) lands at Semitropic Ridge Preserve; the CNLM, Plains Exploration & Production Company (PXP), and Bureau of Land Management (BLM) lands in the Lokern Natural Area; the Oxy conservation lands near Elk Hills; the BLM, The Nature Conservancy, and California Department of Fish and Wildlife (CDFW) lands of the Carrizo Plain National Monument; the Coles Levee Ecological Preserve; and Kern Water Bank Conservation Lands (Service 2010, p. 6). The management plan for the Ciervo-Panoche Natural Management Area is currently in draft form (Westphal pers. comm. 2019), as are management plans for CDFW Ecological Reserves (Tennant *in litt*. 2019). Other areas that have blunt-nosed leopard lizard management and monitoring tasks in their management plans include the CNLM Panoche Preserve, and several mitigation parcels related to the high-speed rail (Alkali Flats, CD Hillman, and Poso Plains) (Hacker *in litt*. 2019).

Chapter 5. Future Condition

In this chapter, we predict the future viability of the 24 blunt-nosed leopard lizard populations under three plausible scenarios. These scenarios consider different combinations of climate change impacts, land use change, and conservation efforts. This analysis will help us predict how viability of the blunt-nosed leopard lizard may change in the future.

Factors Influencing Viability

In this section, we discuss factors that may influence blunt-nosed leopard lizard viability in the future. All factors influencing viability discussed above are still applicable to future condition of the species, but have not been expanded on except when interactions are expected, which are then discussed in the context of emerging threat, or when trends or models can predict changes to these factors. We have updated our influence diagram to reflect these additional threats and the way in which we expect them to interact with ongoing threats and needs (Figure 17).

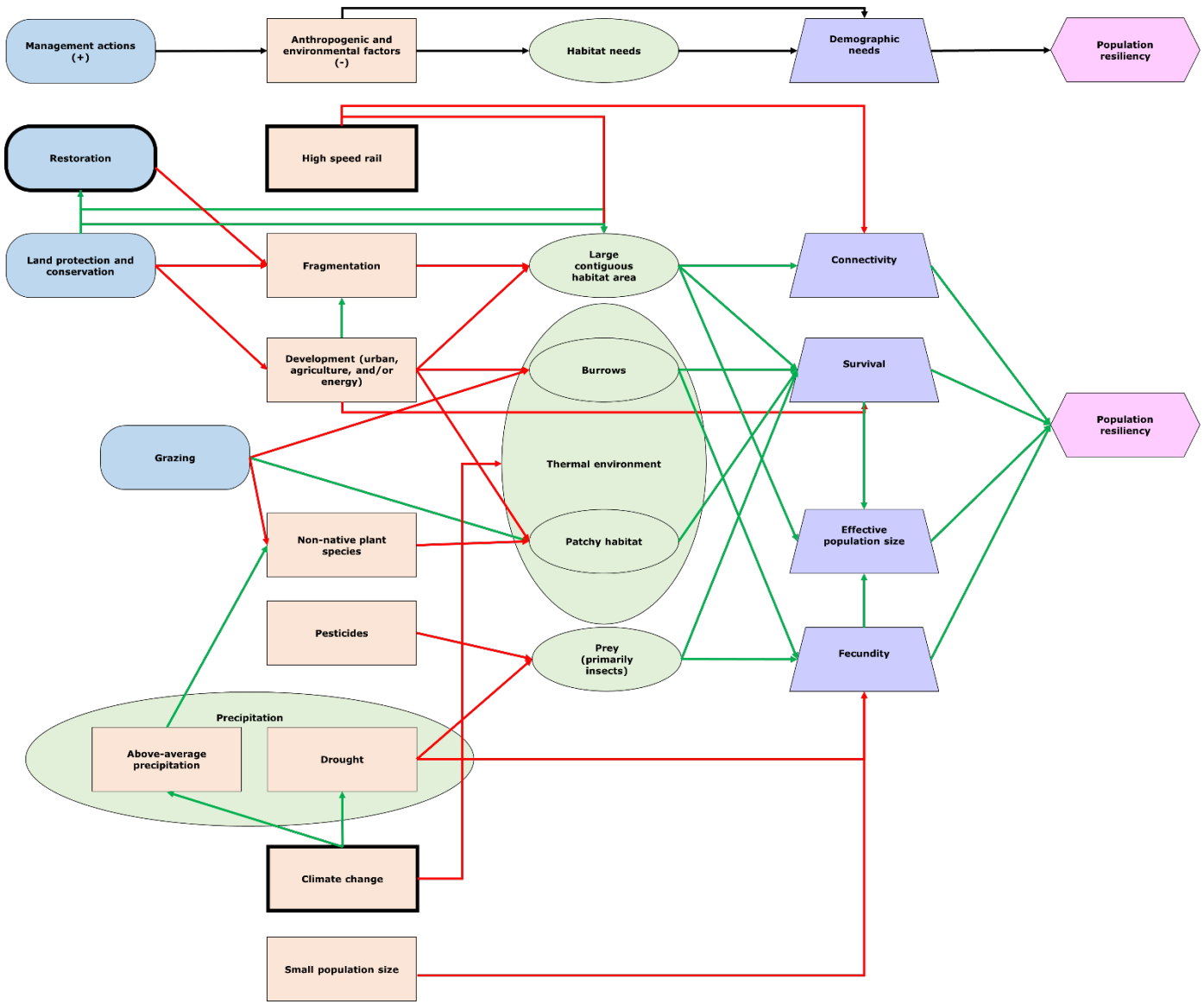


Figure 17. Influence diagram with additional future threats (climate change and the high-speed rail) and management (restoration) highlighted in bold and incorporated into the existing conceptual model. Green lines represent positive relationships, and red lines represent negative relationships.

Climate Change

There is consensus that the increase in greenhouse gas (GHG) emissions during the 20th century 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, pp 2-3). Climate change may affect blunt-nosed leopard lizard populations through changes in temperature and precipitation, with associated changes to plant productivity, vegetative communities, and prey base for the species. Climate change is also associated with increased risk of catastrophic events including flooding and wildfires.

Climate models for California under various emissions scenarios predict an overall warming of 1.7 to 5.8 degrees Celsius (3.0 to 10.4 degrees Fahrenheit) from 2000 to 2100 (Cayan *et al.* 2008, p. 7). These changes in temperature can influence blunt-nosed leopard lizard aboveground activity because it is dependent upon temperature (see *Activity* above). Aboveground activity is critical for blunt-nosed leopard lizard reproduction and foraging, and thus, increases in temperature can narrow the windows available for the species to perform these activities. Telemetry studies demonstrate that blunt-nosed leopard lizards can retreat to shade to lower their temperatures rather than going belowground, which may allow them to continue foraging and/or mating (Germano 2019, p. 436; Ivey *et al*. 2020, p. 5). Ivey *et al*. (2020, pp. 6-7) predicts an increase in the number of hours that the species will be restricted to burrows or shade with a temperature increase of 2 degrees Celsius. Ivey *et al*. (2020, pp. 4-6) also modeled thermal environment for blunt-nosed leopard lizards with expected temperature increases. Assuming similar increases across microhabitats, including burrows, the study predicts that burrows may exceed preferred body temperatures for part of the day with predicted warming. The study acknowledges that unilateral increases across microhabitats are unlikely. However, potential for temperature increases to impact burrow suitability of burrows that are 1 m below ground (as in Ivey *et al*. 2020) raises a question about the future suitability of self-made lizard burrows, which may be substantially shallower than mammal burrows.

Using extinction models based on eco-physiology, Sinervo *et al*. (2017, pp. 10, 18) predicted local extirpations in lower elevation sites by 2070, with climate refugia in higher elevation sites including the Carrizo Plain and Panoche region. Rather than exceeding critical thermal maximums, the models predicted extinction from sites based on hours of restricted activity (calculated by using daily maximum air temperature and blunt-nosed leopard body temperatures). Although Sinervo *et al*. (2010, entire; 2017, entire) discusses climate change and altered thermal niches leading to lizard extinctions, Germano (2019, pp. 438-439) argues that the flexibility exhibited by this species and others may allow the species to behaviorally cope with increased temperatures predicted from climate change. Populations of the congeneric long-nosed leopard lizard experience hotter active season temperatures (Germano pers. comm. 2019; Stewart *et al*. 2019, SOM), raising the possibility that blunt-nosed leopard lizards may be able to adapt to hotter environments. Behavioral flexibility could include shifts in daily activity to earlier in the day, or shifts into suitable microhabitats.

Climate change is also associated with changes in precipitation. Precipitation extremes are expected to increase, as evidenced by a prediction for higher frequency of both extremely wet

and extremely dry years (Swain *et al.* 2018, pp. 427-433). Precipitation extremes are expected to reduce the resiliency of blunt-nosed leopard lizard populations, as discussed in *Above- or Below-Average Precipitation* above. Specifically, blunt-nosed leopard lizard survival is expected to decrease in wet years, and reproduction is expected to decrease in dry years. Extremely wet years could see an increase in flooding events. Floods can be catastrophic for blunt-nosed leopard lizard populations in extremely flat areas because it can inundate burrows while the species are in brumation. With regard to extremely dry years, the occurrence of drought years has been higher in the past two decades than the preceding century, and the co-occurring warm and dry conditions that correlate with drought are expected to continue (Diffenbaugh *et al.* 2015, pp. 3932-3933). Although not all projections point to an increase in the number of droughts, increases in temperature can increase the rate of drying which may cause future droughts to be more intense when they do occur (Trenberth *et al.* 2014, p. 17). Smaller habitat patches and smaller populations may be more at risk from long-term droughts (Westphal *et al*. 2016, p. 6), because decreases in reproduction or abundance could have severe consequences on the population. Within-patch heterogeneity or between-patch connectivity will be important to mitigate these population declines. Changes to climate are also associated with an increased risk of wildfires, including both large fire occurrence and total area burned (Westerling *et al.* 2011, p. S2457). Large-scale fires have the potential to be catastrophic to blunt-nosed leopard lizard populations.

Additionally, climate change will likely result in changes in the vegetative and prey communities within blunt-nosed leopard lizard habitat. Increased vegetative growth in wet years could lead to less suitable habitat for blunt-nosed leopard lizards, particularly in areas without vegetation management such as grazing. Other ramifications of climate-related changes to vegetative and prey community changes are as yet unclear.

Small population size

Although genetic studies suggest that the blunt-nosed leopard lizard genome still represents the pre-converted landscape (Richmond *et al*. 2017, p. 3628), low population abundances in small or fragmented habitat patches have the potential to lead to inbreeding depression and loss of genetic diversity. Both of these genetic factors can contribute to extinction risk (reviewed in Frankham 2005, entire). Small populations can have lower fecundity because of difficulty in finding mates. Populations in highly fragmented habitat, with small areas of suitable habitat, or that lack connectivity to larger source populations are particularly vulnerable. For example, isolated populations on small areas of protected land may be at risk of small population size. Populations at Allensworth Ecological Reserve and Buttonwillow Ecological Reserve consistently have detections of blunt-nosed leopard lizards in opportunistic surveys, but populations are notably lower than at other sites (Tennant *et al*. 2018, pp. 2, 30).

Habitat Modification and Destruction

Habitat modification and destruction via land use changes (*e.g.*, agricultural development, energy development, and housing) are all expected to continue in blunt-nosed leopard habitat, and are most likely to affect unprotected habitat on privately held lands. Although agricultural

development is expected to continue, models generally predict an increase in fallowed croplands (see *Restoration* below).

Solar photovoltaic development is a key renewable energy source that is expected to contribute to California's commitment to meet half of the state's energy demand by renewable resources by 2030 (de León 2015, p. 93). Phillips and Cypher (2015, pp. 15-16) identified approximately 4,145 km^2 (1,601 mi^2) of habitat with moderate to high potential for both solar energy development and listed species, including the blunt-nosed leopard lizard. Instead, they recommend siting solar facilities in areas with low habitat value for listed species but high potential for solar projects, identifying 8,436 km^2 (3,257 mi^2) in the southern San Joaquin Valley, especially in western Fresno County, southern Kings County, and southern Kern County. Pearce *et al*. (2016, entire) summarizes a process for identifying least-conflict lands for solar development.

Habitat modification and destruction via housing or commercial development is expected to continue in the future. As the population in the San Joaquin Valley increases, housing/commercial development continues to threaten blunt-nosed leopard lizard habitat, albeit at a lower level than the threat posed by other types of development. The total number of households in the San Joaquin Valley is projected to increase by just over 1 percent per year from 2010 to 2050, with the highest annual growth rates in Merced and Madera Counties (The Planning Center 2012, pp. 13-14). The population is projected to increase on average by an annual rate of 1.27 percent, increasing from approximately 4 million people in 2010 to over 6.5 million in 2050, with the highest expected increase in Merced County and the lowest increases predicted for Tulare and Fresno Counties (The Planning Center 2012, pp. 17-18). Direct or indirect impacts to the species due to energy or development projects is expected to largely be offset through mitigation or other measures.

Restoration

Agricultural development will be influenced by changes to the climate, with crop conversion, continued farming, or retirement depending on water availability. Retirement of agricultural lands across the San Joaquin Valley may be as great as 500,000 acres (over 202,000 hectares) by 2040 if retirement is used as the sole strategy to meet recent groundwater regulations (i.e., the Strategic Groundwater Management Act of 2014) (Hanak *et al.* 2017, p. 29). Strategic restoration of retired agricultural land has the potential to aid in recovery of endangered species including the blunt-nosed leopard lizard (discussed in Lortie *et al.* 2018, entire). Stewart *et al*. (2019) identified areas that would be suitable for restoration by overlaying previously suitable blunt-nosed lizard habitat with fallowed (not in agricultural production) agricultural lands. This analysis highlighted over 1,000 km^2 of potentially fallowed farmland located on previously suitable blunt-nosed lizard habitat that the authors recommend for habitat restoration and reintroduction. Further, their analysis highlighted areas that were adjacent to existing suitable habitat and could be restored to contribute to large contiguous areas, of which over 600 km^2 of potentially fallowed farmland were identified (Stewart *et al*. 2019, p. 5-10). Strategic restoration focuses on the restoration of retired lands adjacent to existing natural areas to create a network of protected lands (Kelsey *et al*. 2018). The Land Retirement Demonstration Project included a

Habitat Restoration Study to experimentally investigate the efficacy of restoration techniques on vegetation and wildlife, which is detailed in Uptain *et al*. (2005, pp. 107-175) and Laymon *et al*. (2010, entire). It is unknown how long it would take for fallowed farmlands to return to suitable condition for blunt-nosed leopard lizards without active restoration. Translocation may be necessary to counteract population declines or to reintroduce the species into restored areas that are not adjacent to occupied habitat (Service 2010, p. 45; Westphal *in litt.* 2019).

High-speed Rail

The high-speed rail (HSR) is a publicly funded rail system currently under construction. Currently, the HSR is projected to route between Merced and Bakersfield. The project originally included extensions to San Francisco and Los Angeles, but these were indefinitely postponed due to costs and timing. Although we include a discussion of the HSR here to highlight it as a future threat to the species, the threat is likely limited to the population level, and could result in reduced connectivity for select populations.

The HSR is currently projected to cross between some State-managed Ecological Reserves (ER) that have extant blunt-nosed leopard lizard populations (Figure 18). The proposed footprint of the HSR passes between Allensworth Ecological Reserve and Semitropic Ecological Reserve, reducing potential for connectivity between these populations. We note, however, that there is not contiguous habitat currently connecting these populations.

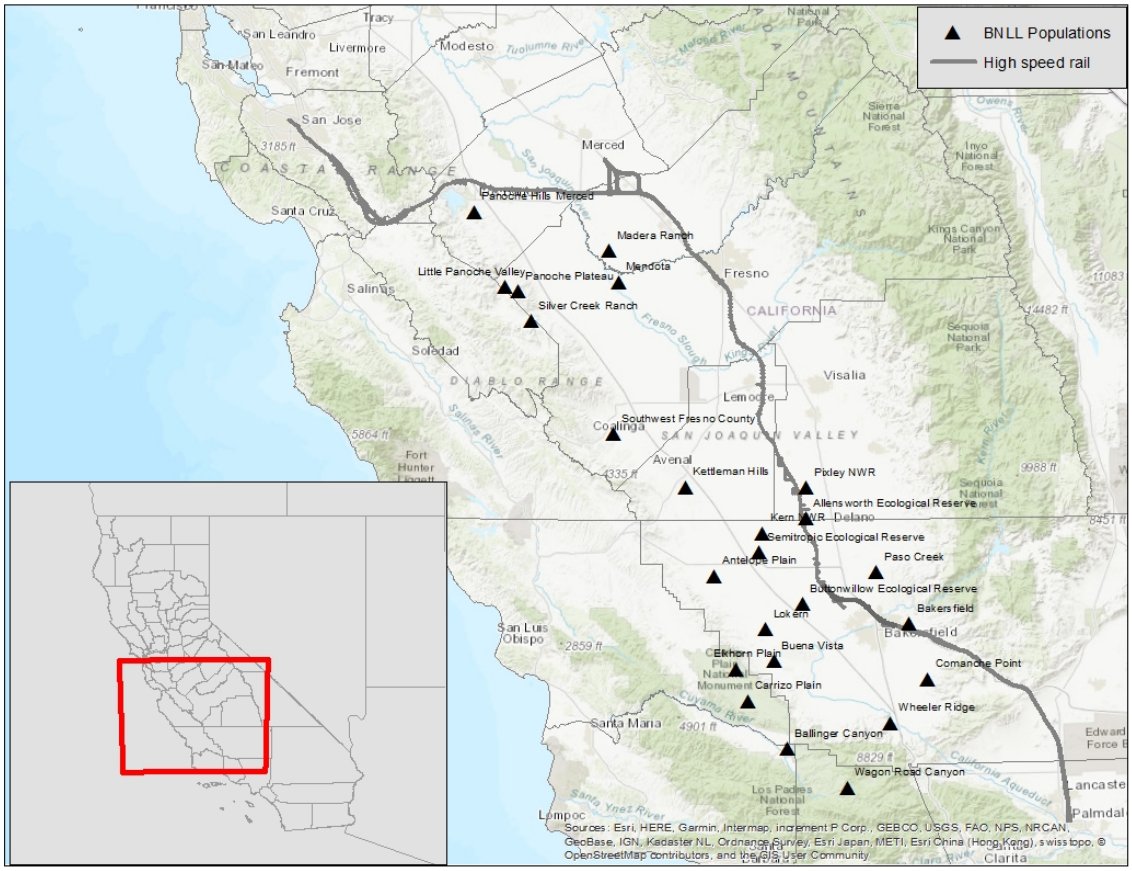


Figure 18. Planned route for the high speed rail. The current route crosses close to Allensworth Ecological Reserve, cutting off this population and the population at Pixley NWR from other populations including Semitropic Ecological Reserve.

Future Scenarios

For our analysis of the blunt-nosed leopard lizard's future condition, we constructed three future scenarios focused on changes in threats and levels of conservation efforts. All scenarios may not be equally plausible. To analyze future condition, we projected each scenario approximately 60 years into the future, corresponding to climate projections for this area. 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 blunt-nosed leopard lizard's range. Notably, however, the potential large-scale population extirpations presented in Sinervo *et al*. (2017, pp. 10, 18) are not represented to the same extent in the scenarios described below, and we defer to that publication as another possible outcome related to climate change effects.

These scenarios are based on two global circulation models (GCMs) and two Representative Concentration Pathway greenhouse gas trajectories that were selected from among 12 considered to represent a range of future conditions for California by the end of the 21st century. In comparison to current conditions, the GCMs chosen are hotter and drier (MIROC-ESM), or warmer and wetter (CNRM-CM5). The RCPs (4.5 and 8.5) represent lower and higher levels of greenhouse gas concentrations; RCP 8.5 is in line with the current trend in greenhouse gas emissions. Taken together, the GCMs and RCPs represent a range of warming statewide from

1.99 to 4.56 degrees Celsius and between a 24.8 percent decrease in precipitation and a 22.9 percent increase, respectively. These two climate projections are both used in California Department of Fisheries and Wildlife (CDFW) reports on terrestrial vegetation (Thorne *et al.* 2016, pp. 17-18) and mammals, including the San Joaquin kit fox (Stewart *et al.* 2016, p. 11). They are also used in an assessment of habitat restoration opportunities for blunt-nosed leopard lizards in the San Joaquin Desert (Stewart *et al*. 2019, entire). More information about the climate projections are available in those documents.

Notably, our scenarios assume that behavioral flexibility exhibited by blunt-nosed leopard lizards will allow them to persist in hotter environment conditions. We acknowledge that Sinervo *et al*. (2017, pp. 10, 18) projects that the species may go extinct from large central portions of the range under a 2070 RCP 8.5 scenario, with one large refugium in the Carrizo National Monument and two smaller refugia in the Panoche Plateau and north of the Tejon Conservancy. A white paper by Sinervo *et al*. (2017, entire) details this assessment of extinction risk for the species.

Scenarios

In Scenario 1, we assume conditions will be warm and wet (CNRM-CM5, RCP 4.5). We assume that under warm and wet conditions there will be increased annual precipitation that will result in increased amounts of herbaceous vegetation (i.e., lower patchiness). Under these conditions, Stewart *et al*. (2019, supplemental online figure S4) projects a range contraction for blunt-nosed leopard lizards by 2080. We assume that development continues at current rates on unprotected lands, with the potential to decrease habitat size for blunt-nosed leopard lizard populations and connectivity between them. We also assume that management and restoration continues at current levels.

In Scenario 2, we assume conditions will be hot and dry (MIROC-ESM, RCP 8.5). In this scenario, hot and dry conditions will result in an overall decrease in precipitation, which leads to a potential northward expansion of suitable habitat (Stewart *et al*. 2019, p. 8). However, without active restoration or translocation, we do not anticipate that this habitat will necessarily be occupied by the species. Because Stewart *et al*. (2019, p. 8) predicts stable habitat suitability or a range expansion under these climatic conditions, we did not make any changes to patchy habitat. We assume that under hotter and drier conditions there will be an increase in fallowed croplands, especially in the Central Valley. We also assume that development continues at current rates on unprotected lands, with the potential to decrease habitat size for blunt-nosed leopard lizard populations and connectivity between them. We assume that management and restoration continues at current levels.

In Scenario 3, we again assume that conditions will be hot and dry, using the same climatic conditions as in the second scenario. We assume that there is strategic restoration of retired agricultural land in the central part of the species range such that habitat size and connectivity will not be reduced (in comparison to Scenarios 1 and 2). We assume that this restoration will occur in the locations highlighted by Stewart *et al*. (2019, p. 7) as potential areas for habitat restoration, such that connectivity may actually increase in some areas.

In all scenarios, we assume that there will be increased precipitation extremes, meaning that drought years and years with above-average precipitation are likely to become more frequent. We also assume that the High Speed Rail will be completed according to the projected route. Although the HSR is expected to reduce connectivity between populations and will reduce habitat connectivity across the route, we do not project that it will affect the specific habitat or demographic conditions in our condition analysis. Scenarios are summarized in Table 11.

Table 11. Plausible future scenarios used to evaluate future condition of blunt-nosed leopard lizard populations. Scenario 1 assumes low emissions (RCP 4.5) and global circulation model (CNRM-CM5) that predicts warm and wet conditions, while Scenarios 2 and 3 both assume high emissions (RCP 8.5) and a global circulation model (MIROC-ESM) that predicts hot and dry conditions.

Scenario 1	**Scenario 2**	**Scenario 3**
Warm and wet conditions lead to potential range contraction due to herbaceous vegetation growth under increased precipitation	Hot and dry conditions leads to a potential northern expansion of suitable habitat	Hot and dry conditions leads to a potential northern expansion of suitable habitat
Increase in precipitation extremes increases the number of drought years	Increase in precipitation extremes increases the number of drought years	Increase in precipitation extremes increases the number of drought years
Development continues on unprotected areas, and management continues on protected lands, at current rates	Development continues on unprotected areas, and management continues on protected lands, at current rates	Restoration of fallowed croplands in the Central Valley and increased land protections in some areas, but continued development in some areas

Analysis of Future Condition

We predicted the future condition of each population based on the variations in precipitation, climate, extent of suitable habitat, and restoration as specified in our future scenarios. Specifically, we predicted changes to the three habitat and two demographic factors identified in our current condition analysis. 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 to related changes in habitat in the various scenarios. Below, we describe our predicted changes under each of the habitat and demographic factors under each scenario.

Scenario 1

For habitat size, we made changes in two situations. First, we assumed there would be a decrease in the condition of a population when we expected habitat suitability to decrease. Second, we assumed a decrease in condition in areas with unprotected lands, because we assumed there would be continued development. In the first situation, decreases in habitat suitability under warm and wet conditions are expected because increased herbaceous vegetation can lower survival of juvenile and adult blunt-nosed leopard lizards. Stewart *et al*. (2019, supplemental online material Fig. S4) used habitat modeling to predict a potential range contraction under the Scenario 1 climatic conditions in the mesic margins of the species range, and we used their

projected maps of range suitability when assessing future habitat size in relation to habitat suitability. On unprotected lands within the projected range contraction, we decreased the condition for habitat size relative to the projected suitable habitat in the model. However, we expected that protected areas (including those within the potential modelled range contraction) would have management (such as grazing) to combat negative effects of increased vegetation, thus mitigating these changes and leaving habitat size unchanged. In the second situation presented above, we decreased habitat size by one level for populations on unprotected land, under the expectation of continued development. For populations where we expected decreases in both habitat suitability and continuation of development (e.g., Madera), we categorized future habitat size condition as low.

We also changed the patchy habitat condition based on the climatic contraction modeled by Stewart *et al*. (2019). Under warm and wet conditions, we assumed that the amount of bare ground would decrease because of increased herbaceous vegetation. For populations that fell within the range retraction projected by Stewart *et al*. (2019), we changed patchy habitat to low (e.g., Panoche Hills Merced, Mendota). However, we assumed that areas with management plans or on State Ecological Reserves used grazing or other management actions to maintain appropriate levels of RDM for the species, with no change in patchy habitat condition for these populations.

Under the precipitation category, we assumed that all populations that are currently in high or moderate condition would decrease one level in the future because of increases in drought years. We assumed that the increases in drought would lead to decreases in reproduction across the species range. We acknowledge that assuming that drought frequency increases in a uniform manner across the San Joaquin Valley drastically oversimplifies both the climate and the future of the San Joaquin Valley. However, the frequency of both above- and below-average precipitation years are expected to increase with climate change, and threats associated with both of these extremes are expected to decrease habitat conditions for the blunt-nosed leopard lizard. Thus, although the predicted changes might not align perfectly with the categorical descriptions in our condition category table, we feel that decreasing the precipitation category condition uniformly across all populations is an appropriate assumption in the future.

We were conservative with our estimates of effective population size. We expected that populations with unknown abundance would have increased stress under this scenario, either because of projected changes in precipitation and vegetation, or because of continued development. Because of the uncertainty in projecting changes to an unknown condition, we only projected changes for populations that have not been observed in 20 years according to CNDDB, or those that were isolated from other recently observed populations and experienced decreases in any habitat conditions. For those populations, we assumed that effective population size would drop to Low/Extirpated.

For connectivity, we decreased population condition based on projected changes to habitat suitability, development, or land protection and restoration. We assumed that in unprotected areas within the climatic range contraction modeled by Stewart *et al*. (2019), connectivity would decrease to low condition because of decreases in habitat suitability (related to wet conditions

and herbaceous vegetation combined with continued development), but that in protected areas that management would mitigate changes to vegetation (leaving it unchanged). We assumed that unprotected habitat would continue to have development (agricultural conversion, energy development, and/or housing/commercial development) at current rates, which would lead to decreases in connectivity in these areas. Population conditions under this scenario are shown in Table 12.

Table 12. Condition for habitat and demographic factors, and overall condition, under assumptions described in Scenario 1.

Population unit	Habitat size	Patchy habitat	Precipitation	Effective population size (N_e)	Connectivity	Overall
Panoche Hills Merced	Low	Low	Moderate	Low/Extirpated	Low	Low/Extirpated
Madera Ranch	Low	Low	Moderate	Low	Low	Low
Mendota	Low	Low	Moderate	Low/Extirpated	Low	Low/Extirpated
Little Panoche Valley	High	Moderate	Moderate	Unknown	Moderate	Moderate
Panoche Plateau	Low	Moderate	Moderate	Moderate	Low	Low
Silver Creek Ranch	High	Moderate	Moderate	Moderate	Moderate	Moderate
Southwest Fresno County	Low	Moderate	Low	Low/Extirpated	Low	Low/Extirpated
Kettleman Hills	Moderate	High	Low	Moderate	Low	Moderate
Pixley National Wildlife Refuge	High	High	Moderate	Unknown	Moderate	Moderate
Allensworth Ecological Reserve	Low	Low	Low	Unknown	Low	Low
Kern National Wildlife Refuge	High	High	Low	Low/Extirpated	Moderate	Low/Extirpated
Semitropic Ecological Reserve	High	Moderate	Low	Moderate	High	Moderate
Antelope Plain	Moderate	Moderate	Low	Unknown	Low	Low
Paso Creek	Low	Moderate	Moderate	Low/Extirpated	Moderate	Low/Extirpated
Buttonwillow Ecological Reserve	High	Moderate	Low	Unknown	Moderate	Moderate
Bakersfield	Low	Moderate	Moderate	Low	Low	Low
Lokern	High	Low	Low	Moderate	Moderate	Moderate
Buena Vista	High	Low	Low	Moderate	Moderate	Moderate
Elkhorn Plain	High	Moderate	Low	Moderate	High	Moderate
Carrizo Plain	High	Moderate	Low	Moderate	High	Moderate
Comanche Point	Low	Low	Moderate	Low	Low	Low
Wheeler Ridge	High	Moderate	Moderate	Unknown	Low	Moderate
Ballinger Canyon	High	Moderate	Low	Unknown	Moderate	Moderate
Wagon Road Canyon	Unknown	Moderate	Moderate	Unknown	Unknown	Low

Scenario 2

Under Scenario 2, we decreased the habitat size condition by one level for populations on unprotected habitat, because we assumed development would continue at current rates. We did not make changes to patchy habitat under this climate scenario because Stewart *et al*. (2019, p. 8) predicts stable habitat suitability.

Under the precipitation category, we assumed that all populations that are currently in high or moderate condition would decrease one level in the future because of increases in drought years. See our discussion about assumptions related to this category under Scenario 1 above.

We expected that populations with already low abundance would have increased stress under this scenario, either because of projected changes in precipitation and vegetation, or because of continued development. For populations that have not been observed in 20 years according to CNDDB, or those that were isolated from other recently observed populations and experienced continued threats, we assumed that effective population size would drop to Low/Extirpated. However, because Silver Creek Ranch currently has the highest effective population size, we assumed slight population growth would raise the effective population size condition to high under stable habitat suitability.

We assumed that unprotected habitat would continue to have development (agricultural conversion, energy development, and/or housing/commercial development) at current rates, and decreased the condition for connectivity by one level for these populations. Population conditions under this scenario are shown in Table 13.

Table 13. Condition for habitat and demographic factors, and overall condition, under assumptions described in Scenario 2.

Population unit	Habitat size	Patchy habitat	Precipitation	Effective population size (N_e)	Connectivity	Overall
Panoche Hills Merced	Moderate	High	Moderate	Low/Extirpated	Low	Low/Extirpated
Madera Ranch	Low	Moderate	Moderate	Low	Low	Low
Mendota	Moderate	High	Moderate	Low/Extirpated	Low	Low/Extirpated
Little Panoche Valley	High	Moderate	Moderate	Unknown	Moderate	Moderate
Panoche Plateau	Low	Moderate	Moderate	Moderate	Low	Low
Silver Creek Ranch	High	Moderate	Moderate	High	Moderate	High
Southwest Fresno County	Low	Moderate	Low	Low/Extirpated	Low	Low/Extirpated
Kettleman Hills	Moderate	High	Low	Moderate	Low	Moderate
Pixley National Wildlife Refuge	High	High	Moderate	Unknown	Moderate	Moderate
Allensworth Ecological Reserve	Low	Low	Low	Unknown	Low	Low
Kern National Wildlife Refuge	High	High	Low	Low/Extirpated	Moderate	Low/Extirpated

Population unit	Habitat size	Patchy habitat	Precipitation	Effective population size (N_e)	Connectivity	Overall
Semitropic Ecological Reserve	High	Moderate	Low	Moderate	Moderate	Moderate
Antelope Plain	Moderate	Moderate	Low	Unknown	Low	Low
Paso Creek	Moderate	Moderate	Moderate	Low/Extirpated	Low	Low/Extirpated
Buttonwillow Ecological Reserve	High	Moderate	Low	Unknown	Low	Moderate
Bakersfield	Low	Moderate	Moderate	Unknown	Low	Low
Lokern	High	Low	Low	Moderate	Low	Moderate
Buena Vista	High	Low	Low	Moderate	Low	Moderate
Elkhorn Plain	High	Moderate	Low	Moderate	High	Moderate
Carrizo Plain	High	Moderate	Low	Moderate	High	Moderate
Comanche Point	Moderate	Moderate	Moderate	Low	Low	Low
Wheeler Ridge	High	Moderate	Moderate	Unknown	Low	Moderate
Ballinger Canyon	High	Moderate	Low	Unknown	Moderate	Moderate
Wagon Road Canyon	Unknown	Moderate	Moderate	Unknown	Unknown	Low

Scenario 3

This scenario had the same climatic conditions as Scenario 2. We made most changes for all categories as in that scenario. However, we assumed there would be aggressive land protection and restoration in this scenario, which caused us to make some exceptions to the changes made in Scenario 2. In this scenario, we projected that land protection and restoration would take place on fallowed agricultural lands in the central part of the species range. Notably, although we projected that the population at Kern National Wildlife Refuge may become extirpated in the other two scenarios, in this scenario we assumed population persistence with restoration and recovery actions connecting this population to the population at Semitropic. Population conditions under this scenario are shown in Table 14.

Table 14. Condition for habitat and demographic factors, and overall condition, under assumptions described in Scenario 3.

Population unit	Habitat size	Patchy habitat	Precipitation	Effective population size (N_e)	Connectivity	Overall
Panoche Hills Merced	Moderate	High	Moderate	Low/Extirpated	Low	Low/Extirpated
Madera Ranch	Low	Moderate	Moderate	Low	Low	Low
Mendota	Moderate	High	Moderate	Low/Extirpated	Low	Low/Extirpated
Little Panoche Valley	High	Moderate	Moderate	Unknown	Moderate	Moderate
Panoche Plateau	Low	Moderate	Moderate	Moderate	Low	Low

Population unit	Habitat size	Patchy habitat	Precipitation	Effective population size (N_e)	Connectivity	Overall
Silver Creek Ranch	High	Moderate	Moderate	High	Moderate	High
Southwest Fresno County	Low	Moderate	Low	Low/Extirpated	Low	Low/Extirpated
Kettleman Hills	Moderate	High	Low	Moderate	Low	Moderate
Pixley National Wildlife Refuge	High	High	Moderate	Unknown	Moderate	Moderate
Allensworth Ecological Reserve	Low	Low	Low	Unknown	Moderate	Low
Kern National Wildlife Refuge	High	High	Low	Unknown	High	Moderate
Semitropic Ecological Reserve	High	Moderate	Low	Moderate	High	Moderate
Antelope Plain	Moderate	Moderate	Low	Unknown	High	Moderate
Paso Creek	Moderate	Moderate	Moderate	Low/Extirpated	Low	Low/Extirpated
Buttonwillow Ecological Reserve	High	Moderate	Low	Unknown	Moderate	Moderate
Bakersfield	Low	Moderate	Moderate	Unknown	Low	Low
Lokern	High	Low	Low	Moderate	High	Moderate
Buena Vista	High	Low	Low	Moderate	High	Moderate
Elkhorn Plain	High	Moderate	Low	Moderate	High	Moderate
Carrizo Plain	High	Moderate	Low	Moderate	High	Moderate
Comanche Point	Moderate	Moderate	Moderate	Low	High	Moderate
Wheeler Ridge	High	Moderate	Moderate	Unknown	High	Moderate
Ballinger Canyon	High	Moderate	Low	Unknown	High	Moderate
Wagon Road Canyon	Unknown	Moderate	Moderate	Unknown	High	Low

Future Condition Uncertainty

There is a lot of uncertainty regarding climate models and the way in which blunt-nosed leopard lizards might resolve to changing climate. Models have great utility because they allow us to make predictions of how climate may change in the future, but their results should be interpreted cautiously. The models that we used in our future condition analysis are ones that are relatively much drier or wetter than most of the climate models, and were chosen to present a possible range of future conditions. Models are mathematical representations of what can happen, but they do not always accurately predict future events. One key assumption in our analysis was that effects from drought would occur uniformly across the species range, and we acknowledge that drought impacts will be more nuanced than we have projected. However, based on the best available science regarding climate predictions, it seems likely that the species will face increased climate stress in the future, thus supporting the general decrease in habitat conditions

in our future condition analysis. Maintenance of environmentally diverse habitats will be important towards maintaining resilient populations.

Uncertainty about blunt-nosed leopard lizard behavioral flexibility to projected thermal changes also exists. We again acknowledge a white paper by Sinervo *et al*. (2017, p. 18) that predicts potential extinctions for blunt-nosed leopard lizard populations by the years 2050 and 2070. However, even with these projections, climate refugia in the Panoche Valley and Carrizo Plain National Monument exist. We took an optimistic viewpoint in this analysis that the species will exhibit flexibility to changing thermal conditions such that the species will be able to persist throughout their current range.

There is also some uncertainty regarding the efficacy of conservation efforts in the future. There has been a big push towards preserving natural lands in the San Joaquin Valley, which is demonstrated in our future condition analysis of habitat and demographic factors related to habitat size and connectivity. Pilot studies on strategic restoration of land will be important in directing future recovery actions.

Synopsis of Future Condition

We used the best available science to forecast the future condition of blunt-nosed leopard lizards under three plausible scenarios. The results of the future condition analysis generally show modest decreases in population resiliency, with associated declines in representation and redundancy (Table 15). Decreases in population resiliency are expected because changes to climate are expected to put increased stress on populations, including reducing reproductive opportunities during droughts and changes to vegetation. Habitat development and agricultural conversion continue to threaten the species on unprotected lands, which can directly influence populations or restrict gene flow between them. Continued management on protected lands is essential towards maintaining resilient populations across the species range.

A handful of populations are projected to decrease in condition such that they may become extirpated. Loss of these populations, which tend to be on the boundaries of the species range or isolated from other populations, would result in losses for species representation. These populations are not in the areas that we projected targeted restoration efforts based on models for strategic restoration in the San Joaquin Valley. Indeed, the magnitude of restoration efforts will likely be one of the biggest factors driving differences between the outcomes in our projected scenarios.

The continued presence of moderately resilient populations in the northern and southwest genetic clusters across all three scenarios suggests that the species will maintain moderate levels of redundancy and representation, although both measures are likely to be lower in the future.

Table 15. Comparison of current condition of 24 blunt-nosed leopard lizard populations with projected condition under three plausible future scenarios.

Analysis unit	Overall	Scenario 1	Scenario2	Scenario 3
Panoche Hills Merced	Low	Low/Extirpated	Low/Extirpated	Low/Extirpated
Madera Ranch	Moderate	Low	Low	Low
Mendota	Low	Low/Extirpated	Low/Extirpated	Low/Extirpated

Analysis unit	Overall	Scenario 1	Scenario2	Scenario 3
Little Panoche Valley	Moderate	Moderate	Moderate	Moderate
Panoche Plateau	Low	Low	Low	Low
Silver Creek Ranch	High	Moderate	High	High
Southwest Fresno County	Low	Low/Extirpated	Low/Extirpated	Low/Extirpated
Kettleman Hills	High	Moderate	Moderate	Moderate
Pixley National Wildlife Refuge	High	Moderate	Moderate	Moderate
Allensworth Ecological Reserve	Low	Low	Low	Low
Kern National Wildlife Refuge	Low	Low/Extirpated	Low/Extirpated	Moderate
Semitropic Ecological Reserve	Moderate	Moderate	Moderate	Moderate
Antelope Plain	Moderate	Low	Low	Moderate
Paso Creek	Low	Low/Extirpated	Low/Extirpated	Low/Extirpated
Buttonwillow Ecological Reserve	Moderate	Moderate	Moderate	Moderate
Bakersfield	Low	Low	Low	Low
Lokern	Moderate	Moderate	Moderate	Moderate
Buena Vista	Moderate	Moderate	Moderate	Moderate
Elkhorn Plain	High	Moderate	Moderate	Moderate
Carrizo Plain	High	Moderate	Moderate	Moderate
Comanche Point	Moderate	Low	Low	Moderate
Wheeler Ridge	Moderate	Moderate	Moderate	Moderate
Ballinger Canyon	Moderate	Moderate	Moderate	Moderate
Wagon Road Canyon	Low	Low	Low	Low

Chapter 6. Species Viability

Status Assessment Summary

We used the best available information to evaluate the current condition and forecast the likely future condition of the blunt-nosed leopard lizard. We have considered what the blunt-nosed leopard lizard needs at the individual, population, and species-level and how they relate to viability (Chapter 3), and we evaluated the species' current condition in relation to those needs (Chapter 4). We also forecast how the species' condition may change in the future under three different scenarios (Chapter 5). 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 blunt-nosed leopard lizard, with emphasis on resiliency, redundancy, and representation.

Resiliency

Resiliency describes the ability of the species to withstand stochastic disturbance events, an ability that is associated with population size, growth rate, and habitat quality.

Historically, one of the biggest threats to the blunt-nosed leopard lizard was habitat modification and destruction, and this continues to threaten the species today. Agricultural conversion changed the landscape of the San Joaquin Valley immensely, and continues today--albeit at a lesser level because the majority of lands suitable for agriculture have already been converted. Pesticide use on agricultural lands is a threat to the species, although the specific magnitude of the threat remains unknown. Development pressures continue, although the type of development has shifted. Energy development is expected to continue, particularly solar development, and housing will likely continue to expand outward from current urban centers. Non-native grasses introduced by European settlers continue to alter grasslands throughout the species range.

Although it is unclear how abundant blunt-nosed leopard lizard populations were historically, there is little doubt that the species has experienced large losses throughout the species range. Existing populations are on a landscape fragmented by agriculture and development. We used the best available science to assess the resiliency of current populations. To do so, we assessed habitat and demographic factors for 24 populations across the species range. Based on our analysis, the species has 5 populations in high condition, 10 populations in moderate condition, and 9 populations in low condition. In the future, under all three plausible scenarios, we projected that most of the high condition populations would have reduced resiliency to drop to moderate condition, and that some of the populations currently in low condition have the potential to become extirpated.

Redundancy

Redundancy describes the ability of a species to withstand catastrophic events, an ability that is related to the number, distribution, and resilience of populations.

The current distribution of the blunt-nosed leopard lizard is distributed throughout suitable habitat for the species, with the caveat that large sections of the historical range have been converted to agriculture or housing and commercial development. Currently, there are multiple populations within each of the geographic areas targeted as important for recovery of the species.

Presence of extant populations throughout the species range makes it unlikely that a catastrophic event, such as a long-term drought, could extirpate all of the populations at once. In particular, populations in at least some of the areas identified as potential climate change refugia persist in all three plausible future scenarios. Redundancy throughout the three future scenarios is similar, although the potential loss of some populations could reduce redundancy for the species.

Representation

Representation describes the ability of a species to adapt to changing environmental conditions, which is related to the breadth of genetic and ecological diversity within and among populations.

The San Joaquin Valley is characterized as an arid desert with variable precipitation, and the species is adapted to temperature and precipitation fluctuations. Indeed, the ability of individual blunt-nosed leopard lizards to remain belowground for two winters represents an important adaptation. Genetic analyses showing ancestral polymorphisms (primordial structure) that helped to define clusters of populations (Richmond *et al*. 2017, pp. 3624-2627) identifies areas in which it is important to maintain resilient populations to preserve representation. Reduced resiliency in populations within each of these genetic clusters across all of our plausible future scenarios makes it possible that representation could be reduced as well. For example, in the northern cluster the only population with high resiliency in any of these future scenarios is Silver Creek Ranch, with several populations dropping in resiliency to low or potentially becoming extirpated. Populations that currently have high resiliency in the southwestern and southeastern clusters are reduced in all future scenarios to moderate resiliency.

Climate projections for the future that predict increases in temperature and both above- and below-average precipitation further highlight the importance of maintaining resilient blunt-nosed leopard lizards across large and variable landscapes. Areas identified as climate change refugia may be especially important in the future. Although the blunt-nosed leopard lizard is likely to have reduced representation in the future, strategic restoration has the potential to increase connectivity for populations on the valley floor.

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APPENDIX A – SUMMARY AND RESPONSE TO PEER REVIEW COMMENTS

We solicited independent peer review from species experts and partners between the draft and final revision of the SSA. Criteria used for selecting peer reviewers included their demonstrated expertise and specialized knowledge related to the species. The qualifications of the peer reviewers are in the decision file and the administrative record for this SSA.

In total, we solicited and received reviews from four peer reviewers. Peer reviewers included representatives from one federal agency, one state agency, and two academic institutions. In general, the draft SSA was well-received by the peer reviewers and garnered positive comments.

Peer review comments ranged from providing minor editorial suggestions to specific recommendations on SSA content and analysis, and several reviewers provided additional specific information, including documents and citations. We have considered all substantive comments; we thank the reviewers for these comments and to the extent appropriate, we have incorporated the applicable information or suggested changes into the final SSA. In general, these comments did not lead to significant changes in the draft SSA. Below, we provide a summary of specific comments received from peer reviewers with our responses. In addition, minor editorial edits throughout the document were incorporated into the revised SSA but did not warrant an explicit response and, thus, are not presented here. We appreciate the input from all reviewers, which helped us to consider and incorporate the best available scientific and commercial information during development and approval of the SSA.

Peer Review:

Peer Review Comment: One reviewer commented that there were sizes and weights larger than the range we had presented in the species description, with suggested citations to check.

Response: Thank you for this correction. We have the revised the range of size and weights in the species description, incorporating information from Germano and Williams 2005 and Tennant *et al*. 2018. We also separated gravid and non-gravid females when presenting information on size and weight.

Peer Review Comment: One reviewer commented that the picture referenced in our species description showed a gravid female.

Response: We have incorporated this information into the caption, and also added a photo showing breeding coloration.

Peer Review Comment: One reviewer suggested that we change our characterization of size classes from hatchlings, juveniles and adults (>90 mm) to hatchlings (40-57 mm SVL), juveniles (58-82 SVL), small adults (83-97 mm SVL), and adults (≥98 mm SVL).

Response: We made the suggested change.

Peer Review Comment: One reviewer suggested that we incorporate size classes into the Gantt chart, and extend hatch time period into September (and maybe October).

Response: We made the suggested changes.

Peer Review Comment: One reviewer suggested that we add mean number of eggs into the life history section.

Response: We added the suggested information to the document.

Peer Review Comment: One reviewer commented that two clutches was commonly the case, in reference to a statement citing that females typically produce one clutch.

Response: We added to our statement that females typically produce one clutch per year to say that in some years and/or locations two or more clutches may be common. In both the draft and final version, we state that females are known to produce up to four clutches in a year.

Peer Review Comment: One reviewer commented on our description of sexual maturity and size/age that the paragraph references one study in one location, and that growth rates and size distribution can be different at other sites. The reviewer suggested acknowledging differences in growth rates between sites.

Response: We removed the reference to size with regard to sexual maturity, but added that individuals reaching sexual maturity are usually emerging after their first winter below-ground (and retained text stating that some individuals don't breed until the following year). We added several sentences related to growth rates in the paragraph directly above the sentences about sexual maturity, and added that population structure may vary across sites/years in the paragraph below.

Peer Review Comment: One reviewer commented that the grassland habitat in one of our photos did not show good habitat because it lacked bare ground.

Response: We changed the existing habitat pictures, and added several more to show variation in habitat.

Peer Review Comment: One reviewer suggested that we include site location for photos in Figure 7 (blunt-nosed leopard lizards using cow patties and minor topographical changes).

Response: We have added this information to the figure caption.

Peer Review Comment: One reviewer suggested that we rearrange the list of mammal burrows used by blunt-nosed leopard lizards to reflect which burrows they most frequently use, and provided several additional mammal species that they use burrows of.

Response: We have made the suggested change and incorporated these additional mammals.

Peer Review Comment: One reviewer corrected information in Table 4 that the Germano and Rathbun 2016 paper refers to telemetry data from the Lokern Natural Area, not the Elkhorn Plain.

Response: Thank you for catching this error, we have corrected the table.

Peer Review Comment: One reviewer suggested that we add Pixley NWR as an example of a location in the eastern San Joaquin Valley that experienced breeding during droughts.

Response: We have made the suggested addition to the document.

Peer Review Comment: One reviewer commented that flooding can result in changes to local topography, vegetation composition and structure, and prey base composition (in addition to being a risk of inundated burrows, as stated in the draft SSA). They also suggested that we add populations that might be vulnerable to flooding.

Response: We added this information about flooding and the populations that might be vulnerable in the *Above- or Below-Average Precipitation* section.

Peer Review Comment: Several reviewers corrected citation errors (*e.g.*, listing two authors instead of *et al*., listing an author's first name instead of last).

Response: We thank the reviewers for their careful reading and for correcting these errors. We have made the appropriate changes.

Peer Review Comment: One reviewer commented that some of the occurrences lost after the species received federal protection included several sites adjacent to protected lands.

Response: We have incorporated this information.

Peer Review Comment: One reviewer commented that although retirement of marginal farmland has potential with proper SGMA implementation, the wording in the draft SSA describing this as a trend towards retirement was an overstatement.

Response: We revised the text in *Current Condition* to mention evidence of retired farmland during drought years and to reference the *Restoration* section that discusses SGMA and strategic retirement of farmland.

Peer Review Comment: One reviewer suggested that we acknowledge that population fluctuations/instability in blunt-nosed leopard lizards (and other wildlife) is natural.

Response: We added a sentence to this point: "Fluctuations are characteristic of population dynamics in many animal and plant species in the San Joaquin Valley (Service 1998) and elsewhere, and are often associated with changes in resource availability."

Peer Review Comment: One reviewer suggested that we remove a sentence in the section about recovery permits saying "Standard methodology also contributes to long-term monitoring on a grid on the Pixley National Wildlife Refuge" because it doesn't necessarily relate to protocol-level surveys.

Response: We made the suggested removal.

Peer Review Comment: One reviewer commented that fallowed agricultural lands might be used by blunt-nosed leopard lizards in the absence of active restoration if you wait "a really long time."

Response: We revised our statement that it was unlikely that fallowed agricultural lands would be used by blunt-nosed leopard lizards to say that it is unknown how long it would take for fallowed agricultural lands to become suitable without active restoration.

Peer Review Comment: One reviewer recommended we replace our description of the San Joaquin Valley as "characterized *by dry conditions* with variable precipitation" with "characterized *as an arid desert* with variable precipitation." (Italics for emphasis of the suggested change only, not to represent font emphasis in the document.)

Response: We made the suggested change.

Peer Review Comment: One reviewer suggested that we clarify that high precipitation and associated vegetation biomass were among the most important environmental variables in models (as opposed to among the most important variables).

Response: We added "environmental" before variables in this statement.

Peer Review Comment: One reviewer suggested that we incorporate information from Germano and Williams 2007 into our coloration description.

Response: We agree that this reference provides useful additional information, and have incorporated it into our description. We also added a photo that shows the yellow coloration described in this reference.

Peer Review Comment: Several reviewers commented on use and dependence of burrows. One reviewer emphasized that blunt-nosed leopard lizards use their own burrows along with rodent burrows during the active season, not just for egg laying or brumation in response to text in our *Analysis of Current Condition*, and suggested that we make this point earlier. Another reviewer argued that the dependence by blunt-nosed leopard lizards on burrows cannot be superseded by anecdotal evidence of self-burying (in reference to our decision not to include burrows in the CCT), citing Ivey *et al*. 2020 in addition to references already in the SSA. They argue that literature directly ties burrow use to crucial thermoregulatory needs.

Response: We agree that blunt-nosed leopard lizards need burrows, which is why the SSA has burrows identified as an individual need. We added a sentence in the habitat description to say that individuals can make their own burrows throughout the active season, and added "during the active season" into the sentence in the *Analysis of Current Condition* where we discuss individuals digging burrows for egg-laying or brumation. However, we make it clear that self-made burrows are less supported in the literature than the use of mammal burrows, and question the suitability of self-made burrows in the future (both in *Current Condition Uncertainty* and *Climate Change*). We have incorporated information about thermal environments in burrows from Ivey *et al*. 2020 in the *Activity and Thermoregulation* section of the SSA (this section was called Activity in the draft version but we added an emphasis on Thermoregulation). We acknowledge uncertainty in quantitative measures to delineate habitat quality based on burrows, and documentation of lizard-made burrows, as reasons not to include burrows in the CCT.

Peer Review Comment: One reviewer suggested that we add "unprotected" in front of habitat in the sentence stating "Habitat modification and destruction via land use changes (e.g., agricultural development, energy development, and housing) are all expected to continue in blunt-nosed leopard habitat..."

Response: Although we agree that habitat modification and destruction via land use changes is more likely to occur in unprotected habitat, evidence of modification and destruction after the species was protected through the Act adjacent to protected areas makes it likely that some level of change could occur even on protected lands (e.g., modification on unprotected habitat adjacent to protected habitat could increase pesticide use near protected lands, which could have impacts to blunt-nosed leopard lizards near the intersection of those lands). We added "unprotected" to the reference to habitat on privately held lands to make it clear that unprotected habitat is more at risk.

Peer Review Comment: Several reviewers commented regarding shrubs. One reviewer acknowledged that the beginning of the Individual Needs section makes the points that we do not consider shrubs a need, but suggested that we change the tone of the habitat section to make this more clear (i.e., de-emphasize shrubs). Another reviewer emphasized the important of shrubs, and suggested several recent references to incorporate into the document (Ivey *et al*. 2020 and Lortie *et al*. 2020) and preliminary data demonstrating microhabitat use. They questioned how much, if any, shrubless habitat occurred within the San Joaquin Desert historically. They agreed that shrubs are not an obligate need at the individual level, but suggested that they are a "need" at the population level.

Response: These two comments are somewhat contradictory, and we have done our best to address both sides. In the first paragraph of our description of habitat used by the species, we still include grasslands as a vegetation community used by the species, but add text that these grasslands may have historically been scrub habitat. At the beginning of the habitat paragraph describing shrub use, we added a modifier stating that the shrubs are an important resource for "populations that have this resource". However, we also reference studies showing relationships between shrubs and blunt-nosed leopard lizard habitat use and the importance of shrubs in relation to the thermal environment for the species (including references to the suggested publications and preliminary data). Although we agree that shrubs are a component of high quality habitat, we chose not to explicitly include it as a population need at this time. In our *Analysis of Current Condition*, although we do not include shrubs in our analysis of patchy habitat, we acknowledge that shrubs would be a preferred component of the vegetation communities interspersed with bare ground. The comment regarding individual vs. population needs made us rethink the way that we had treated them in the document, and we combined the Individual Needs and Population Needs into one section. We removed the table specific to individual needs as these are all included in the figure showing population habitat and demographic needs.

Peer Review Comment: Several reviewers commented regarding our analysis of precipitation for current condition. One reviewer commented that our assumption relating the number of drought years over the last 30 years to condition was a big assumption, and added that: previous year's

rainfall can play a role in terms of the effect of a drought year; large amounts of RDM from a previous year might lessen the effect of a drought year; and, that response to drought might vary across the range (populations in the northern part of the range might actually do better in drought years because lower rain leads to patchier habitat). Another reviewer commented that drought does not always lead to low reproduction, but that timing of rains can be important as well. Drought years with herbaceous plants that are well-represented but not dense can still have good numbers of hatchlings (e.g., Lokern surveys during 2015 and 2016 drought).

Response: We agree that the assumptions that went into our analysis of precipitation and drought are large, and that there are likely interactions and factors related to drought and blunt-nosed leopard lizard population condition in addition to those noted by the reviewers. Although some of the uncertainty and assumptions were already discussed, we added text to the description of current condition and the *Current Condition Uncertainty* section to acknowledge potential interactions and the limits of our analysis. Additional information could lead to a different analysis related to precipitation or interactions between precipitation and other variables in a future version of the SSA.

Peer Review Comment: One reviewer suggested that we change sentence beginning "Although blunt-nosed leopard lizards probably occurred in connected populations throughout the historical range…" to "Although blunt-nosed leopard lizards probably occurred in connected populations (within major subpopulations) throughout the historical range…"

Response: We have made the suggested change.

Peer Review Comment: One reviewer commented that the phrase "The northern cluster had additional substructure in the Panoche Plateau using microsatellite data…" was slightly inaccurate, and suggested "Within the northern cluster, microsatellite data recovered additional structure in the Panoche Hills region..."

Response: We made the suggested change.

Peer Review Comment: One reviewer commented on thermal needs for blunt-nosed leopard lizard, and shared a recently published study on thermal ecology of the species (Ivey *et al*. 2020). They suggested that temperature should always be considered a "need" for diurnal reptiles, and that we should add thermal environment to the condition category table. They also referred to Sinervo *et al*. 2010 and a large body of literature on lizard thermal ecology.

Response: We added text about thermal environment throughout the *Habitat* and *Activity* sections of the paper, and incorporated thermal environment into the influence diagrams showing habitat and demographic needs and factors influencing these needs. We discuss the relationship of patchy habitat and burrows with thermal environment. We do not explicitly include thermal environment or temperature as a need in the CCT, but added text that individuals would not survive in temperatures exceeding the critical thermal maximum. We removed some text in the *Individual and Population Needs* section explaining why we did not include a temperature range as a population need, moving a sentence about hotter active season temperatures in long-nosed

leopard lizard habitat into the *Climate Change* section where we discuss potential behavioral flexibility in blunt-nosed leopard lizards.

Our discussion of climate change already referenced models in Sinervo *et al*. 2010 and Sinervo *et al*. 2017, and we expanded to add more details about the potential extirpations modeled in these studies. While the future scenarios in this SSA do not have extirpations to the extent that Sinervo *et al*. 2017 predicts with the same RCPs, we acknowledged that there are infinite possible scenarios including potential extirpations presented in the referenced publications.

Peer Review Comment: One reviewer suggested that we revise "The genetic study revealed historical population connectivity within clusters and ancestral polymorphisms (primordial structure) that helped to define the clusters" to "The genetic study revealed historical population connectivity within clusters and deep primordial divisions between the clusters".

Response: We made the suggested change.

Peer Review Comment: One reviewer reminded us of the use of scat detection dogs to obtain genetic samples (Statham *et al*. 2019) and offered that it will be an important censusing tool moving forward.

Response: We have incorporated the suggested citation. In addition to discussing the utility of scat detection dogs for locating scat samples for genetic analysis, we note caveats mentioned in the paper that could limit its use for regulatory compliance.

Peer Review Comment: One reviewer commented that there are plans to fund a collaboration among several labs to study the link between malathion and prey abundance for blunt-nosed leopard lizards.

Response: We thank the reviewer for this update. We look forward to citing data/reports from this collaboration in the future.

Peer Review Comment: One reviewer suggested adding reference to Filazzola *et al.* 2017 when discussing RDM.

Response: We made the suggested addition.

Peer Review Comment: One reviewer commented that all Federal agencies are mandated under the Act to conserve endangered species, correcting a statement in the draft SSA that some federally-owned lands have no mandate for biodiversity protection.

Response: Our statement referred to GAP-4 areas in the USGS Protected Areas Database, which are areas that are not protected. We removed the statement because areas without protection were not included in our maps or assessments of protected areas, and are not federally owned.

Peer Review Comment: One reviewer commented that we don't understand the dynamics between precipitation and prey base other than that droughts can be detrimental (regarding a sentence saying that resilient populations need appropriate amounts of precipitation to support prey populations, but that above- or below-average levels could threaten the species).

Response: We revised the statement to begin "Appropriate amounts of precipitation are important to support vegetation and prey within the species habitat…" instead of "Appropriate amounts of precipitation are important to support large prey populations" so as to not overstate our understanding of relationships between precipitation and blunt-nosed leopard lizard prey. We removed an arrow indicating a positive relationship between precipitation and prey in our influence diagram.

Peer Review Comment: One reviewer suggested that we use effective population sizes for to roughly calculate population density in *Historical and Current Population Density* in cases where the patch occupied by BNLL is well delimited (*e.g*. Panoche Plateau, Silver Creek Ranch).

Response: We appreciate the suggestion. However, because of uncertainty in the relationship between effective population size and census population size (discussed in *Population Needs*), we did not attempt to calculate population density at this time.

Peer Review Comment: One reviewer suggested that we remove a sentence that potentially linked overgrazing to low abundance in the Bitterwater Creek Corridor because the reference was anecdotal and not causal.

Response: We changed our statement to reference the observation as "anecdotal evidence" of overgrazing, and explicitly state that we don't have quantitative information regarding grazing levels, blunt-nosed leopard lizard abundance, or a relationship between them. We also incorporated this sentence earlier in the *Grazing* section than it was in the draft.

Peer Review Comment: One reviewer suggested that we incorporate references linking grazing to increases in non-native plants, although they also mentioned that it is unclear how it might affect blunt-nosed leopard lizards in landscapes already dominated by non-native species.

Response: We incorporated information about grazing and non-native plant species, and added that grazing management for blunt-nosed leopard lizard habitat should be done in balance with biodiversity or other conservation efforts.

Peer Review Comment: One reviewer commented that the broad range of species in the diet of blunt-nosed leopard lizard, and observations that diet varies seasonally, does not in itself suggest that the species forages opportunistically.

Response: Both references that we cite regarding opportunistic foraging use that word specifically in their publication. However, we changed our statement that they "tend to feed opportunistically" to say that "observations of the species' diet suggest that they feed opportunistically".

Peer Review Comment: One reviewer commented that our statement that habitat fragmentation has led to demographic isolation of some clusters was misleading because both fragmentation and primordial separation may have played a role in the structuring of the Panoche Hills populations.

Response: We revised our statement to say that habitat fragmentation as well as primordial structure have contributed to population structure.

Peer Review Comment: One reviewer commented that redundancy is scaled within clusters, and that loss of populations in the Northern clade are not backed up by populations in the Southern clades because this would amount to the loss of unique alleles. They suggested that major clades in Richmond *et al*. (2017) would be best partitioned into different management units, and that DPS designation would be the best mechanism to codify these partitions.

Response: The SSA framework evaluates the condition of the species using conservation biology principles (resiliency, redundancy, and representation) but is distinct from policy application. Designation of distinct population segments, as suggested by this reviewer, would be considered policy application and is therefore beyond the scope of this report.

The example provided in this comment is actually related to representation, which deals with genetic diversity within the species, while redundancy can be evaluated by the distribution of resilient populations compared to the potential footprint of catastrophic events. We agree that preserving genetic diversity is important, as is having multiple resilient populations within each of the genetic clusters, which is discussed with regards to representation of the species. The draft SSA focused on genetic clusters (nuclear DNA), while this comment focuses more on clades (mtDNA). We added/edited text to more directly address the comment: "Maintaining multiple resilient populations within each of these genetic clusters is important for species viability. Although this could be also be seen as a sort of scaled redundancy, because of the emphasis on multiple populations, we include this under the representation heading according to the definitions of the 3Rs in the SSA framework;" and "Two regional clades were supported by mtDNA (northern vs. southern), while nuclear DNA revealed 5 major clusters, with populations distributed throughout each of the clusters (Figure 9). The northern regional clade only includes one of the genetic clusters, emphasizing a need to preserve multiple populations within the northern cluster to preserve genetic diversity in this clade."

Peer Review Comment: One reviewer commented that they have personally observed 2 roadkill blunt-nosed leopard lizards, with specific locality information.

Response: We added to our statement that the species affinity for open areas, including roads, makes them vulnerable to vehicle strikes, to say that this is supported by observations of roadkill individuals.

Peer Review Comment: One reviewer commented that in the interest of transparency we should note that the Service permitted a solar project in Panoche Valley identified as occupied habitat within the Biological Opinion, and indeed individual lizards were found within the construction site subsequent to the permit being issued.

Response: We did not include information about that project specifically, but we do talk about permitting and mitigation. As noted in *Regulatory mechanisms that provide conservation benefits*, the Service analyzes projects that might result in take of blunt-nosed leopard lizards through Section 7(a)(2) and 10(a)(1)(B). Development projects, including solar development, typically include measures to minimize and mitigate adverse impacts, including habitat compensation. More information about specific Service consultations and permits can be found at: <https://ecos.fws.gov/ecp0/profile/speciesProfile?spcode=C001>.

Peer Review Comment: One reviewer suggested that we add reference to Lucero *et al*. (2019) regarding interactions between shrubs and non-native grasses.

Response: We added several sentences about facilitation of exotic annual plants by shrubs, including a citation of this reference.

Peer Review Comment: One reviewer suggested that we add discussion of blunt-nosed leopard lizard habitat's resilience to disturbance (fire and otherwise) (suggested citation Lortie *et al*. 2017), and reference habitat that had been converted to grassland by recent fires. They commented that Germano 2019 explicitly notes habitat used by blunt-nosed leopard lizards that was previously burned.

Response: We removed a partial sentence stating that we are unaware of specific responses of the species to fire, and added reference to use of a previously burned site (Germano and Rathbun 2016 and Germano 2019). We added several sentences in *Non-Native Plants* discussing a potential feedback loop between grasses and fire. To further emphasize habitat resilience, we discuss shrub regrowth following aboveground damage (Lortie *et al*. 2017).

Peer Review Comment: One reviewer noted that a challenge to managing blunt-nosed leopard lizards is that populations under non-public ownership may not be adequately monitored, and Federal researchers attempting to survey for them or conduct other work associated with their conservation may be (and have been) rebuffed by landowners

Response: We have added information about lack of monitoring due to access issues on private lands in *Historical and Current Population Density*.