Reviewer Name	Chapter	Page	Line #	Comment
Joe Stewart	5	65		Celsius not Celcius
Joe Stewart	4	44		Stewart et al. 2019 not 2017
Joe Stewart	4	54		Stewart et al. 2019 not 2017
Joe Stewart	4	55		Modeling demonstrated high precipitation, and associated vegetation biomass, to be the most limiting ENVIRONMENTAL variables for the species
Joe Stewart	4	57		Stewart et al. 2019 not 2017
Joe Stewart	4	58		Stewart et al. 2019 not 2017
Joe Stewart	4	60		Stewart et al. 2019 not 2017
Joe Stewart	4	69		Stewart et al. 2019 not 2017
Joe Stewart	throughout	throghout		Stewart et al. 2017 should be changed to Stewart et al. 2019 throughout the document
Joe Stewart	throghout	throghout		You appear to have assembled and considered the best available scientific and commercial information relevant to this species.
Joe Stewart	throghout	throghout		Your analyses appear correct.
Joe Stewart	throghout	throghout		Your scientific conclusions are reasonable in light of available informatioin.

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

Photo credit: USFWS

Month YEAR
U.S. Fish and Wildlife Service
Region 8
Sacramento, California

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.

Table of Contents

Chapter 1. Introduction 8
Federal History 8
The Species Status Assessment Framework 9
Summary of New Information 10
Uncertainties and Assumptions 11
Chapter 2. Background 12
Taxonomy and Genetics 12
Species Description 13
Range and Distribution 14
Historical Distribution 14
Current Distribution 15
Chapter 3. Species Ecology and Needs 17
Species' Ecology 17
Life history 17
Habitat 19
Foraging 22
Activity 23
Survival 24
Sex ratios 24
Home Range Behavior and Movements 25
Blunt-nosed Leopard Lizard Needs 28
Individual Needs 28
Population Needs 29
Species Needs 30
Summary of Species Ecology and Needs 33
Chapter 4. Historical and Current Condition 34
Historical and Current Population Density 34
Factors Influencing Viability 35
Habitat Modification and Destruction 36
Above- or Below-Average Precipitation 41
Pesticide Use 41

Conservation and Management ... 43
Analysis of Current Condition ... 46
Current Condition Uncertainty ... 58
Current Condition ... 59
Current Condition Relative to Recovery Criteria ... 61
Population Density ... 61
Occupied Protected Habitat ... 62
Management Plans ... 62
Chapter 5. Future Condition ... 63
Factors Influencing Viability ... 63
Climate Change ... 64
Small population size ... 66
Habitat Modification and Destruction ... 66
Restoration ... 67
High-speed Rail ... 67
Future Scenarios ... 68
Scenarios ... 69
Analysis of Future Condition ... 70
Scenario 1 ... 70
Scenario 2 ... 73
Scenario 3 ... 74
Future Condition Uncertainty ... 75
Synopsis of Future Condition ... 76
Chapter 6. Species Viability ... 78
Status Assessment Summary ... 78
Resiliency ... 78
Redundancy ... 78
Representation ... 79

List of Table and Figures

Tables

Table 1. Taxonomic status of the blunt-nosed leopard lizard ... 12

Table 2. Gantt timeline chart for one year in the life cycle of the blunt-nosed leopard lizard 17
Table 3. Sex ratios of adult, juvenile, and hatchling blunt-nosed leopard lizards at three sites. .. 24
Table 4. Blunt-nosed leopard lizard home range size from studies in various locations..... 27
Table 5. Resource needs for individual blunt-nosed leopard lizards 28
Table 6. Individual, population, and species needs for the blunt-nosed leopard lizard. 33
Table 7. Habitat Conservation Plans that include the blunt-nosed leopard lizard as a covered species. 46
Table 8. Blunt-nosed leopard lizard habitat acreage and land protections 44
Table 9. Estimated regression parameters, standard errors, z-values and P-values for the Poisson GLMM comparing mean winter precipitation and number of drought years. 55
Table 10. Habitat and demographic factors used to assess blunt-nosed leopard lizard population resiliency 58
Table 11. Current condition table rating blunt-nosed leopard lizard populations as high, moderate, or low in habitat and demographic categories 60
Table 12. Plausible future scenarios used to evaluate future condition of blunt-nosed leopard lizard populations. 70
Table 13. Condition for habitat and demographic factors, and overall condition, under assumptions described in Scenario 1. 72
Table 14. Condition for habitat and demographic factors, and overall condition, under assumptions described in Scenario 2. 73
Table 15. Condition for habitat and demographic factors, and overall condition, under assumptions described in Scenario 3. 74
Table 16. Comparison of current condition of 24 blunt-nosed leopard lizard populations with projected condition under three plausible future scenarios. 76

Figures

Figure 1. The Species Status Assessment framework 10
Figure 2. Blunt nosed leopard lizard 13
Figure 3. Male blunt-nosed leopard lizards have enlarged postanal scales and femoral pores. ... 14
Figure 4. Blunt-nosed leopard lizard historical range and contemporary populations, including hybrids. 16
Figure 5. The life cycle of the blunt-nosed leopard lizard includes eggs, hatchlings, juveniles, and adults. 18
Figure 6. Example grassland habitat and saltbush habitat occupied by blunt-nosed leopard lizards. 20
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 21
Figure 8. Blunt-nosed leopard lizard population habitat and demographic needs 29
Figure 9. Map from the rangewide genetic study. Map from Richmond *et al*. (2017). 31
Figure 10. Influence diagram showing the pathways through which factors may influence habitat needs or demographic parameters of the blunt-nosed leopard lizard 35

Figure 11. Blunt-nosed leopard lizard element occurrences (CNDDD) and occurrences putatively lose to agriculture and urban development (data from Stewart *et al*. 2019) 38
Figure 12. Malathion use in 2017 across blunt-nosed leopard lizard habitat 42
Figure 13. Protected lands within the historical range of blunt-nosed leopard lizard populations45
Figure 14. Blunt-nosed leopard lizards used in SSA analysis. 53
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. 56
Figure 16. Current condition of blunt-nosed leopard lizard populations, loosely grouped into genetic clusters. 61
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 64
Figure 18. Planned route for the high speed rail 68

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.

<u>Downlisting Criteria</u>

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.

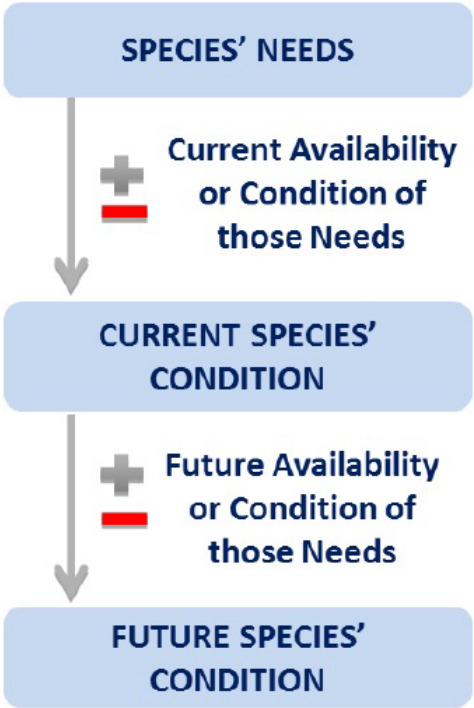

Figure 1. The Species Status Assessment framework

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.

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, H. M. 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 37.4 grams (01.1 to 1.3 ounces); females range from 86 to 111 millimeters (3.4 to 4.4 inches) SVL and weigh 20.6 to 29.3 grams (0.7 to 1.0 ounces) (Tollestrup 1982, p. 11; Uptain *et al*. 1985, pp. i, 22).

Figure 2. Blunt nosed leopard lizard. Photo credit: Thomas Leeman, USFWS.

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 and sex. Juveniles have blood-red spots on the back that darken with age (Montanucci, Richard R. 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). 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). Postnuptial females have bright red-orange markings on the sides of the head and body and the undersides of the thighs and tail that fade to pink or light orange by late July (Montanucci 1965, p. 272).

Figure 3. Male blunt-nosed leopard lizards have enlarged postanal scales and femoral pores. Photo credit: 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 *Habitat Modification by 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).

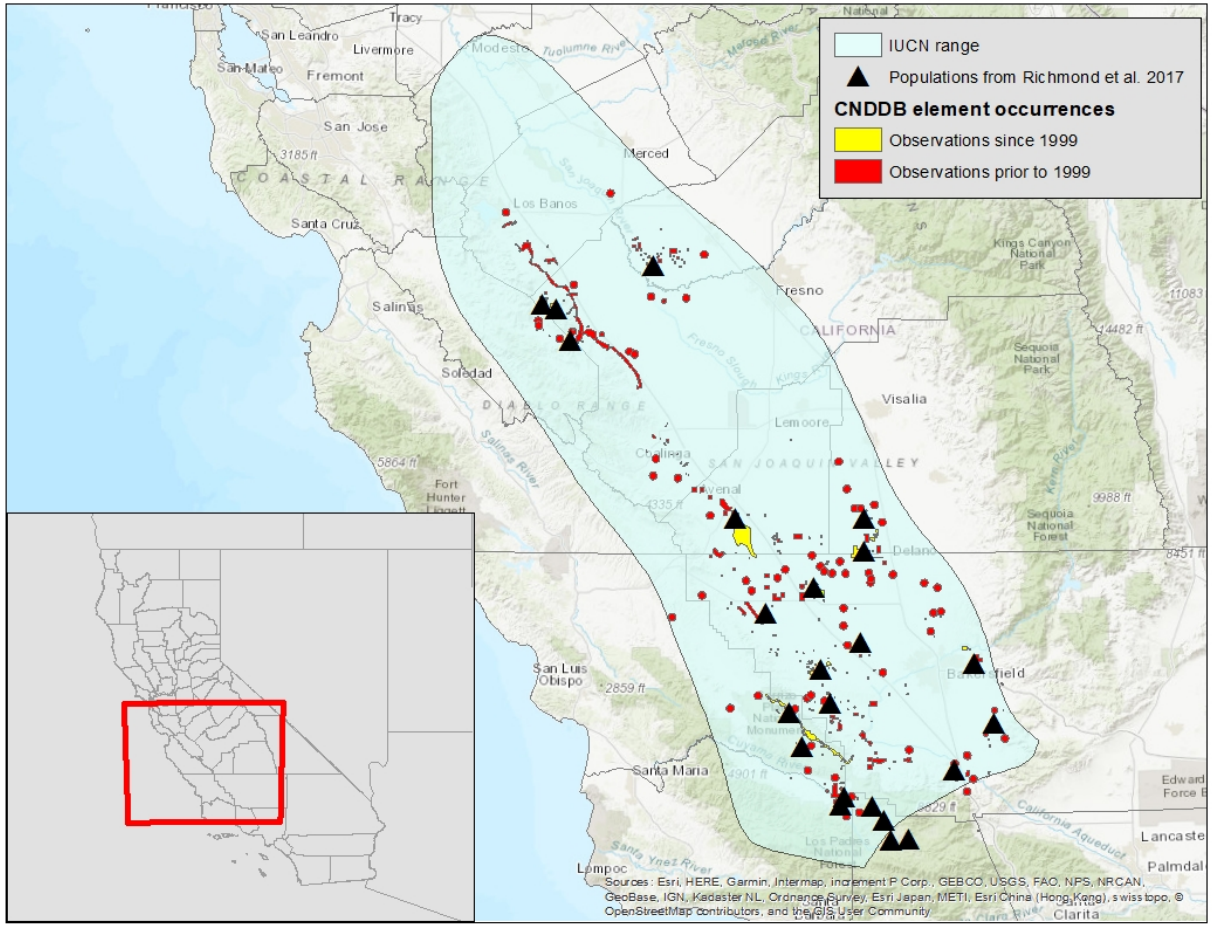

Figure 4. Blunt-nosed leopard lizard historical range and contemporary populations, including hybrids. Historical range (data from IUCN Red List, version 3, May 2017) is represented as a polygon around the presumed extent of the range, although not all habitat within the polygon was suitable habitat 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 withint 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, and adults (Figure 5). We refer to individuals as hatchlings in their first calendar year of hatching (*i.e.* through December 30 in the year of hatching) (Tollestrup 1982, p. 3). We distinguish juveniles from adults based on size, using the cut-off of ~90 mm following Germano and Williams (2005, pp. 1-2). Although it is usually possible to distinguish between individuals emerging from their first winter dormancy with 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), distinguish small adults from large adults (Germano and Williams 2005, p. 2), or fail to elucidate criteria for distinction.

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

Life Stage	Jan	Feb	Mar	Apr		May	Jun	Jul	Aug		Sep	Oct	Nov	Dec
Eggs							In chamber underground							
								Hatch						
Hatchlings								Active above ground/Foraging						
												Brumation		
Juveniles			Active season (Above ground/foraging)											
	Brumation											Brumation		
Adults					Breeding									
				Active season (Above round/foraging)										
	Brumation								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 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).

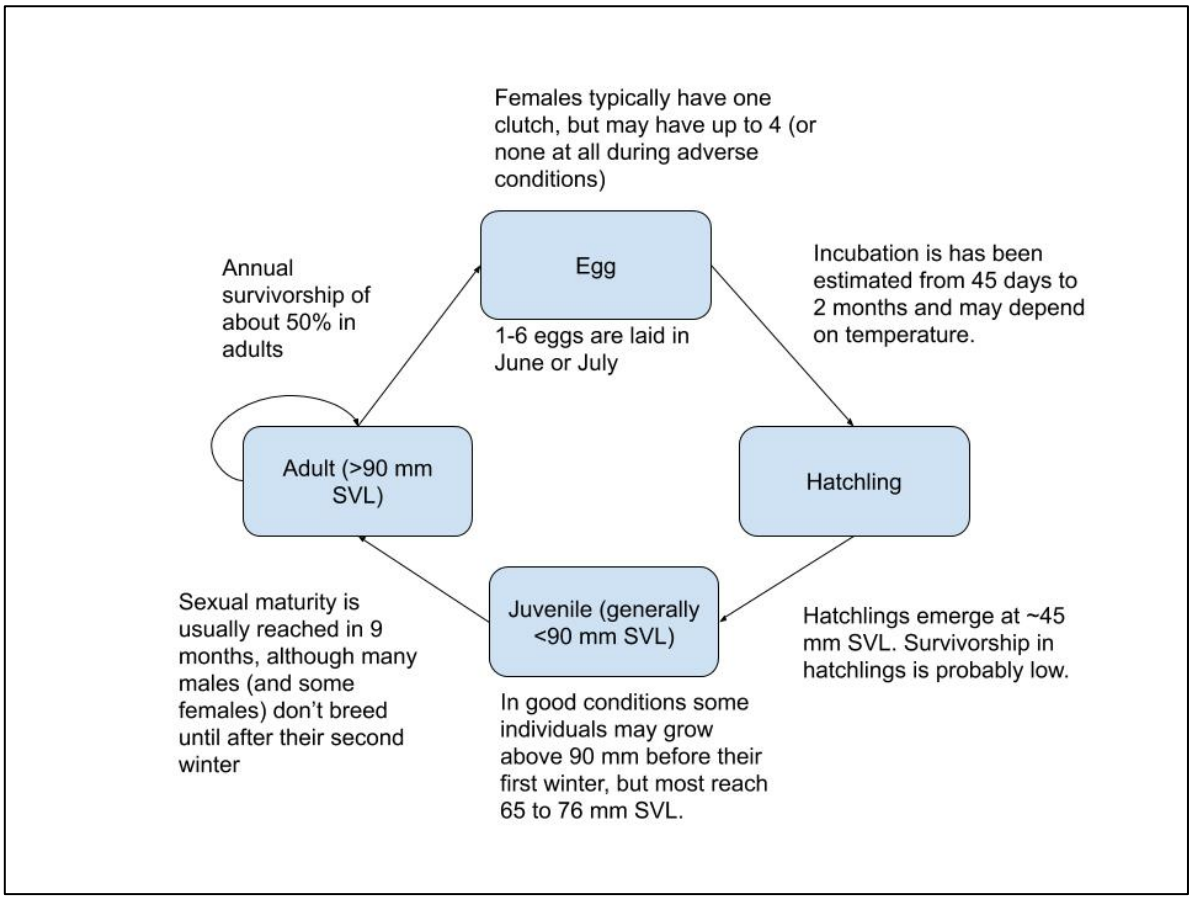

Figure 5. The life cycle of the blunt-nosed leopard lizard includes eggs, hatchlings, juveniles, and adults.

Females typically produce one clutch of eggs per year (Tollestrup 1982, p. 7), although some may produce up to four under favorable environmental conditions (Germano and Williams 2005, p. 10). 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). 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). 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 experiment study in another member of the Crotaphytid family, the collared lizard (*Crotaphytus collaris*) (Santoyo-Brito *et al.* 2017, p. 199). Hatchlings ranging in size from 42 to 47 millimeters (1.7 to 1.9 inches) SVL

emerge above ground as early as July (Montanucci 1965, p. 279). Before their first winter, hatchling leopard lizards usually reach 65 to 76 millimeters (2.6 to 3.0 inches) SVL (Montanucci 1965, p. 279) but may grow above 90 mm (3.5 inches) SVL (Germano and Willams 2005, p. 15). Males generally grow faster than females (Tollestrup 1982, p. 8).

Sexual maturity is usually reached in about nine months for both sexes at around 90 mm SVL, 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).

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.

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). 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, 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).

Figure 6. Example grassland habitat and saltbush habitat occupied by blunt-nosed leopard lizards.

Several papers demonstrate the importance of shrubs as a component of the blunt-nosed leopard lizard habitat. Males use shrubs as perches more frequently than do females (Germano 2019, p. 436). Although populations can persist in areas with relatively few shrubs or without shrubs (Westphal *et al.* 2018, p. 12159), the use of shrubs for thermal facilitation and as shelter from predators has been demonstrated using both a priori hypothesis testing (Westphal *et al.* 2018, entire) and post-hoc analyses (Germano and Rathbun 2016, pp. 431-432). Although home range size was not predicted by shrub cover, blunt-nosed leopard lizards did select saltbush habitat relative to open habitat (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). Behaviors associated with cooling were also more common underneath shrubs than in the open (Westphal *et al*. 2018, pp. 12156-12157). This finding, combined with data demonstrating that shrub microclimates were significantly cooler compared to open areas (Filazzola *et al.* 2017, p. 56), further supports the importance of shrubs for thermal regulation. 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). 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.

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. 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 abandoned ground squirrel (*Spermophilus beecheyi*) tunnels, or occupied or abandoned kangaroo rat tunnels (*Dipodomys* spp.); abandoned badger (*Taxidea taxus*) dens or gopher burrows (*Thomomys bottae*) are used less frequently (Montanucci 1965, pp. 273-274). 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 tend to 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

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 Celcius (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 Celcius (106 degrees Fahrenheit). Telemetry studies demonstrate that most surface activity occurs when air temperatures are between 26 and 41 degrees Celcius (79 to 106 degrees Fahrenheit) and can occur up to 45 degrees Celcius (113 degrees Fahrenheit), albeit at this air temperature most individuals are in the shade (Germano 2019, pp. 431-435). Individuals can reduce their internal temperatures by about 3 degrees Celcius by retreating to the shade, which allows them to continue foraging or mating behaviors that would otherwise be precluded if they retreated to burrows (Germano 2019, p. 438). 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). Germano (2019, p. 439) speculates that the species may have behavioral flexibility to become active earlier in the day under hotter future conditions. 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.

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

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).

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
Elkhorn Plain	2003	7.93±1.37	13	4.48±0.88	12	Germano and Rathbun 2016[1]	Radio Telemetry	100% MCP
Elkhorn Plain	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 Needs

Individual blunt-nosed leopard lizard needs vary somewhat by life stage (Table 5). 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. 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). Although insects comprise the majority of the diet, the species is flexible and forages opportunistically. Although the species has specific temperatures that are associated with activity, we do not include a temperature range as a need because of the flexibility in activity demonstrated in behavioral studies (Germano 2019, pp. 431-435). An additional reason that we do not include temperature as a need is the hotter active season temperatures experienced by some populations of the congeneric long-nosed leopard lizard (Germano pers. comm. 2019; Stewart *et al*. 2019, SOM).

Table 5. Resource needs for individual blunt-nosed leopard lizards. Resources functions include feeding (F), sheltering (S), breeding (B), and dispersal (D).

Resource	Life Stage	Resource Function
Burrows	All	S, B
Insects (and other prey)	Adults	F
Patchy habitat with low relief	Adults, Juveniles	B, F, S, D

Population Needs

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).

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. We describe population resiliency in terms of the habitat and demographic needs (Figure 8).

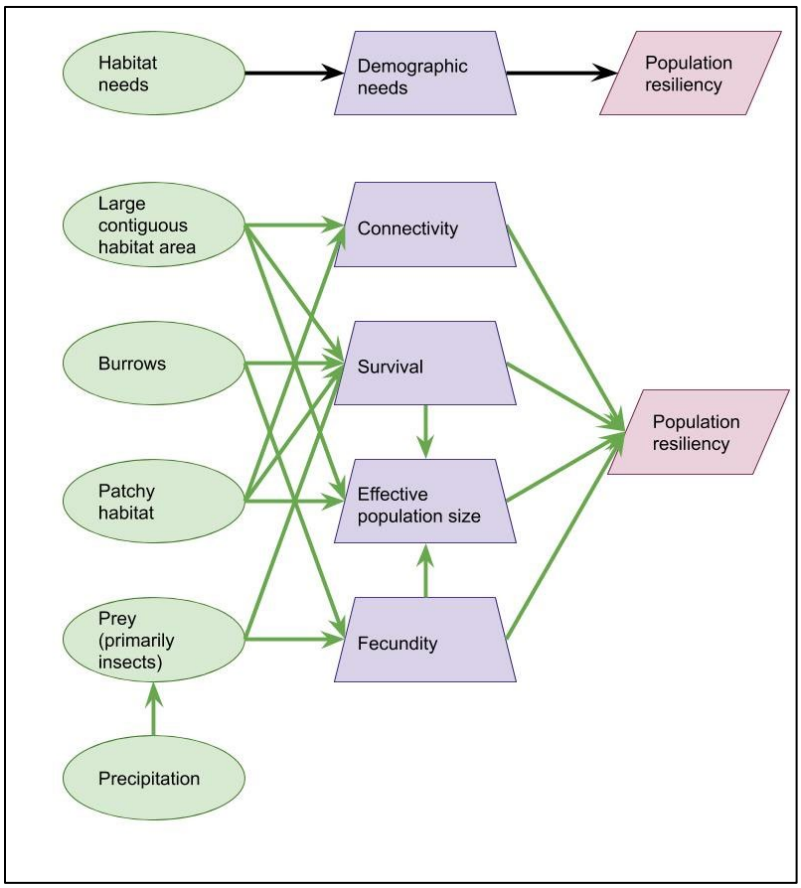

Figure 8. Blunt-nosed leopard lizard population habitat and demographic needs. Green arrows represent positive relationships.

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 large prey populations, 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 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).

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 ancestral polymorphisms (primordial structure) that helped to define the clusters (Richmond *et al*. 2017, pp. 3624-2627).

Genetic analyses revealed 5 major clusters, with populations distributed throughout each of the clusters (Figure 9). These 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). The northern cluster had additional substructure in the Panoche Plateau using microsatellite data, 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). Because of habitat fragmentation, 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).

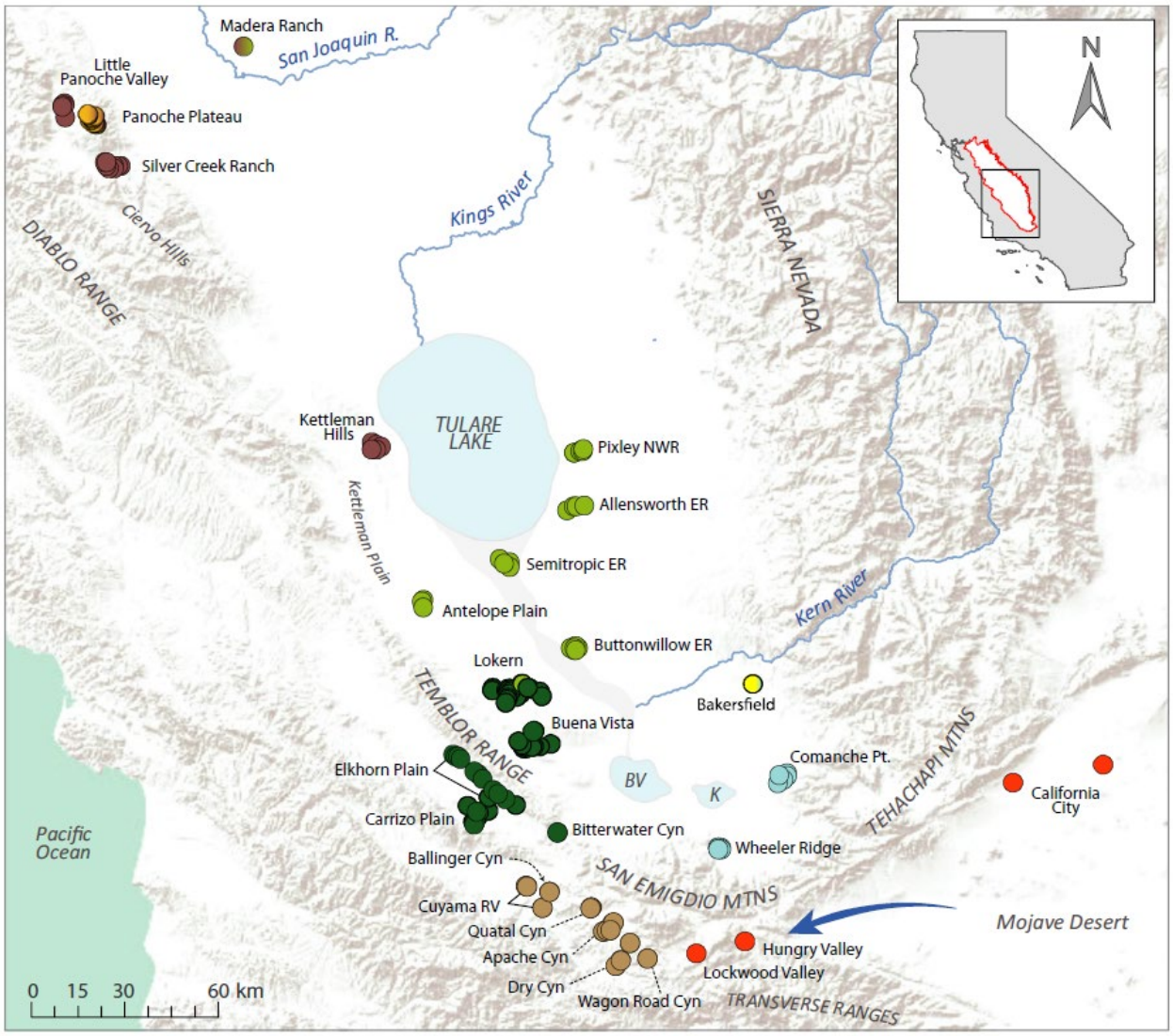

Figure 9. Map from the rangewide genetic study. Points represent samples, and colors represent cluster assignments at K=6, with exception that orange dot represent mtDNA and nuclear genomes that are unambiguously G. wislenzii. Blue arrow indicates the entryway in the San Joaquin Desert for the ancestor to G. sila (but see caveats in journal article). Map from Richmond et al. (2017).

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).

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.

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.

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 6).

Table 6. 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 (William *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).

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.

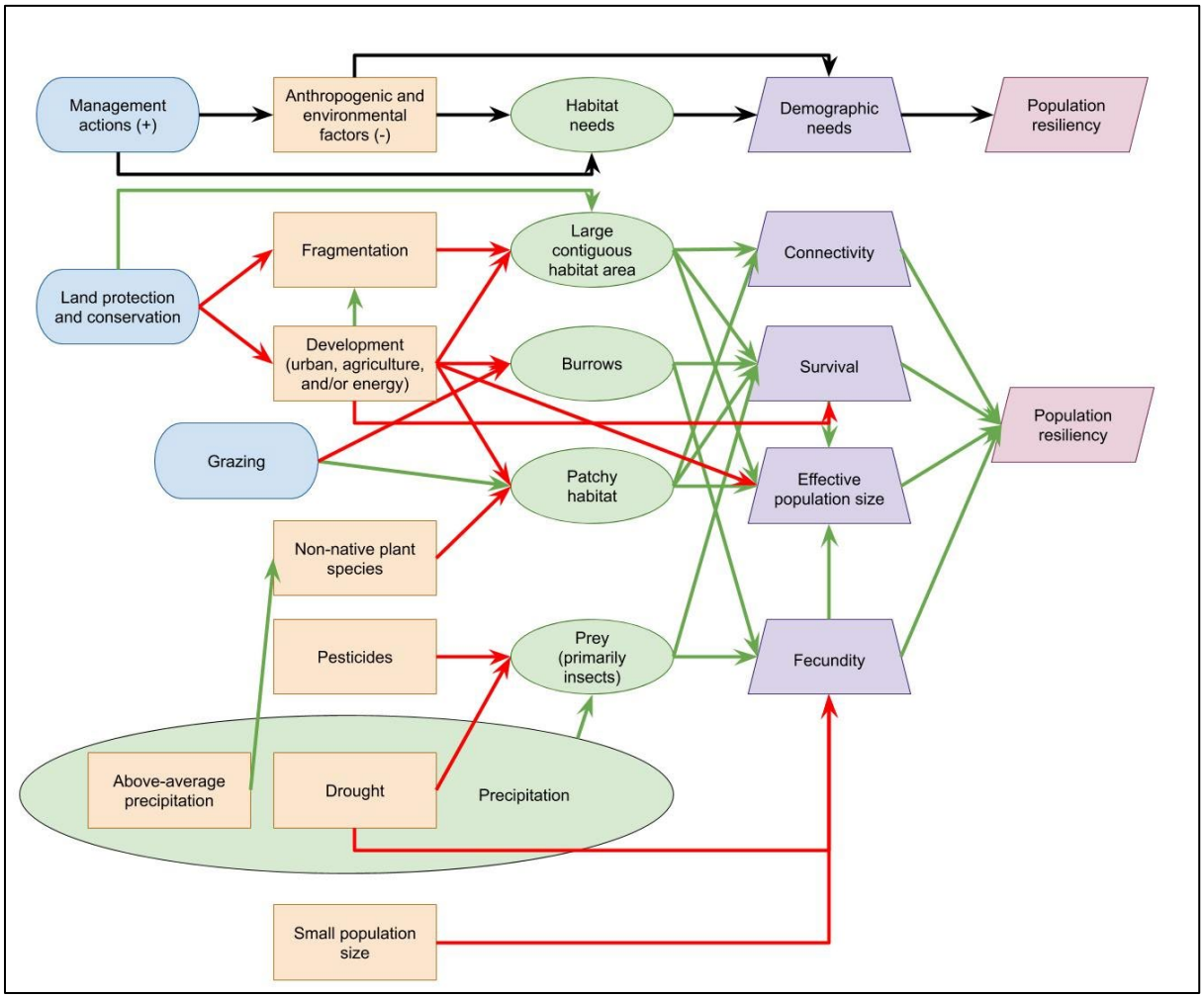

Figure 10. Influence diagram showing the pathways through which factors may influence habitat or demographic needs of the blunt-nosed leopard lizard. Green lines indicate positive relationships, and red lines indicate negative relationships.

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.

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. 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.

Although agricultural conversion has been a powerful influence shaping land use of the San Joaquin Valley, there is also a trend towards retirement of marginal farmland (Melton *et al.* 2015, pp. 3-7).

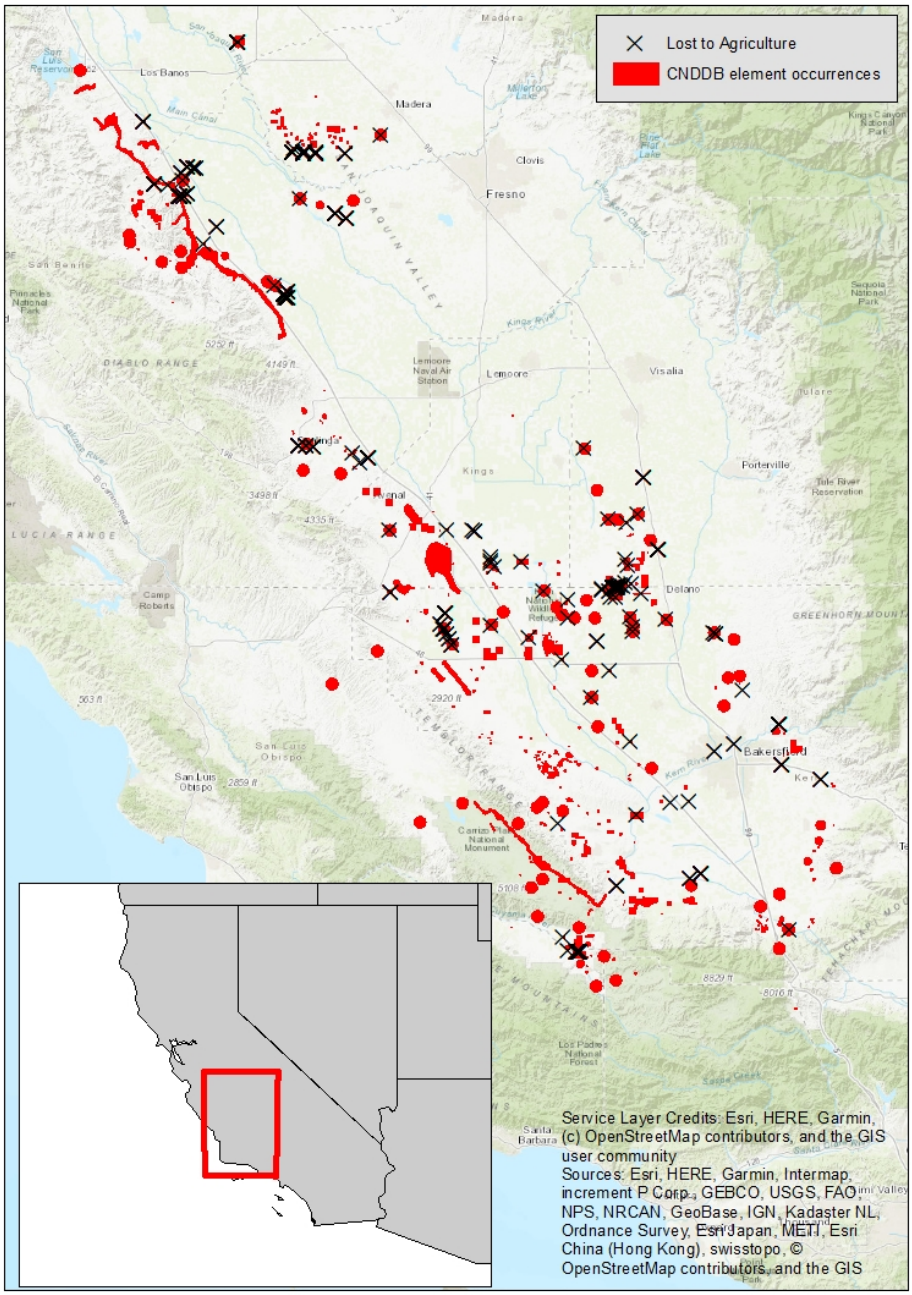

Figure 11. Blunt-nosed leopard lizard element occurrences (CNDDD) and occurrences putatively lose to agriculture and urban development (data from Stewart et al. 2019). For description of methods for extirpated populations, see Stewart et al. (2019).

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.

Habitat Modification by 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 these 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, as noted in *Individual and Population Habitat Needs*.

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

Blunt-nosed leopard lizard populations show a lot of instability, much of which is 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).

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).

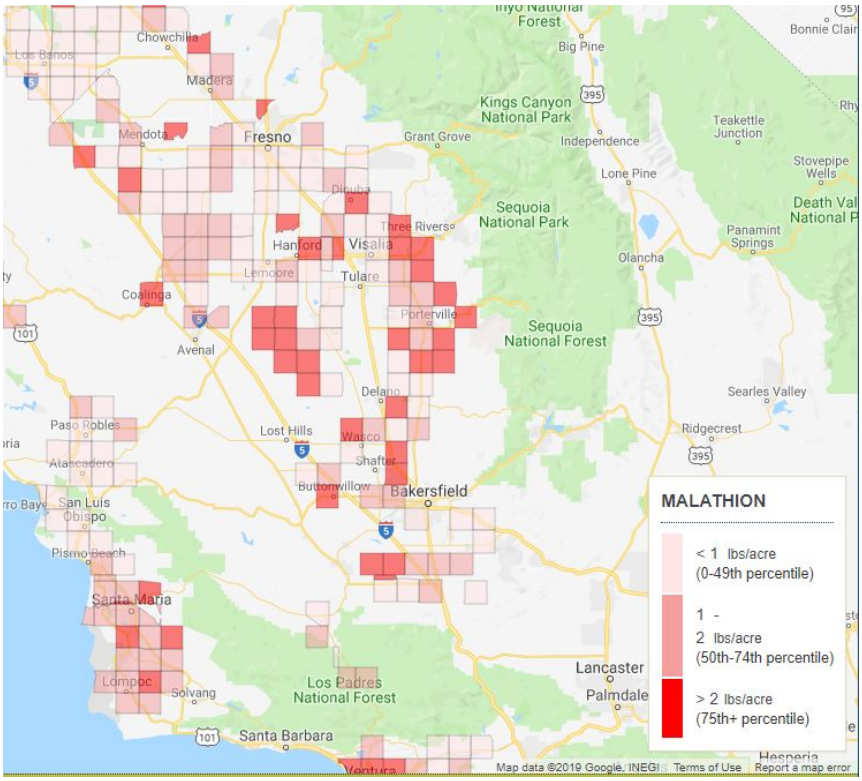

Figure 12. Malathion use in 2017 across blunt-nosed leopard lizard habitat. Data shows application rates (pounds/acre) averaged over townships. Data from the California Environmental Health Tracking Pro.

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. 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. In the Bitterwater Creek corridor, an important historical corridor between sites on opposite sides of the Temblor Range, only one lizard was collected in the 2016 genetic study, and it was noted that livestock grazing had severely degraded the habitat at this site (Westphal *in litt*. 2019).

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*. (2017) (Table 8). We note that some of the federally-owned lands in the USGS Protected Areas database (USGS PAD) have no known mandate for biodiversity protection (i.e., GAP-4). Additionally, 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 7. 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. 2017).

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.

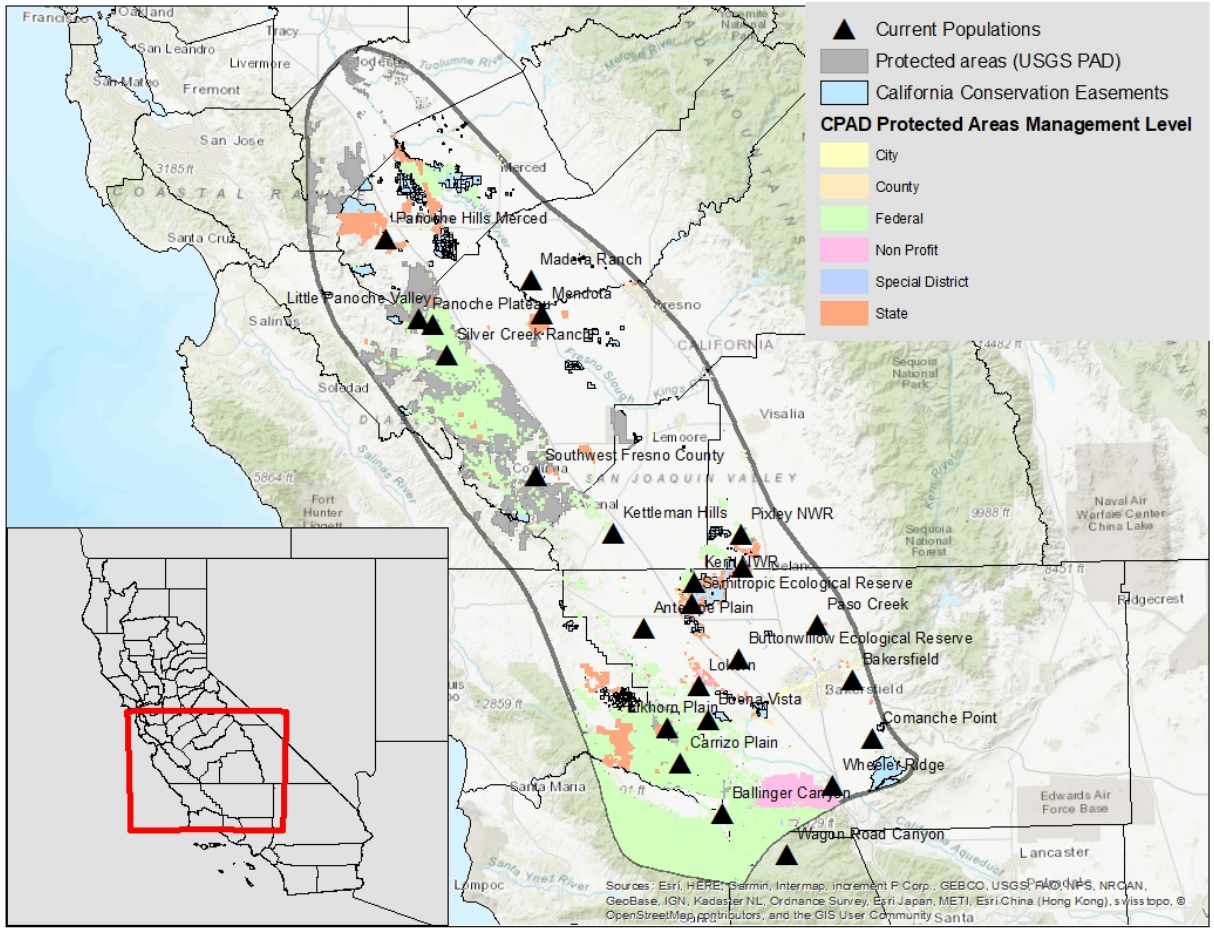

Figure 13. Protected lands within the historical range of blunt-nosed leopard lizard populations. General locations for populations are from Richmond et al. (2017); protected lands are from the California Conservation Easement Database, California Protected Areas Database, and USGS Protected Areas Database.

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 (ESA); 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 ESA 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) and Safe Harbor Agreements (note that at this time there are no Safe Harbor Agreements for the blunt-nosed leopard lizard). In addition to reducing the amount of overall habitat loss for the species, Section 10(a)(1)(A) of the Act allows for permits to be issued for recovery activities that result in take. Recovery activities are those activities that are specifically implemented for scientific purposes or to enhance the propagation or survival of the affected species, including interstate commerce activities.

Conservation Banks

A conservation bank is a site, or suite of sites (i.e., umbrella bank), that is conserved and managed in perpetuity, and provides ecological functions and services for specified listed species or resources. Conservation banks function to offset adverse impacts to these species that occurred elsewhere; therefore, the Service approves a specified number of credits that the bank owner may sell to developers or other project proponents for use as compensation for adverse impacts their projects have on those species. The bank owner then uses the money from the credit purchases to permanently protect and manage the land for those species and resources.

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

Habitat compensation through permittee-responsible mitigation for the 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 provide a pathway forward to balance wildlife conservation with development. The primary objective of the HCP program is to conserve species and the ecosystems they depend on while streamlining permitting for economic development. Being included as a covered species under an HCP means that habitat will be set aside and managed for the species as compensation for covered activities, such as planned urban development, within the area the HCP covers.

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).

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 compensati on	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. Standard methodology also contributes to long-term monitoring on a grid on the Pixley National Wildlife Refuge.

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.

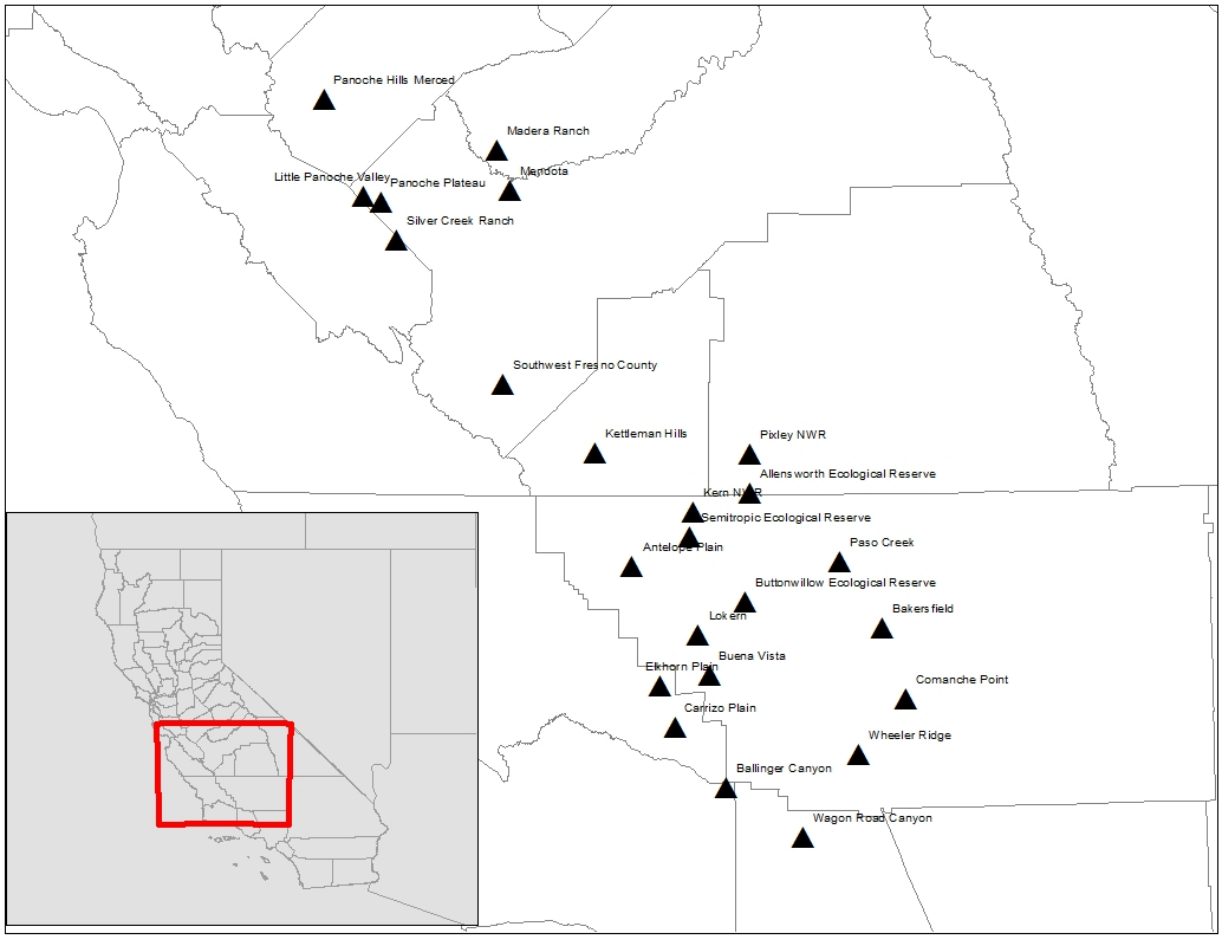

Figure 14. Blunt-nosed leopard lizards used in SSA analysis.

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 as large areas of contiguous habitat, burrows, patchy habitat, and prey, and demographic needs of 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 based on data availability. 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 to lay eggs and for brumation make 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 10). 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*. 2017, 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.

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 9; 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 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

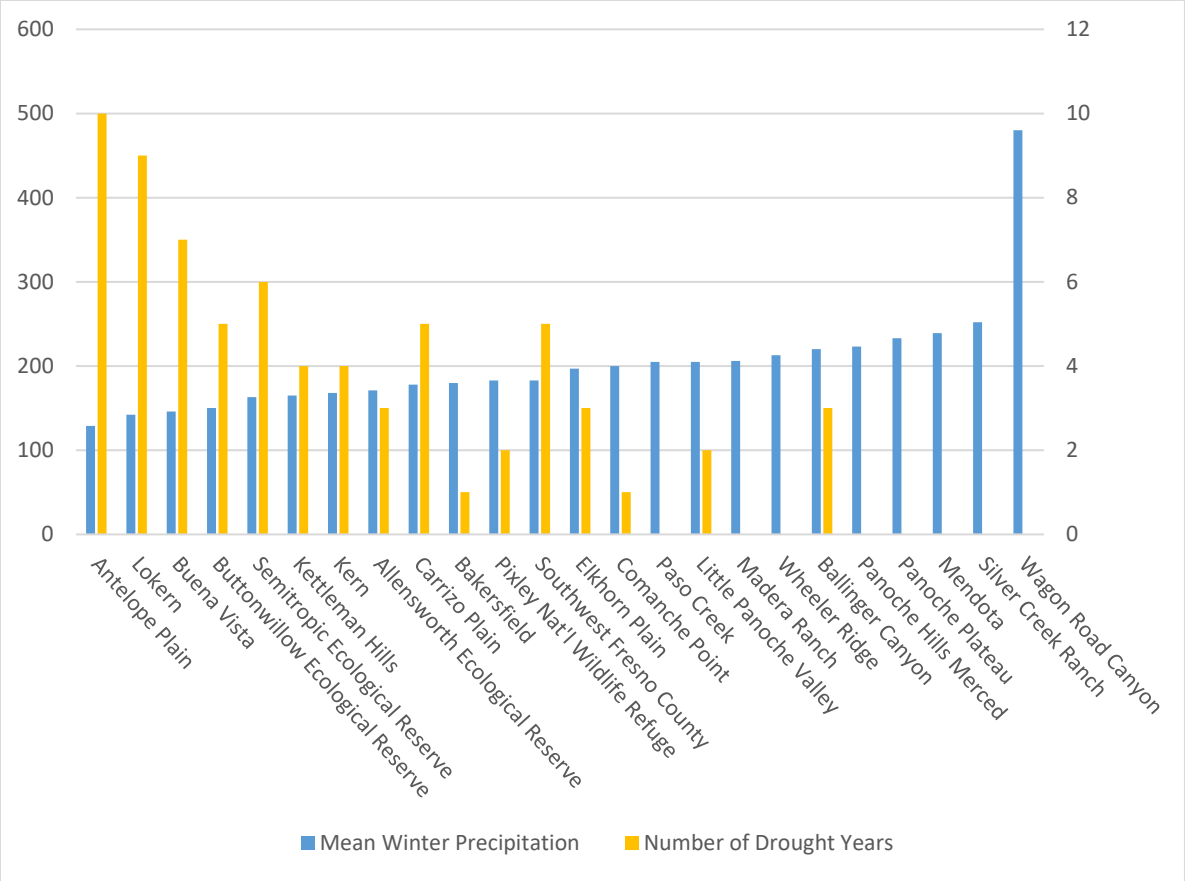

Figure 15. Mean winter precipitation from 1988 through 2018 and the number of drought years (defined as years with less than 92 mm winter precipitation) at locations centered on blunt-nosed leopard lizard population analysis units.

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.

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*. 2017, 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 conditions category table (Table 10) were used to determine the overall current condition of each blunt-nosed leopard lizard population (Table 11). The habitat and demographic factors (habitat size, patchy habitat, winter precipitation, effective population size, and connectivity) included in Table 10 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 4. 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 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 Craig and Bailey (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*. (2017) 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. 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 11). 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. 2017 habitat suitability model.

[2]Bare ground data from NASA WELD dataset.

[3]Data from Prism Climate Group 2019

[4]Data from USGS 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.

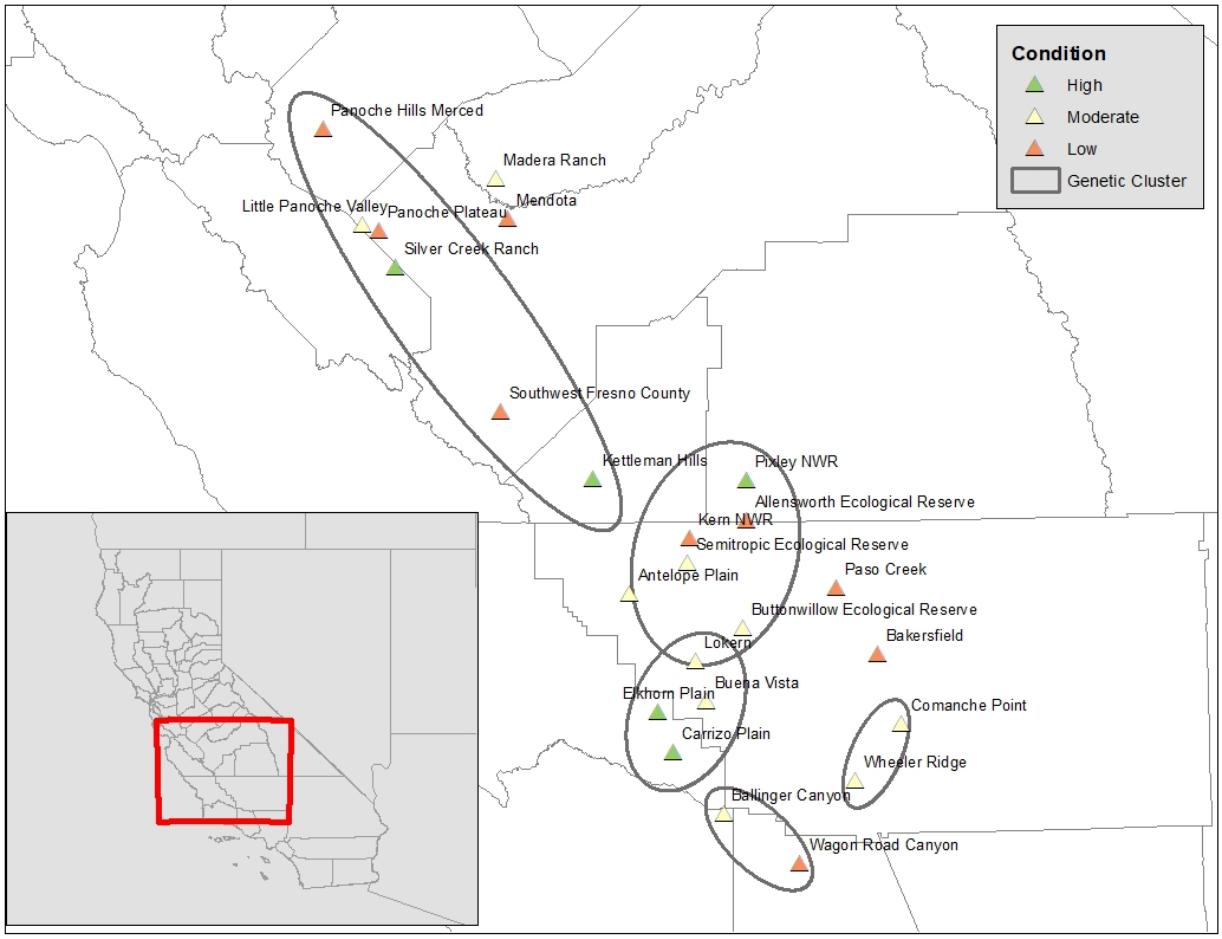

Figure 16. Current condition of blunt-nosed leopard lizard populations, loosely grouped into genetic clusters.

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).

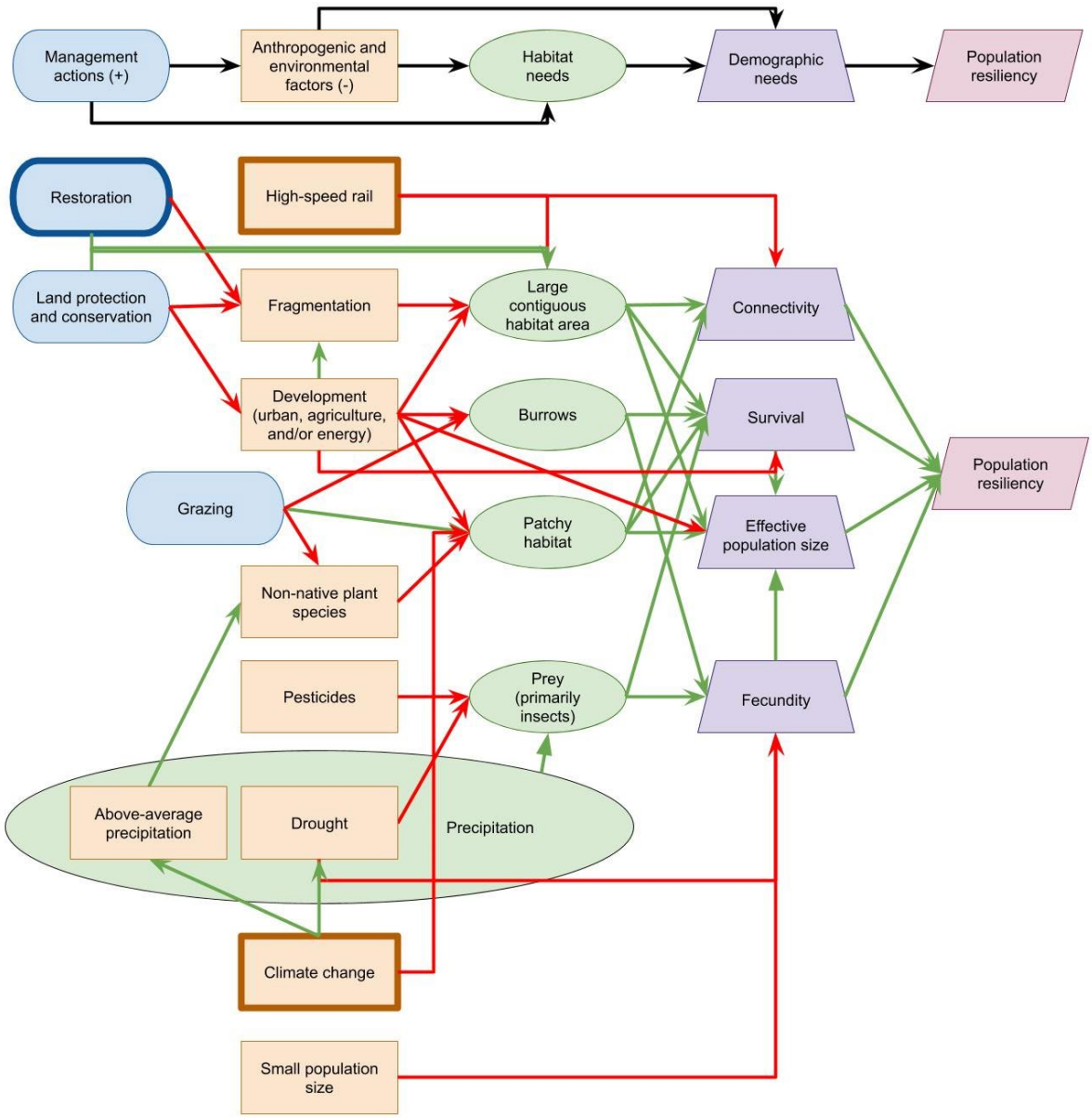

Figure 17. Influence diagram with additional future threats (climate change and the high-speed rail) and management (restoration) highlighted in bold and incorporated into the existing conceptual model. Green lines represent positive relationships, and red lines represent negative relationships.

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 precipitation and temperature, 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 Celcius (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, allowing them to continue foraging and/or mating (Germano 2019, p. 436). 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. Behavioral flexibility could also involve shifts in daily activity to earlier in the day.

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, although we are unaware of reports on specific responses of the species to fire.

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 habitat on privately held lands. Although agricultural development is expected to continue, models generally predict an increase in fallowed croplands (see *Strategic Retirement and 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). Isolated fallowed agricultural lands are unlikely to be used by blunt-nosed leopard lizards without active restoration. 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). 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.

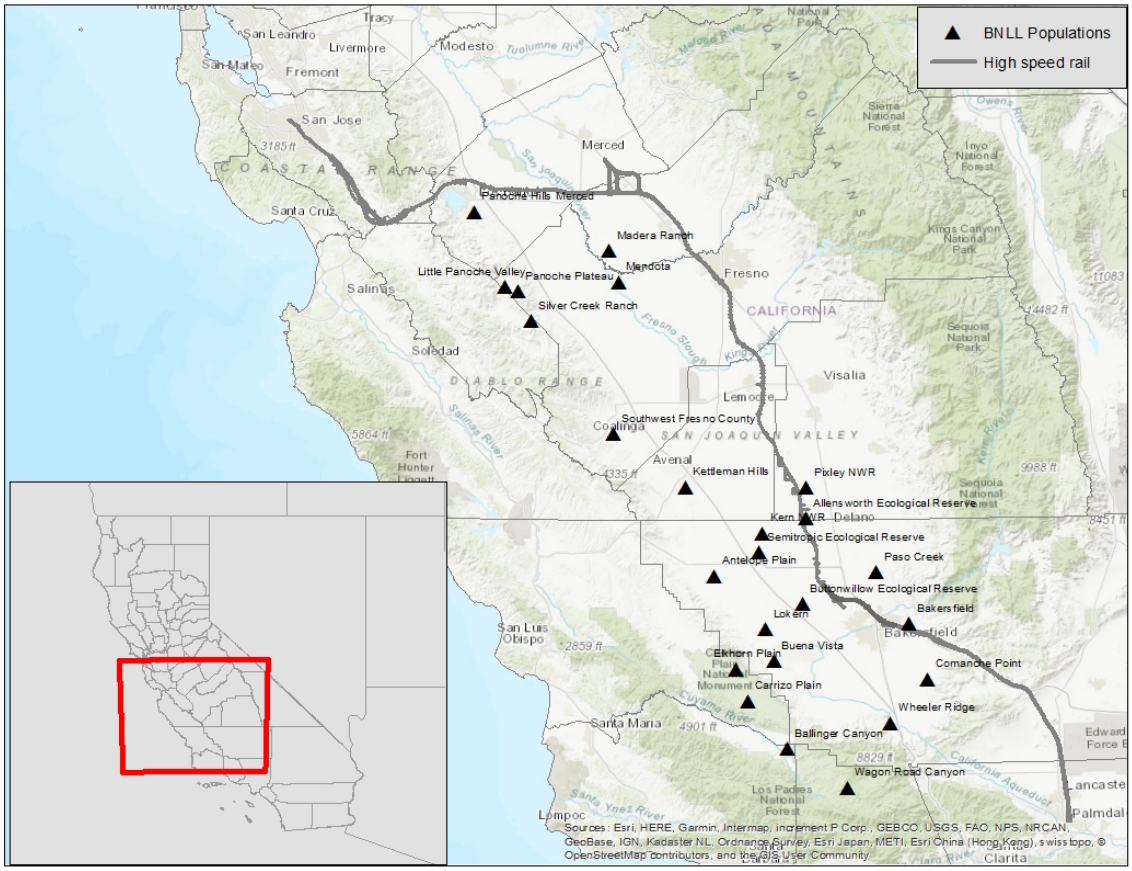

Figure 18. Planned route for the high speed rail. The current route crosses close to Allensworth Ecological Reserve, cutting off this population and the population at Pixley NWR from other populations including Semitropic Ecological Reserve.

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. 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. 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.

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*. (2017, Fig. 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*. 2017, 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*. (2017, 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 12.

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*. (2017, 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*. (2017), 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*. (2017), 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 13.

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 14.

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 15.

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 16). 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 by dry conditions 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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Reviewer Name	Chapter	Page	Line #	Comment
D. Germano	2			description of coloration would benefit from incorporating information from Germano and Williams 2007
D. Germano	3			Habitat: The section on shrubs implies shrubs are a necessary component for BNLL survival. Even though BNLL use shrubs when available, shrubs may not be necessary in the strictest sense. Apparently healthy BNLL populations have survived for decades in large shrubless areas. I suggest changing the tone of this section a bit to emphasize that shrubs may not be an absolute necessity for BNLL survival.
D. Germano	3	28		My concern above is incorporated into the beginning of Individual Needs section. It still might be better to note the abundance of BNLL in shrubless areas in the earlier section more forcefully.
	4	36		In first paragraph under Habitat Modification and Destruction, change Germano and Rathbun 2011 to Germano et al. 2011.
	4	53		"Further, evidence that blunt-nosed leopard lizards can dig their own burrows to lay eggs and for brumation make it less practical…..." Although the point could be made earlier, BNLL also use their own burrows along with rodent burrows during the active season, not just for egg laying or brummation. I saw this several times while radio-tracking on the Lokern. The point is, which you have stated, that BNLL do not absolutely relie on rodent burrows.
	4	54		"….fecundity is addressed through our inclusion of precipitation in the table, because drought years are associated with low reproductive success." Another point to be made is that what can be considered drought (much below average rainfall) does not always lead to low reproduction. Timing of rains can be important. On the Lokern reference site in 2015 and 2016, good numbers of hatchling/young BNLL were found by Erin Tennant and her crews. Both years were considered drought years but herbaceouse plants were well represented and in fact not dense (good BNLL conditions). You are doing a good job trying to tie this altogether: Just be aware of the complications.
	4	58		To what does the reference Craig and Bailey 2016 refer? Do you mean Bailey and Germano 2016?
	5	66		Habitat modification and destruction…….to continue in blunt-nosed leopard habitat,…. Insert "unprotected" (habitat). As it reads, it seems all habitat will have development

Re: Peer Review Request from USFWS - Blunt-nosed Leopard Lizard

Westphal, Michael F <mwestpha@blm.gov>

Thu 4/16/2020 11:27 PM

To: Aguilera, Amber <amber_aguilera@fws.gov>

8 attachments (5 MB)

Ivey et al 2020.pdf; Lortie et al 2020.pdf; Lortie_et_al-2017-Ecology_and_Evolution.pdf; Lucero et al 2019.pdf; Statham et al 2020.pdf; Reviewer Comment Matrix Westphal BNLL 4 16 2020.xlsx; LDNe summary table.xlsx; BNL COI_form_peerreview_Westphal_signed.pdf;

Hi Amber,

Please find attached my review of the blunt-nosed leopard lizard SSA.

This is a great document, a huge resource for anyone interested in the species, it will guide us for years. Kudos to the team that drafted it!

I am attaching several papers on BNLL that should be cited in the document as well as a table of effective population sizes calculated by Jon Richmond ("LDNe summary")

Your COI form would not let me type into the fields so Ihad to build a new one in Word YOU OWE ME!!!

Thanks again for letting me review this, a culmination of something I have been working towards for a long time.

Cheers,

Mike

****

Michael F. Westphal -- Acting California State Lead for Listed Species
Bureau of Land Management -- California State Office

mwestpha@blm.gov
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From: Aguilera, Amber <amber_aguilera@fws.gov>
Sent: Thursday, April 16, 2020 4:25 PM
To: Westphal, Michael F <mwestpha@blm.gov>
Subject: Re: Peer Review Request from USFWS - Blunt-nosed Leopard Lizard

Hi Mike,

That sounds great!!!

Thank you and take care,
Amber

Reviewer Name	Chapter	Page	44:75-93
Westphal	3	28	Westphal et al (2018 p 12159) do not invoke "persisent populations without this resource" (=shrubs) but rather cite the low use of shrubs by some individuals as evidence that a population could theoretically exist in shrubless areas. The intention of this observation was to highlight the population-scale resilience of the species over some undefined temporal scale should BNLL be deprived of a preferred habitat element. The primary conclusion of Westphal et al 2018 is that lizards actively choose to be close to shrubs. Germano & Rathbun 2016, in the right column of p 433, do invoke "robust populations" in shrubless areas (as an implicit pers comm) to defend their perspective that G. sila does not "need" shrubs, and would be the more appropriate citation here. However -- and this is an important point -- this SSA should also note that the landscape described in Germano & Rathbun 2016 is the same study site as in Germano 2019, wherein the author notes in detail that the shrubless landscape being used by BNLL was converted to grassland by recent wildfires. Populations of species can remain on converted land for a period after the conversion event (and even experience short-term booms due to various kinds of ecological release) but the long-term resilience of a species on a permanently converted landscape cannot be taken for granted. I would like to note also that the reference of Germano & Rathbun 2016 to shrubless landscapes does not take into account the long-term recent anthropogenic conversion of shrublands to grasslands in the San Joaquin Desert via wildfires or deliberate removal by ranchers ("chaining.") It is not clear how much, if any, unshrubbed habitat existed primordially within the historical San Joaquin Desert. With respect to the importance of shrubs in BNLL landscapes, two published papers not cited in this document should be cited here and elsewhere in the SSA: 1. Ivey KN, Cornwall M, Crowell H, Ghazian N, Nix E, Owen M, Zuliani M, Lortie CJ, Westphal M, Taylor E. 2020. Thermal ecology of the federally endangered blunt-nosed leopard lizard (Gambelia sila). Conservation Physiology, Volume 8, Issue 1, 2020, coaa014, https://doi.org/10.1093/conphys/coaa014 2. Lortie CJ, Braun J, Westphal M, Noble T, Zuliani M, Nix E, Ghazian N, Owen M, Butterfield HS. 2020. Shrub and vegetation cover predict resource selection use by an endangered species of desert lizard. Nature Scientific Reports 10 article number 4884. The compelling evidence that BNLL associates preferentially with shrubs suggests an adaptive response to heterogenrous habitats. Although BNLL may not be an obligate shrub species at the individual level, shrubs should nonetheless be included as a 'need' due to their importance to the species at the population level. Identifying this aspect of their ecology in this SSA will be *crucial* to guiding and funding appropriate habitat restoration and the promotion of habitats that will buffer the species against climate change.

Westphal		28	We know much more about thermal needs of BNLL from both laboratory and field experiments than transmitted in Germano 2019. The ranges of BNLL thermal preference and tolerance have been explicitly described(Ivey et al 2020, above) and are crucial factors of survival. Temperature must *always* be denoted as a "need" of diurnal desert lizards in the face of climate change, and this is widely acknowledged among lizard ecologists -- Ref Ivey et al 2020, but also Sinervo et al 2010 and an exceptionally large body of literature on lizard thermal ecology.
Westphal		28	With respect to prey items: the observation that BNLL has a number of species represented in its diet, or that diet varies seasonally, does not by itself suggest that the species forages opportunistically.
Westphal		30	The partial sentence: "Although blunt-nosed leopard lizards probably occurred in connected populations throughout the historical range (Richmond et al. 2017, p. 3628)…" is misleading. The sentence should be: "Although blunt-nosed leopard lizards probably occurred in connected populations (within major subpopulations) throughout the historical range (Richmond et al. 2017, p. 3628),
Westphal		30	This sentence would better reflect the findings of the cited study by stating: "The genetic study revealed historical population connectivity within clusters and deep primordial divisions between the clusters (Richmond et al. 2017, pp. 3624-2627)."
		31	The following partical sentence is slightly awkward (and inaccurate): "The northern cluster had additional substructure in the Panoche Plateau using microsatellite data…" I suggest this revision: "Within the northern cluster, microsatellite data recovered additional structure in the Panoche Hills region..."
		31	This clip: "Because of habitat fragmentation, populations within these clusters are for the most part demographically independent," is a little misleading because it implies that recent anthropogenic actions have caused the fragmentation, whereas the finding in Richmond et al suggest both recent fragmentation and primoridal separation may have played a role in the structuring of the Panoche Hills populations.
Westphal		32	This is the proper place to introduce the concept that, due to the primoridal structure among the subclades within the species, redundancy is scaled. In other words, populations are redundant within the major clades, but not among them -- the loss of populations in the Northern clade are not buffered or "backed up" (in the data sense) by populations in the Southern clade, because loss of a Northern population entails loss of unique alleles. The major clades recovered by Richmond et al 2017 strongly imply the partitioning of the species into different management units, and the DPS designation provision in the ESA would be the best mechanism to codify these important partitions.

		34	Jon Richmond has calculated effective population sizes for a number of populations of BNLL and these can be applied to roughly calculate density at some places where the patch occupied by BNLL is well delimited (eg Panoche Plateau, Silver Creek Ranch). I have attached his table to the email that conveys these comments.
		35	Thermal environment should have a box in this (otherwise excellent) chart
		37	I have personally observed 2 roadkilled BNLL over the years, one on Soda Lake Road on the Carrizo Plain, and one on a dirt farm road next to the Allenworth ER.
		40	In the service of transparency, it should be noted here under the discussion of solar development that USFWS permitted a solar project in Panoche Valley that, by stipulation, was identified as occupied habitat within the Biological Opinion, and indeed individual lizards were found within the construction site subsequent to the permit being issued (David Hacker, pers. comm).
		40	It should be additionally noted that nonnative grasses have complex interactions with important BNLL habitat elements such as shrubs. A study that explicitly studied the interaction of nonnative grasses with BNLL - occupied Ephedra should be cited: Lucero JE, Noble T, Haas S, Westphal M, Butterfield HS, Lortie CJ. The dark side of facilitation: native shrubs facilitate exotic annuals more strongly than native annuals. NeoBiota
		40	Nonnative grasses are not, as stated here, addressed under Individual and Populations Needs previously in the SSA. Also, Filazzola et al 2017 found a negative correlation between RDM and BNLL and should be cited here.
		43	FYI this year BLM is funding a large scale collaboration among several labs to study the link between malathion and prey abundance for BNLL
		51	Use of scat detection dogs for obtaining genetic samples has been optimized and will be an important tool for censusing BNLL going forward. Citation: Statham MJ, (Smith) Woollett DA, Pfeiffer J, Richmond J, Whitelaw A, Richards NL, Westphal MF, Sacks BN. 2019. Noninvasive Identification of Herpetofauna: Pairing Conservation Dogs and Genetic Analysis. Journal of Wildlife Management https://doi.org/10.1002/jwmg.21772
		53	Westphal et al 2018 and Ivey et al 2020 contain a wealth of data showing the dependence of BNLL on burrows and anecdotal claims about lizards self-burying CANNOT supersede this conclusion, which is based on large, well-analyzed data sets and which, in the case of Ivey et al 202, directly tie burrow use to crucial thermoregulatory needs of the species.
		58	Craig and Bailey should be Bailey & Germano (lol this is the kind of mistake I make)
		44	The SSA erroneously claims that some federally-owned lands have no mandate for biodiversity protection. All Federal agencies are mandated under the Federal ESA to conserve (=recover, by definition of conserve, in ESA) endangered species.

Westphal		65	"we are unaware of reports on specific responses of the species to fire." Germano 2019 explicitly notes that BNLL use a landscape converted to grassland by recent fires. Also, resilience of BNLL habitat to fire and other disturbance should be addressed. The folowing paper, which addresses habitat resilience in service of a population of BNLL, should be cited: Lortie CJ, Gruber E, Filazzola A, Noble T, Westphal M. 2017. The Groot Effect: Plant facilitation and desert shrub regrowth following extensive damage. Ecology and Evolution 2017:1-10
Westphal			A general note: one challenge to managing BNLL 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. This is a critical management issue at the Madera site but has also been encountered at Tejon Ranch and the Panoche Valley Preserve.