Species Status Assessment Report for the Plateau Spot-Tailed Earless Lizard (*Holbrookia lacerata*)

Version 1.0

Photo: © Michael Price

June 2023
U.S. Fish and Wildlife Service
Austin Ecological Services Field Office
Austin, Texas

Acknowledgements

This document was prepared by Maritza Mallek (U.S. Fish and Wildlife Service (USFWS)-Austin Ecological Services Field Office).

We greatly appreciate the assistance of:

- Dr. Paul Crump (Texas Parks and Wildlife Department (TPWD)) Dr. Toby Hibbitts (Texas A&M University (TAMU)), Dr. Carlos Portillo-Quintero (Texas Tech University (TTU)), Nathan Rains (TPWD) Dr. Wade Ryberg (TAMU), and Dr. Danielle Walkup (TAMU) for review of the analytical framework.
- Dr. Zara Dowling (University of Massachusetts-Amherst), Chelsea Jones (Texas Comptroller), Dr. Toby Hibbitts (TAMU), Dr. Jake Jackson (Texas Comptroller), Dr. Travis LaDuc (University of Texas, Austin (UT-Austin)), Dr. Matthew Moskwitz (USFWS), Dr. Jon Paul Pierre (Natural Resources Conservation Service), Dr. Wade Ryberg (TAMU), Dr. Danielle Walkup (TAMU), and Dr. Brad Wolaver (Southwest Hydrology Consulting) for assistance accessing and analyzing datasets or literature.
- Diane Barber (Fort Worth Zoo), Trey Barron (TPWD), Jenny Blair (Blair Wildlife Consulting) Joshua Blanek (Texas A&M AgriLife Extension), Blake Hendon (TPWD), Dr. Scott Henke (TAMU-Kingsville), Dr. Toby Hibbitts (TAMU), Dr. Jake Jackson (Texas Comptroller), Dr. Samantha Kahl (Blackburn College), Dr. Travis LaDuc (UT-Austin), John McLaughlin (TPWD), John McEachern (TPWD), Joyce Moore (TPWD), Stoney Newberry (TPWD), Kory Perlicheck (TPWD), Dr. Carlos Portillo-Quintero (TTU), Nathan Rains (TPWD), Dr. Wade Ryberg (TAMU), Dr. Danielle Walkup (TAMU), and Ian Witt (TPWD) for providing information about Plateau spot-tailed earless lizard biology and ecology, and/or habitat conditions.
- Nathan Allan (USFWS), Dr. Justin Bohling (USFWS), Dr. Jonathan Cummings (USFWS), Dr. Brenna Forester (USFWS), Dr. Ashley Goode (U.S. Geological Survey (USGS), Florida Cooperative Fish and Wildlife Research Unit), Dr. Travis LaDuc (UT-Austin), Dr. Connor McGowan (USGS, Florida Cooperative Fish and Wildlife Research Unit), Sandra Lee (USFWS), and Michael Warriner (USFWS) for helpful discussions that improved the report.
- Dr. Paul Crump (TPWD), Chelsea Jones (Texas Comptroller), Sandra Lee (USFWS), and Nathan Rains (TPWD) for assistance in identifying potential contacts.
- iNaturalist users nightglowreptiles and johnwilliams for Plateau spot-tailed earless lizard locality information and habitat conditions.
- Dr. Javan Bauder (University of Arizona), Dr. Scott Henke (TAMU-Kingsville), Dr. Travis LaDuc (UT-Austin), Dr. Carlos Portillo-Quintero (TTU), Dr. Corey Roelke (University of Texas, Arlington), and Dr. Geoffrey Rogers Smith (Denison University), who completed peer or partner reviews and provided helpful comments on the draft report.

Suggested Citation: U.S. Fish and Wildlife Service. 2023. Species Status Assessment Report for the Plateau Spot-Tailed Earless Lizard (*Holbrookia lacerata*). Version 1.0. Species Status Assessment Reports. Austin, Texas Ecological Services Field Office.

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Executive Summary

This report is intended to provide the biological support for the decision on whether or not to propose to list the species as threatened or endangered under the Endangered Species Act of 1973, as amended (Act). The process and this SSA report do not represent a decision by the U.S. Fish and Wildlife Service (Service) regarding whether to list a species under the Act. Instead, this SSA report provides a review of the best available information strictly related to the biological status of the Plateau spot-tailed earless lizard. The report summarizes a species status assessment (SSA) conducted for the Plateau spot-tailed earless lizard (*Holbrookia lacerata*), in which we considered what the species needs to maintain viability by characterizing the status of the species in terms of its resiliency, redundancy, and representation (together, the three Rs). Resiliency is the ability of a species to withstand environmental stochasticity, periodic disturbances within the normal range of variation, and demographic stochasticity. It is examined at the population analysis unit level. Redundancy is the ability of a species to withstand catastrophes. Representation is the ability of a species to adapt to both near-term and long-term changes in its physical and biological environments. Redundancy and representation are examined at the regional level and across the species' range.

Species Ecology and Needs

The Plateau spot-tailed earless lizard is a small, ground-dwelling lizard that is associated with the grasslands of central and western Texas, primarily within the Edwards Plateau region. It may also be found in areas dedicated to row-crop agriculture. Individual Plateau spot-tailed earless lizards spend most of their time underground and are able to self-bury under loose soil or utilize existing animal burrows or soil fissures for shelter. They need minimal woody plant canopy cover, open areas, and warm, sunny days so that they can bask and increase their internal body temperature before moving around on the surface. The Plateau spot-tailed earless lizard is believed to be a sit-and-wait predator and an "opportunistic generalist" in terms of diet, which includes a variety of arthropods (e.g., beetles, grasshoppers, and termites).

Plateau spot-tailed earless lizard species-level needs are summarized in Table 2.2. Ultimately, Plateau spot-tailed earless lizard viability depends on there being a sufficient number and distribution of healthy populations to ensure that the species can withstand annual variation in its environment (i.e., resiliency), catastrophes (i.e., redundancy), and novel biological and physical changes in its environment (i.e., representation).

Table 1.1. Plateau spot-tailed earless lizard species level needs, based on the 3 Rs of resiliency, redundancy, and representation.

3 Rs	Requisites of long-term viability
Resiliency	• Healthy populations (stable to increasing abundance) occupying habitats that support key resource functions (e.g., breeding, feeding, sheltering) • Potential for periodic dispersal or migration events across population units
Redundancy	• Sufficient distribution of individuals and populations to recover from catastrophic events
Representation	• Maintain healthy populations across the full range of habitats currently supporting the species • Maintain population abundance and intrapopulation connectivity at sufficient levels to ensure healthy genetic diversity and maintain potential adaptive capacity in the extant populations

Species Range, Distribution, and Population Analysis Units

The historical range of the Plateau spot-tailed earless lizard is centered on the Edwards Plateau. The Pecos River, Colorado River, and Balcones Escarpment form the boundaries of the species' range. There is some uncertainty regarding the extent of potential range contraction over the past several decades as the species' range is expansive and it has proven difficult for researchers to access private lands for survey efforts. Recent surveys were unable to confirm the persistence of the Plateau spot-tailed earless lizard within much of the Texas Hill Country region, presumably due to urban development and the succession of grasslands into tree- and shrub-dominated landscapes. We used recent localities (observations from between 2008 and 2022) and potential annual movement data to develop a set of 16 population analysis units, which are the focal point of our resiliency analysis (Figure ES.1).

Influences on Viability

The primary factor impacting the viability of the Plateau spot-tailed earless lizard is the loss or degradation of suitable habitat. This habitat consists of open areas for basking, foraging, and movement, and of soils that allow access to the subsurface, which is used for sheltering and nesting. Above-ground habitat is characterized by low levels of overstory shrubs and trees, and a density of grasses, forbs, and other plants that allows for patches of bare ground. Subsurface habitat is characterized by the presence of either numerous animal burrows or fissures, or friable soils that allow the Plateau spot-tailed earless lizard to self-bury and to dig nests. Both historical and current anthropogenic influences, including development, suppression of disturbance processes, and grazing practices, have directly and indirectly impacted the availability of suitable habitat with the Plateau spot-tailed earless lizard range. A second important factor impacting viability is mortality associated with vehicle strikes to Plateau spot-tailed earless lizards using roadways for basking, foraging, and interacting with other individuals.

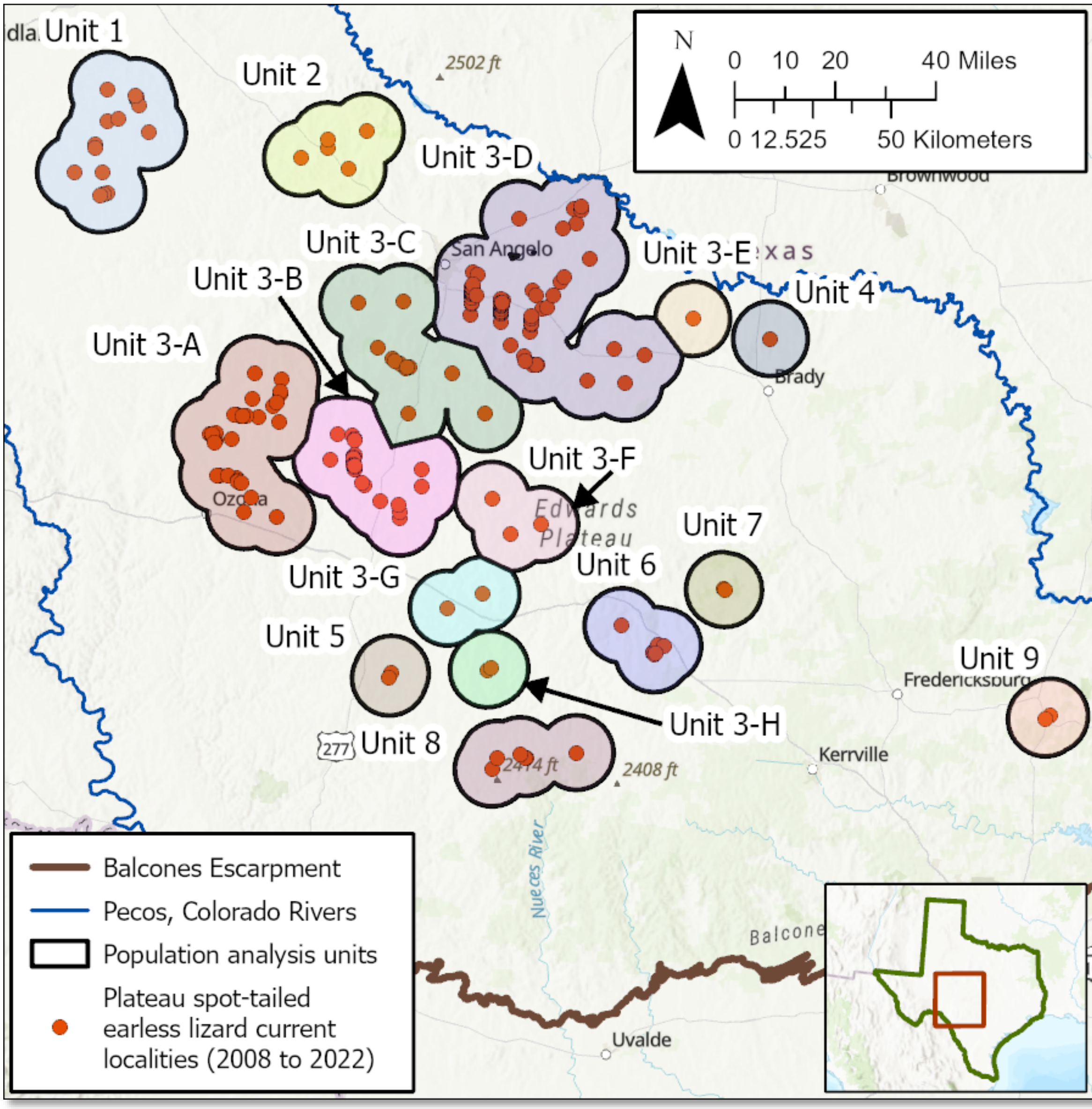

Figure ES.1. Population analysis units used in the Plateau spot-tailed earless lizard species status assessment. Orange circles represent current localities, collected from 2008–2022. The river (shown as a thick blue line) in the western portion of the map is the Pecos River, and the one across the northeast portion of the map is the Colorado River. The Balcones Escarpment is shown as a thick brown line across the southern portion of the map.

Current Condition

To evaluate the current condition of the Plateau spot-tailed earless lizard, we selected one demographic factor (occurrence) and three habitat factors (traffic intensity, suitable habitat, and biophysical setting) for our resiliency analysis. Based on the available data and our understanding of Plateau spot-tailed earless lizard ecology, we developed a basis for assigning a resiliency category for each metric at the population analysis unit level. The resiliency category reflects a qualitative determination of the likelihood that the Plateau spot-tailed earless lizard would be extirpated from a given population analysis unit within 20 years. A population analysis unit characterized as high resiliency has a low likelihood of extirpation at the scale of that population analysis unit, while a population analysis unit characterized as low resiliency has a relatively higher likelihood of extirpation. For redundancy and representation, we assessed the number and distribution of population analysis units in different resiliency categories across the known historical distribution of the Plateau spot-tailed earless lizard. The species is distributed across most of its historical range, multiple ecoregions and continues to occur across a wide range of temperature and precipitation regimes.

Based on our analysis, the current resiliency of the Plateau spot-tailed earless lizard is characterized by having four population analysis units (50% of the total area) in the High Resiliency category, nine (41% of the area) in the Moderate Resiliency category, and three (9% of the area) in the Low Resiliency category (The proportion of area value given in this context is rounded to the nearest whole number.). Given the current conditions of the population analysis units for the Plateau spot-tailed earless lizard, the majority of population analysis units and a majority of the area in population analysis units are characterized by populations with the ability to withstand stochastic events. The species currently has some redundancy within three of the six ecoregions in which it occurs and across its range. Current representation for the Plateau spot-tailed earless lizard is characterized by its occurrence in High or Moderate Resiliency condition within five of the six of the historically occupied ecoregions, and that 13 of 16 population analysis units are in either High or Moderate Resiliency condition. The Plateau spot-tailed earless lizard has presumably maintained representation similar to historical levels in that it is distributed throughout most of its known historical range, and 91% of the area in population analysis units is in either the High or Moderate Resiliency category.

Future Condition

To construct plausible future scenarios, we considered the potential for changes in magnitude and severity of stressors in the future, and correspondingly, how those stressors may negatively impact the species' habitat and demographic needs. As in the current conditions, we evaluated the species' viability in terms of resilience at the population scale (i.e., analysis units), and representation and redundancy at the species scale (i.e., number, proximity, and condition of populations across the species range). We constructed two plausible future scenarios and projected the response of the Plateau spot-tailed earless lizard to the environmental conditions in 2050 in terms of the three Rs, and ultimately, species viability. Scenario 1 corresponds to the lower limit of plausible impacts and Scenario 2 corresponds to the upper limit of plausible impacts, given the best available data (Table ES.1).

Table ES.1. Description of the conditions projected to occur for each influencing factor in the two future scenarios. We also identify the primary metric impacted by a given influencing factor.

Habitat Metric	Influencing Factor	Scenario 1	Scenario 2
Traffic Intensity	Road Mortality	Lower boundary for the 80% prediction interval for the Traffic Intensity index at timestep 2050.	Upper boundary for the 80% prediction interval for the Traffic Intensity index at timestep 2050.
Habitat Suitability	Shrub and Tree Encroachment	Lower boundary for the 95% prediction interval for the average area without woody plant cover at timestep 2050.	Projected average area without woody plant cover at timestep 2050.

Under Scenario 1, we project future declines in the Overall Resiliency of the Plateau spot-tailed earless lizard in four population analysis units at timestep 2050 based on forecasted changes in road mortality and woody vegetation encroachment (Table ES.2). Under this scenario, the overall resiliency of the Plateau spot-tailed earless lizard is characterized by having three population analysis units (38% of the area) in the High Resiliency category, seven population analysis units (38% of the area) in the Moderate Resiliency category, and six population analysis units (23% of the area) in the Low Resiliency category. In total, 10 of 16 population analysis units are categorized as High or Moderate Resiliency at timestep 2050; the majority thus have the ability to withstand stochastic events. In this scenario, as with the current conditions, the species has redundancy within three of the six ecoregions in which it occurs, and across its range. The Plateau spot-tailed earless lizard is projected to experience minimal changes in representation in this future scenario because it will continue to be distributed throughout most of its known historical range, and 77% of the area in population analysis units is in either the High or Moderate Resiliency category (Table ES.3).

In Scenario 2, we project declines in the Overall Resiliency of the Plateau spot-tailed earless lizard in seven population analysis units at timestep 2050 based on forecasting larger changes in road mortality and woody vegetation encroachment (Table ES.2). In this future scenario, the overall resiliency of the Plateau spot-tailed earless lizard is characterized by having three population analysis units (38% of the area) in the High Resiliency category, four population analysis units (31% of the area) in the Moderate Resiliency category, and nine population analysis units (31% of the area) in the Low Resiliency category. In total, the number of population analysis units categorized as High or Moderate Resiliency is 7 of 16 at timestep 2050; thus, fewer than half are assumed to be able to withstand stochastic events. In this scenario, the species has some redundancy within one of the six ecoregions in which it occurs but maintains redundancy at the scale of the entire species' range. The Plateau spot-tailed earless lizard is projected to maintain some representation in this future scenario because it will continue to be distributed throughout most of its known historical range, and 69% of the area in population analysis units is in either the High or Moderate Resiliency category (Table ES.3).

Table ES.2. Overall Resiliency categories for Plateau spot-tailed earless lizard population analysis units under current and future projections in 2050. Compared to the current conditions, in Future Scenario 1, four units have lower resiliency, while in Future Scenario 2, seven units have lower resiliency. Arrows in the columns for Scenarios 1 and 2 indicate changes from the current resiliency category.

Population Analysis Unit	Unit Area (km^2)	Current Overall Resiliency	Future Scenario 1 Overall Resiliency	Future Scenario 2 Overall Resiliency
Unit 1	1,823	High	High	High
Unit 2	1,152	Moderate	Moderate	Moderate
Unit 3-A	2,321	High	Moderate ↓	Moderate ↓
Unit 3-B	1,686	High	High	High
Unit 3-C	2,221	Moderate	Moderate	Moderate
Unit 3-D	3,985	High	High	High
Unit 3-E	424	Moderate	Moderate	Moderate
Unit 3-F	947	Moderate	Low ↓	Low ↓
Unit 3-G	712	Moderate	Low ↓	Low ↓
Unit 3-H	478	Moderate	Moderate	Low ↓
Unit 4	447	Moderate	Moderate	Low ↓
Unit 5	489	Moderate	Moderate	Low ↓
Unit 6	852	Low	Low	Low
Unit 7	458	Low	Low	Low
Unit 8	1,113	Moderate	Low ↓	Low ↓
Unit 9	494	Low	Low	Low

Table ES.3. Summary of the number of units and the proportion of the area covered by all units assigned to a particular resiliency category for the current conditions, future scenario 1, and future scenario 2. The proportion of area value given in this context is rounded to the nearest whole number.

Overall Resiliency	Current		Future Scenario 1		Future Scenario 2	
	Number of Units	Proportion of Area in All Units	Number of Units	Proportion of Area in All Units	Number of Units	Proportion of Area in All Units
High Resiliency	4	50%	3	38%	3	38%
Moderate Resiliency	9	41%	7	38%	4	31%
Low Resiliency	3	9%	6	23%	9	31%

1 Introduction: Analytical Framework

The SSA report, the product of conducting an SSA, is intended to be a concise review of the species' biology and factors influencing the species, an evaluation of its biological status, and an assessment of the resources and conditions needed to maintain long-term viability. The intent is for the SSA report to be easily updated as new information becomes available, and to support all functions of the Endangered Species Program. As such, if the Plateau spot-tailed earless lizard is listed under the Act, the SSA report will be a living document upon which other documents such as recovery plans and 5-year reviews will be based, supporting future decisions about the species' listing status and, eventually, a post-delisting monitoring plan.

The objective of this SSA report is to thoroughly describe the viability of the Plateau spot-tailed earless lizard (*Holbrookia lacerata*) based on the best scientific and commercial information available (Smith et al. 2018, entire). Through our assessment, we determined what the species needs to support viable populations, its current condition in terms of those needs, and its forecasted future condition under plausible future scenarios. In conducting this analysis, we took into consideration the likely changes that are happening in the environment – past, current, and future – to help us understand what factors drive the viability of the species. For the purpose of this assessment, we define viability as the ability of the Plateau spot-tailed earless lizard to sustain populations in their natural habitat over time. Viability is not a specific state, but rather a continuous measure of the likelihood that the species will sustain populations over time (U.S. Fish and Wildlife Service 2016, p. 9). Using the SSA framework (Figure 1.1), we consider what the species needs to maintain viability by characterizing the status of the species in terms of its resiliency, redundancy, and representation (Wolf et al. 2015, entire; U.S. Fish and Wildlife Service 2016, entire).

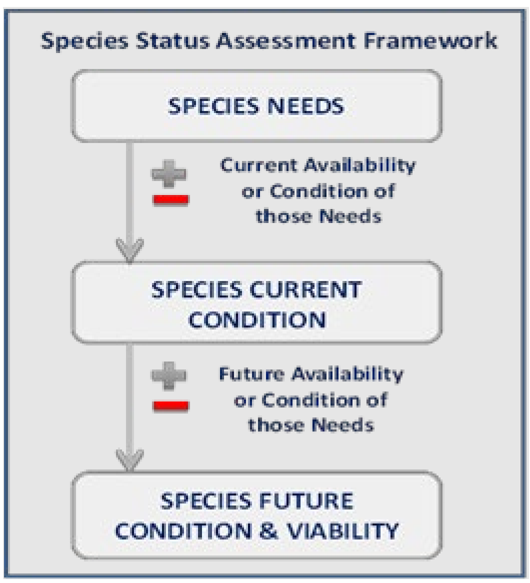

Figure 1.1. Species Status Assessment Framework

- **Resiliency** is the ability of a species to withstand environmental stochasticity (normal, year-to-year variations in environmental conditions such as temperature, rainfall), periodic disturbances within the normal range of variation (fire, floods, storms), and demographic stochasticity (normal variation in demographic rates such as mortality and fecundity) (Redford et al. 2011, p. 40). Simply stated, resiliency is the ability to sustain populations through the natural range of favorable and unfavorable conditions. We can best gauge resiliency by evaluating population level characteristics such as: demography (abundance and the components of population growth rate: survival, reproduction, and migration), genetic health (effective population size and heterozygosity), connectivity (gene flow and population rescue), and habitat quantity, quality, configuration, and heterogeneity.

- **Redundancy** is the ability of a species to withstand catastrophes. Catastrophes are stochastic events that are expected to lead to population collapse regardless of population heath and for which adaptation is unlikely (Mangel and Tier 1993, p. 1083). We can best gauge redundancy by analyzing the number and distribution of populations relative to the scale of anticipated species-relevant catastrophic events. The analysis entails assessing the cumulative risk of catastrophes occurring over time. Redundancy can be analyzed at a population or regional scale, or for narrow-ranged species, at the species level.

- **Representation** is the ability of a species to adapt to both near-term and long-term changes in its physical (climate conditions, habitat conditions, habitat structure, etc.) and biological (pathogens, competitors, predators, etc.) environments. This ability to adapt to new environments—referred to as adaptive capacity—is essential for viability, as species need to continually adapt to their continuously changing environments (Nicotra et al. 2015, p. 1269). We can best gauge representation by examining the breadth of genetic, phenotypic, and ecological diversity found within a species and its ability to disperse and colonize new areas. In the absence of species-specific genetic and ecological diversity information, we evaluate representation based on the extent and variability of the species' morphology, habitat characteristics within the geographical range, or both.

The decision whether to list a species is based *not* on a prediction of the most likely future for the species, but rather on an assessment of the species' risk of extinction. Therefore, to inform this assessment of extinction risk, we describe the species' current biological status and assess how this status may change in the future under a range of scenarios to account for the uncertainty of the species' future. We evaluate the current biological status of the Plateau spot-tailed earless lizard by assessing the primary factors negatively and positively affecting the species to describe its current condition in terms of resiliency, redundancy, and representation (together, the 3Rs). We then evaluate the future biological status of the Plateau spot-tailed earless lizard by describing a range of plausible future scenarios representing a range of conditions for the primary factors affecting the species and forecasting the most likely future condition for each scenario in terms of the 3Rs. As a matter of practicality, the full range of potential future scenarios and potential future conditions for each potential scenario are too large to individually describe and analyze; therefore, our analysis is intentionally limited in scope. These scenarios do not include all possible futures, but rather include specific plausible scenarios that represent examples from the continuous spectrum of possible futures. Consequently, the results of this SSA do not describe the overall risk to the species. Recognizing these limitations, the results of this SSA nevertheless provide a framework for considering the overall risk to the species in listing decisions.

2 Species Ecology and Needs

In this chapter we describe basic biological information about the Plateau spot-tailed earless lizard, including its taxonomic history, genetics, morphological description, and known life history traits. We then outline the resource needs of individuals and populations of the Plateau spot-tailed earless lizard. We focus on those aspects of the life history of the species that are important to our analysis. For further information about the Plateau spot-tailed earless lizard, refer to (Axtell 1956, entire; 1968, entire; 1998, entire; Hibbitts and Hibbitts 2015, pp. 23–42, 108–110; Duran 2017, entire; LaDuc et al. 2018, entire; Hibbitts et al. 2019, entire; 2021, entire; BIO-West Inc. 2020, entire).

Physical Description

The size of adult Plateau spot-tailed earless lizards averages 54 millimeters (mm) (2.1 inches [in]) snout-vent length (SVL); males and females are similarly sized (Axtell 1968, pp. 56.1–56.2; Hibbitts and Hibbitts 2015, p. 108; Hibbitts et al. 2019, pp. 147–148). As depicted in Figure 2.1, Plateau spot-tailed earless lizards have light brown bodies covered in small scales, with irregularly shaped spots or blotches on their back and sides (Hibbitts and Hibbitts 2015, p. 108; Hibbitts et al. 2019, pp. 147–148). These spots are darker than the body color and are outlined by a lighter shade than the general body color (Hibbitts and Hibbitts 2015, p. 108; Hibbitts et al. 2019, pp. 147–148). As illustrated by Figure 2.2, the coloring on the ventral side is white, and the underside of the tail contains up to several dark brown spots. Only the Plateau spot-tailed earless lizard and the Tamaulipan spot-tailed earless lizard have these spots; other congeners (*Holbrookia* spp.) lack them (Cope 1880, pp. 15–16; Axtell 1968, pp. 56.1–56.2). The epithet “earless” refers to the apparent lack of ears visually; in fact, these lizards do have middle and inner ears (Earle 1961, entire; Cox and Tanner 1977, pp. 49–50; Pianka and Vitt 2003, p. 93). Females, and occasionally males, develop a red-orange coloration along their throat and neck during the breeding season; gravid females become pale yellow or yellow-green along the neck and trunk (Axtell 1968, p. 56.1; Hibbitts et al. 2019, p. 148; Figure 2.3). For a more detailed description of the morphological characteristics of the Plateau spot-tailed earless lizard, see Axtell (1968, pp. 56.1–56.2) and Hibbitts et al. (2019, pp. 144–150).

Figure 2.1. Plateau spot-tailed earless lizard from Glasscock County, Texas (Lord 2022). Image by Isaac Lord, some rights reserved (CC BY-NC).

Figure 2.2. Ventral view of Plateau spot-tailed earless lizard from Kimble County, Texas, showing the eponymous spotted tail. This is a male with enlarged post-anal scales and prominent femoral pores (Lively 2018). Image by Joshua Lively, some rights reserved (CC BY-NC).

Figure 2.3. Female Plateau spot-tailed earless lizard from Crockett County, Texas, showing breeding and gravid coloring (Price 2017). Image by Michael Price, some rights reserved (CC BY-NC-ND).

Taxonomy and Genetics

The taxonomy of the Plateau spot-tailed earless lizard has a history of some uncertainty and revision but is not controversial. We use scientific names in this subsection because the species' common names have also been subject to revision. *Holbrookia lacerata* was first described by Cope (1880, pp. 14–16) as one of four *Holbrookia* spp. found in Texas, the others being *H. propinqua*, *H. maculata*, and *H. texana* (now *Cophosaurus texanus*). However, as Axtell (1956, pp. 164–165) documented, Cope's description of the range of *Holbrookia lacerata* (1880, pp. 15–16) was incorrect. Because he described the range of *H. lacerata* as overlapping that of *H. maculata*, for decades most scientists considered *H. lacerata* as a subspecies of *H. maculata* (Axtell 1956, pp. 164–166).

After completing extensive surveys of *Holbrookia* spp. (Axtell 1958, entire), Axtell published a revision of the genus in which *H. lacerata* was shown to not only be a distinct species, but that it was comprised of two subspecies, *H. lacerata lacerata* and *H. lacerata subcaudalis* (Axtell 1956, pp. 167, 172–178). No dispute arose about this revision, and in 1991 Collins (1991, pp. 42–43) suggested that the two subspecies be elevated to species status due to allopatry and morphological differences. Genetic analyses in 2018 (Roelke et al. 2018, pp. 1022–1024) provided additional support for this change. Finally, in 2019 the subspecies known as *H. l. lacerata* and *H. l. subcaudalis* were formally described as full species, based on differences in genetics, morphology, environmental niche, and allopatry (Hibbitts et al. 2019, entire). The new species description provides accounts for *H. lacerata,* with the common name Plateau spot-tailed earless lizard, and *H. subcaudalis,* with the common name Tamaulipan spot-tailed earless lizard. The Society for the Study of Amphibians and Reptiles periodically publishes a list of the scientific and common names of amphibians and reptiles of the United States and Mexico, but the most recent version (Crother 2017, p. 46) is older than the recent revisions by Hibbitts et al. (Hibbitts et al. 2019, pp. 147–149), and therefore does not yet reflect the elevation of the two subspecies to species. There is no indication that the elevation to species status is controversial.

Recent genetic studies do not indicate substantial genetic variation within sampled Plateau spot-tailed earless lizards (Hibbitts et al. 2019, pp. 143–144; Firneno et al. 2022, pp. 29–30). However, these studies were not able to incorporate samples from the easternmost population in Blanco County, Texas (Hibbitts et al. 2019, p. 140; Firneno et al. 2022, p. 28). We make no assumptions about the presence or absence of genetic differentiation in the areas not sampled.

Life History

Life history information for the Plateau spot-tailed earless lizard comes from both the study of captive individuals and field observations. Older publications do not always differentiate between the Plateau spot-tailed earless lizard and the Tamaulipan spot-tailed earless lizard, so there is some uncertainty in values reported simply for "spot-tailed earless lizards," because the life history characteristics of the two species are similar, but not identical. Most of the information from captive individuals comes from the Fort Worth Zoo, which maintained and bred a small population of each species from 2013 to 2018 (U.S. Fish and Wildlife Service 2022b, p. 1, pers. comm.).

The active period for the Plateau spot-tailed earless lizard is thought to be based on the presence of sunlight and warm temperatures (Axtell 1956, p. 177). Most surveys and occurrence records for Plateau spot-tailed earless lizard span the months of April to September (LaDuc et al. 2018, p. 37; Hibbitts et al. 2021, p. 501), so we are confident that the active period includes these dates. We have one observation in our occurrence dataset from March, and we know of an anecdotal observation in Sterling County, Texas, on a warm February day (Texas Parks and Wildlife Department 2021b; McEachern 2022, p. 3, pers. comm.). Therefore, it is possible that the active period begins earlier than April and extends past September, and that individual Plateau spot-tailed earless lizards may occasionally emerge during the winter months. In 2021, Plateau spot-tailed earless lizards kept in an outdoor enclosure in Kingsville, Texas, stopped emerging above ground by early November (Henke 2022a, p. 1, pers. comm.). We assume that, like other lizards found in temperate North America, the Plateau spot-tailed earless lizard brumates (becomes inactive) during the colder months of the year, and does so by burying itself below ground or by occupying an unoccupied burrow dug by another species (Axtell 1954, p. 42; Pianka and Vitt 2003, pp. 127–128). Again, temperature and sunlight likely drive this behavior, and so the exact dates of the average active period may vary slightly across the species' range.

Reproduction

Mating and egg-laying probably begins soon after Plateau spot-tailed earless lizards emerge from their winter rest period. Gravid (pregnant) females have been observed as early as April during the first surveys of the year (BIO-West Inc. 2020, p. 27). Breeding coloration and courtship have been observed for the Plateau spot-tailed earless lizard from April through July (BIO-West Inc. 2020, p. 27). In results reported across both species, juveniles were detected from June to September (LaDuc et al. 2018, p. 37). This aligns well with egg incubation times reported from captive lizards, which range from 35–44 days (Axtell 1956, p. 178; Duran 2017, p. 5). Thus, breeding and hatching of young can occur throughout the spring and summer months.

In captivity, females as young as six months were able to become pregnant and lay eggs (Duran 2017, p. 5). These lizards were always over 6 grams (g) (0.2 ounces (oz)) in weight (U.S. Fish and Wildlife Service 2022b, p. 2, pers. comm). At the Fort Worth Zoo, Tamaulipan spot-tailed earless lizards (the species for which information was readily available) over 6 g (0.2 oz) laying their first clutch ranged in size from 50.9–62.7 mm (2.0–2.5 in) SVL (Barber 2022, p. 1, pers. comm.). Based on capture data from BIO-West, Inc., Plateau spot-tailed earless lizards weighing at least 6 g (0.2 oz) were also at least 52.5 mm (2.1 in) SVL (BIO-West, Inc. 2021). Although sexual characteristics sufficient to sex individual specimens are apparent in lizards as small as 37 mm (1.5 in) SVL (LaDuc et al. 2018, p. 84), full sexual maturity comes later. For captive individuals held at the Fort Worth Zoo, sexual maturity appears to be correlated more strongly with weight of over 6 g (0.2 oz) as opposed to SVL (U.S. Fish and Wildlife Service 2022b, p. 2, pers. comm.). In the wild, we presume that female Plateau spot-tailed earless lizards can become gravid and lay eggs during the first active period following the one in which they hatch (i.e., the following year). At the Fort Worth Zoo, staff observed female Plateau spot-tailed earless lizards digging test holes, then an actual nest, then depositing their eggs (U.S. Fish and Wildlife Service 2022b, p. 3, pers. comm.). Some females dug nests under objects like rocks or a water bowl (U.S. Fish and Wildlife Service 2022b, p. 3, pers. comm.). We are not aware of any observations of nesting behavior or nests in the wild.

For individuals of both spot-tailed earless lizard species at the Fort Worth Zoo, clutches were either all fertile or all infertile (U.S. Fish and Wildlife Service 2022b, p. 2, pers. comm.). Infertile clutches were common and were associated with females who did not mate with a male (U.S. Fish and Wildlife Service 2022b, p. 1, pers. comm.). Female Plateau spot-tailed earless lizards typically laid eggs twice per year, and younger females sometimes produced three clutches (Duran 2017, p. 5). Among the captive individuals, clutches were occasionally laid in winter if the individual was not put into brumation, indicating a lack of seasonality regulating breeding and clutching behavior (U.S. Fish and Wildlife Service 2022b, pp. 2–3, pers. comm.). Although these were captive individuals, the conclusion that double-clutching (a single female laying two clutches of eggs in the same active season) or even triple-clutching is possible is consistent with observations from the field. For example, Axtell (1956, p. 177) observed female Tamaulipan spot-tailed earless lizards with two complete sets of ova. During more recent studies, juvenile Plateau and Tamaulipan spot-tailed earless lizards were observed during multiple months of the active period (LaDuc et al. 2018, p. 37; BIO-West Inc. 2020, p. 27). Species experts generally accept the potential for double-clutching and have suggested that triple-clutching could be possible in the wild in exceptionally good years (Hibbitts and Hibbitts 2015, p. 110; U.S. Fish and Wildlife Service 2021, p. 2, pers. comm.).

Clutch size ranges from four to twelve eggs (Axtell 1956, p. 177; Duran 2017, p. 5). Younger, smaller females tend to lay fewer eggs, while larger, older females lay more (Axtell 1956, p. 177; Duran 2017, p. 5). Axtell (1954, p. 48), discussing the Tamaulipan spot-tailed earless lizard, suggested that a yearling female up to 55 mm (2.2 in) SVL would lay four to six eggs at her first oviposition in late spring, and five to seven in the second oviposition during the summer. The Fort Worth Zoo's captive Plateau spot-tailed earless lizards averaged six eggs per fertile clutch (of which there were 20 in total); once, a clutch contained ten eggs (U.S. Fish and Wildlife Service 2022b, p. 1, pers. comm.). Weight appears to be a predictor not only of capacity to bear eggs, but also of double-clutching and clutch size, although this has not been precisely quantified (Axtell 1954, p. 48; 1956, p. 177; Duran 2017, p. 5; U.S. Fish and Wildlife Service 2022b, pp. 1–4, pers. comm.). Across both species, at the Fort Worth Zoo, 80–90% of eggs laid hatched successfully (U.S. Fish and Wildlife Service 2022b, p. 2, pers. comm.). Although the zoo varied incubation temperatures in several clutches, the sex ratio of hatchlings across both species were about 1:1, suggesting that sex determination in the Plateau spot-tailed earless lizard may not be temperature-dependent (U.S. Fish and Wildlife Service 2022b, p. 1, pers. comm.).

Longevity, Survival, and Growth

Longevity of the Plateau spot-tailed earless lizard is unknown. Data from the captive population at the Fort Worth Zoo indicates that they can live at least six years, but species experts think that lifespans in the wild are much shorter (U.S. Fish and Wildlife Service 2021, pp. 2–3, pers. comm.; 2022b, p. 3). Capture-mark-recapture studies in different parts of the range across both the Plateau spot-tailed earless lizard and the Tamaulipan spot-tailed earless lizard have mostly yielded very few recaptures, which species experts suggest indicates that they do not typically live more than a few years in the wild (U.S. Fish and Wildlife Service 2021, pp. 2–3, pers. comm.). A negative relationship between lizard annual fecundity and annual survivorship has been established through meta-analyses of various lizard species (Tinkle 1969, entire; Pianka and Vitt 2003, pp. 121–122). Other reproductive traits held by the Plateau spot-tailed earless lizard, including a large ratio of egg to female body weight, multiple clutching, breeding coloration, and courtship displays, are also associated with higher fecundity and lower survivorship (Tinkle 1969, entire; Pianka and Vitt 2003, pp. 110–112). With up to three clutches per year and clutch size ranging from 4–12 eggs, we infer that annual survivorship of the Plateau spot-tailed earless lizard is likely lower than that of an average lizard species. Average life expectancy may be as short as just over a year (Tinkle 1969, p. 503). A study of the Plateau spot-tailed earless lizard from 2017–2020 produced estimates of apparent annual survival rates from 54.79%–70.54% (BIO-West Inc. 2020, p. 77). The widest 95% confidence interval was 19.36%–86.5% around a point estimate of 55.36%, and the narrowest was 66.29% –74.46% around a point estimate of 70.54% (BIO-West Inc. 2020, p. 77). Because of the low recapture rate, survival estimates for juveniles are not available. However, it has been suggested that juvenile survivorship was likely much, much lower than that of adults, even though it has not been quantified (U.S. Fish and Wildlife Service 2021, p. 2, pers. comm.).

The average SVL for Plateau spot-tailed earless lizard hatchlings in captivity at the Fort Worth Zoo was 19.34 mm (0.76 in) and the range was 16.03–22.74 mm (0.63–0.90 in) (Duran 2017, p. 5). The growth rate of captive-raised hatchlings held at Texas A&M University, Kingsville hatchlings was quite fast; across both spot-tailed earless lizard species it was 0.28 mm (0.01 in) per day during the summer, slowing to 0.15 mm (0.006 in) per day by late fall (Henke 2022b, pp. 4–5, pers. comm.). A growth rate estimate of SVL for Plateau spot-tailed earless lizard in the wild from Kimble County was 0.49 mm (0.02 in) per week (BIO-West, Inc. 2021, p. 77). The largest reported Plateau spot-tailed earless lizard SVL is 65 mm (2.56 in) (Axtell 1968, p. 56.2).

Individual Resource Needs

The needs of individual Plateau spot-tailed earless lizards are known in broad rather than specific terms. Much of our understanding comes from inferring that localities where the Plateau spot-tailed earless lizard has been observed since 2008 fulfill some or all individual needs, and from inferring that localities where only historical observations exist are likely to have changed such that those areas no longer fulfill the species' individual needs. A detailed description of individual needs by life stage is presented in Table 2.1.

As a small, ground-dwelling lizard that is potentially prey for a number of species, a major factor in the survival of the Plateau spot-tailed earless lizard is the availability of sheltering habitat. During its inactive period, overnight, and during extended rest periods, the Plateau spot-tailed earless lizard self-buries under loose soil or seeks refuge in existing animal burrows or soil fissures (Axtell 1954, p. 42; 1956, p. 177; Clarke 1963, p. 113; BIO-West Inc. 2020, pp. 27–28). Loose soil is also necessary to allow females to dig nests for their clutches (Neuharth et al. 2018, p. 536; U.S. Fish and Wildlife Service 2022b, pp. 3–4, pers. comm.). While active above ground, the Plateau spot-tailed earless lizard may temporarily shelter under grass clumps or detritus (Hibbitts and Hibbitts 2015, p. 110; Neuharth et al. 2018, p. 536; Roelke et al. 2018, p. 1024; BIO-West Inc. 2020, p. 27; Hibbitts et al. 2021, p. 506). This species also needs minimal woody plant canopy cover, open areas, and warm, sunny days, so that it can bask and increase its internal body temperature before moving around on the surface (Hibbitts and Hibbitts 2015, p. 110; BIO-West Inc 2020, p. 27; Hibbitts et al. 2021, p. 505).

The Plateau spot-tailed earless lizard is considered an "opportunistic generalist" in terms of diet, feeding primarily on a variety of arthropods (e.g., beetles, grasshoppers, and termites) (Axtell 1954, p. 42; Hibbitts and Hibbitts 2015, p. 110; LaDuc et al. 2018, pp. 84–86; BIO-West Inc. 2020, pp. 90–91). Open areas also facilitate its sit-and-wait predation behavior (Axtell 1954, p. 42; Hibbitts and Hibbitts 2015, pp. 6, 17). We have no indication that the Plateau spot-tailed earless lizard requires the presence of specific plants or animals. Finally, suitable habitat must be sufficiently large and well-connected for individuals to find one another and select mates during the breeding period (Axtell 1998, p. 2; Hibbitts and Hibbitts 2015, pp. 109–111).

The Edwards Plateau, High Plains, and Great Plains ecosystems underlying the range of the Plateau spot-tailed earless lizard support the individual needs of the species to various degrees depending on local abiotic factors and level of vegetational succession. Grasslands characterized by short grasses, including sparse vegetation and the presence of barren areas, are best associated with survey success and our current understanding of species biology (Duran 2017, p. 6; LaDuc et al. 2018, pp. 18–22, 45, 85; Neuharth et al. 2018, pp. 536–537; BIO-West Inc 2020, p. 94; Hibbitts et al. 2021, pp. 505–506). These characteristics are associated with frequent disturbance from herbivory and fire in the part of the species' range that would otherwise succeed into shrublands or forests, which themselves become denser over time with a lack of disturbance that resets successional pathways (Hibbitts and Hibbitts 2015, pp. 30–39; LaDuc et al. 2018, p. 39). In other parts of the species' range, edaphic and climate characteristics limit the development of shrublands and forests, maintaining a more open, grass-dominated vegetation community (Hibbitts and Hibbitts 2015, pp. 30–39).

The Plateau spot-tailed earless lizard has also been frequently found in two environments heavily modified by humans that at first glance may not appear to be suitable habitat. The first setting is within intensively managed, row-crop agriculture (LaDuc et al. 2018, p. 39; BIO-West Inc 2020, pp. 27, 94; Hibbitts et al. 2021, p. 504). It has been hypothesized that row-crop agriculture mimics key aspects of their natural preferred habitat: an open canopy for much of their active period, soils in which self-burial is easy, and abundant prey (Roelke et al. 2018, p. 1024; U.S. Fish and Wildlife Service 2021, pp. 4–5, pers. comm.). The second environment is on and along roads, especially narrow, unpaved rural roads (Duran 2017, p. 15; LaDuc et al. 2018, p. 127; Neuharth et al. 2018, pp. 536–537; Hibbitts et al. 2021, p. 505). Areas with energy production, such as oil and gas wells or pipelines, do not appear to exclude the Plateau spot-tailed earless lizard, although the actual impacts on species ecology have not been measured (BIO-West Inc 2020, pp. 12, 27, 94; Hibbitts et al. 2021, pp. 504–507). Roads, well pads, and recently installed pipeline corridors may also function as sites along which basking and social interaction is facilitated, and any vegetation management such as mowing or brush removal would increase the space usable by the Plateau spot-tailed earless lizard (LaDuc et al. 2018, p. 18; BIO-West Inc 2020, pp. 27–28; Hibbitts et al. 2021, p. 506). Although cultivated crops and roads are associated with Plateau spot-tailed earless lizard presence, there is no evidence or speculation that the Plateau spot-tailed earless lizard can be found in urban areas (Duran and Axtell 2011, p. 20; Hibbitts et al. 2021, p. 504).

Two recent studies looked at individual space use by the Plateau spot-tailed earless lizard. Following Hibbitts et al. (2021, p. 498), we use the phrase "individual space use" rather than "home range," even though the calculations are for home ranges, due to the relatively short tracking period used in the studies. A telemetry study conducted on the Plateau spot-tailed earless lizard in Tom Green and Kimble Counties, Texas, calculated individual space use for 21 adult Plateau spot-tailed earless lizards (BIO-West Inc 2020, p. 37). The estimated mean area of individual space using 95% minimum convex polygons (MCP) was 0.61 ha (1.51 ac) with a standard error of 0.24 ha (0.60 ac) for males and 0.55 ha (1.36 ac) with a standard error of 0.15 ha (0.36 ac) for females (BIO-West Inc 2020, p. 38). A telemetry study conducted on the

Plateau spot-tailed earless lizard in Crockett County, Texas, calculated individual space use for nine adult Plateau spot-tailed earless lizards (Hibbitts et al. 2021, pp. 498–502). The estimated mean area of individual space use using 100% MCP was 2.17 ha (5.36 ac) with a standard deviation of 2.36 ha (5.83 ac) (Hibbitts et al. 2021, p. 501). Using 95% Autocorrelated Kernel Density Estimates, the mean area was 6.94 ha (17.14 ac) with a standard deviation of 9.15 ha (22.61 ac) (Hibbitts et al. 2021, p. 501). The authors note that individual space use by the Plateau spot-tailed earless lizard from the latter study was much larger (over an order of magnitude larger) than lizards with similar life histories (Hibbitts et al. 2021, p. 506) as well as larger than similar estimates for the same species in another portion of the range (BIO-West Inc 2020, p. 38).

These studies also reported movement data from the radio-tracked Plateau spot-tailed earless lizards. Individual adult daily movement (sum of distance between relocated individuals during a single day) calculated for 28 adult Plateau spot-tailed earless lizards in Tom Green and Kimble Counties, Texas ranged from a minimum of 0 m (for individuals that were buried beneath the surface for all resightings in one day) to a maximum of 0.54 km (0.33 mi) (BIO-West Inc 2020, pp. 38–40; Jackson 2021a, p. 1, pers. comm.). The mean adult daily movement was 0.05 km (0.03 mi) with a standard error of 0.006 km (0.004 mi) (BIO-West Inc. 2020, p. 40) and the median was 0.03 km (0.02 mi) (Jackson 2021a, p. 1, pers. comm.). The study from Crockett County, Texas, reported total step length across the full span of the time the individual Plateau spot-tailed earless lizards were tracked. The total step length across nine individuals ranged from a minimum of 0.63 km (0.39 mi) for an individual with 26 fixes over a total period of 10 days to a maximum of 5.99 km (3.72 mi) for an individual with 120 fixes over a total period of 64 days (Hibbitts et al. 2021, pp. 513–514).

Table 2.1. Summary of individual needs by life stage. The life stages are eggs, juveniles, and adults. The Resource Function identifier in square brackets identifies whether the resource is needed for Breeding (B), Feeding (F), Sheltering (S), Dispersal or Migration (DM), or Thermoregulation (T).

Life Stage	Resources and/or circumstances needed for individuals to complete each life stage [Resource Function]	Resource Function
Eggs	Approximately 45 days without disturbance (Axtell 1956, p. 178; Duran 2017, p. 5)	S
	Nest cavity remains within temperature range and humidity conducive to embryo development (Henke 2022b, p. 5, pers. comm.)	S
Juveniles and adults	Access to invertebrate prey (e.g., arthropods) (Axtell 1954, p. 42; Hibbitts and Hibbitts 2015, p. 110; LaDuc et al. 2018, pp. 84–86; Roelke et al. 2018, p. 1024; BIO-West Inc 2020, pp. 90–91)	F
	Temperature and sunlight at adequate levels to support movement (Axtell 1956, p. 177; Clarke 1963, pp. 91–97; Hibbitts and Hibbitts 2015, pp. 6–7, 10–11, 110; BIO-West Inc 2020, pp. 62, 69; Henke 2022b, p. 1,4, pers. comm.)	F, T
	Land with sparse vegetation or sufficiently low woody plant canopy cover and/or grass height to support basking (Hibbitts and Hibbitts 2015, p. 110; LaDuc et al. 2018, pp. 18–19; Roelke et al. 2018, p. 1024; Hibbitts et al. 2021, pp. 502–504)	T
	Areas with sparse enough vegetation to allow escaping predation, but also adequate vegetation to support prey species and to provide cover opportunities (Hibbitts and Hibbitts 2015, p. 110; Neuharth et al. 2018, p. 536; Roelke et al. 2018, p. 1024; BIO-West Inc 2020, p. 27; U.S. Fish and Wildlife Service 2021, pers. comm.)	F, S
	Access to friable soils for self-burial and nesting (Axtell 1956, p. 177; Clarke 1963, p. 113; Neuharth et al. 2018, p. 536; Roelke et al. 2018, p. 1024; BIO-West Inc 2020, pp. 27–28; U.S. Fish and Wildlife Service 2022b, pp. 3–4, pers. comm.)	B, S, T
	Access to vacant animal burrows or soil fissures (Axtell 1954, p. 42; Roelke et al. 2018, p. 1024; BIO-West Inc 2020, p. 28)	S, T
	Periodic access to opposite sex for mating (Roelke et al. 2018, p. 1024; BIO-West Inc 2020, pp. 27, 38)	B, DM
	Corridors of suitable habitat to allow for movement to find mates and to disperse (Axtell 1998, p. 2; Hibbitts and Hibbitts 2015, pp. 109–111; U.S. Fish and Wildlife Service 2021, p. 7, pers. comm.)	B, F, DM

Population and Species-level Needs

For the Plateau spot-tailed earless lizard to maintain viability, its populations—or some portion thereof—must be able to withstand, or be resilient to, stochastic events and disturbance. Stochastic events potentially impacting Plateau spot-tailed earless lizard populations theoretically include heat, cold, drought, and fire. To have the highest resiliency to stochastic events, Plateau spot-tailed earless lizard populations need an abundance of individuals within habitat patches of adequate area and quality to maintain survival and reproduction despite these natural and anthropogenic disturbances. The abundance within a population is influenced by fecundity (and other reproduction-related demographic factors), survival, and dispersal (i.e., immigration and emigration). Such movement between populations, or lack thereof, also promotes or hinders gene flow, which can influence whether or to what extent there is geographic variation among populations and across the species as a whole, which in turn can be important to ensure population survival after stochastic events.

To maintain adequate abundance, we assume that resilient Plateau spot-tailed earless lizard populations have sufficient fecundity levels to offset the relatively low juvenile and adult survival rates we inferred based the paucity of recaptures during field studies (Pianka and Vitt 2003, pp. 110–112, 121; LaDuc et al. 2018, p. 39; BIO-West Inc 2020, pp. 93–94; Hibbitts et al. 2021, p. 500). Resilient Plateau spot-tailed earless lizard populations should also have growth rates that are stable or increasing over the long term. Additionally, the habitat resources needed by individuals for basic survival and reproduction (described in Table 2.1) must exist in sufficient quantity and quality to support entire populations. Without all of these factors, a population has an increased likelihood for localized extirpation.

Redundancy describes the ability of a species to withstand catastrophic events. Assuming that catastrophic events are distinct from ongoing phenomena such as vegetational succession, we have not identified catastrophic events that would plausibly impact large swaths of the Plateau spot-tailed earless lizard range. However, redundancy is still a useful measure of species viability because it indicates a reduction in the risk of losing representation from wide-ranging stochastic events that depress or eliminate populations. When a species has redundancy, it also minimizes the effect of localized extirpation on the rangewide persistence of a species (Shaffer and Stein 2000, p. 308; Tear et al. 2005, p. 841; Redford et al. 2011, p. 42). Redundancy for the Plateau spot-tailed earless lizard is characterized by having locally self-sustaining (in terms of abundance and recruitment) populations across a large geographic expanse and among varied vegetational communities. In addition, some level of connectivity is needed to allow for immigration and emigration to subpopulations, and to increase the likelihood of recolonization should a local subpopulation become extirpated.

For a species to persist and thrive over time, it must exhibit attributes across its range that relate to representation. Representation describes the ability of a species to adapt to changing environmental conditions over time and encompasses the "ecological and evolutionary patterns and processes that not only maintain but also generate species" (Shaffer and Stein 2000, p. 308). It is characterized by the breadth of genetic, behavioral, or environmental diversity within and among populations. The more representation, or diversity, that a species has, the more it is capable of adapting to changes (natural or human-caused) in its environment. For the Plateau spot-tailed earless lizard to exhibit adequate representation, resilient populations should occur in the range of ecosystems and climatic regimes characteristic of its historical range. Representation is further bolstered by evidence that the Plateau spot-tailed earless lizard can survive and thrive in ecosystems that have been highly modified by humans, such as within row-crop agriculture or among energy production facilities. Connectivity among populations maintains representation by facilitating genetic exchange and maintaining potential for adaptive capacity.

Plateau spot-tailed earless lizard species-level needs are summarized in Table 2.2. Ultimately, Plateau spot-tailed earless lizard viability depends on there being a sufficient number and distribution of healthy populations to ensure that the species can withstand annual variation in its environment (i.e., resiliency), catastrophes (i.e., redundancy), and novel biological and physical changes in its environment (i.e., representation).

Table 2.2. Plateau spot-tailed earless lizard species level needs, based on the 3 Rs of resiliency, redundancy, and representation.

3 Rs	Requisites of long-term viability
Resiliency	• Healthy populations (stable to increasing abundance) occupying habitats that support key resource functions (e.g., breeding, feeding, sheltering) • Potential for periodic dispersal or migration events across population units
Redundancy	• Sufficient distribution of individuals and populations to recover from catastrophic events
Representation	• Maintain healthy populations across the full range of habitats currently supporting the species • Maintain population abundance and intrapopulation connectivity at sufficient levels to ensure healthy genetic diversity and maintain potential adaptive capacity in the extant populations

3 Species Range, Distribution, and Population Analysis Units

Historical Range and Distribution

The historical range of the Plateau spot-tailed earless lizard is well established (Axtell 1998, p. 3; Duran 2017, pp. 2–3). Figure 3.1 shows the location of the Pecos River, Colorado River, and Balcones Escarpment within the State of Texas relative to historical (1901–2007) localities for the species. The range corresponds roughly to the Edwards Plateau ecoregion and is contained entirely within the State of Texas (Axtell 1956, p. 172). The Colorado River forms the northern boundary of the species' range (Axtell 1998, p. 2). The Balcones Escarpment serves as the southern boundary of the historical range (Axtell 1998, pp. 2–3, 12). The eastern edge of the Balcones Escarpment in Travis County was historically a fuzzy boundary in that a few historical localities exist to the south and east of it near Austin, Texas (Axtell 1998, pp. 2–3, 12). It has also been suggested that the Plateau spot-tailed earless lizard is excluded from the rocky soils of the Llano Uplift (Axtell 1998, p. 2). The western boundary of the species range is the Pecos River, although the extent of localities declines before reaching that boundary (Hibbitts et al. 2019, p. 147). Axtell's hand-drawn range map (1998, p. 12) also shows the exclusion of the Llano Uplift and the separation of the edge of this range from the Pecos River (Figure 3.2).

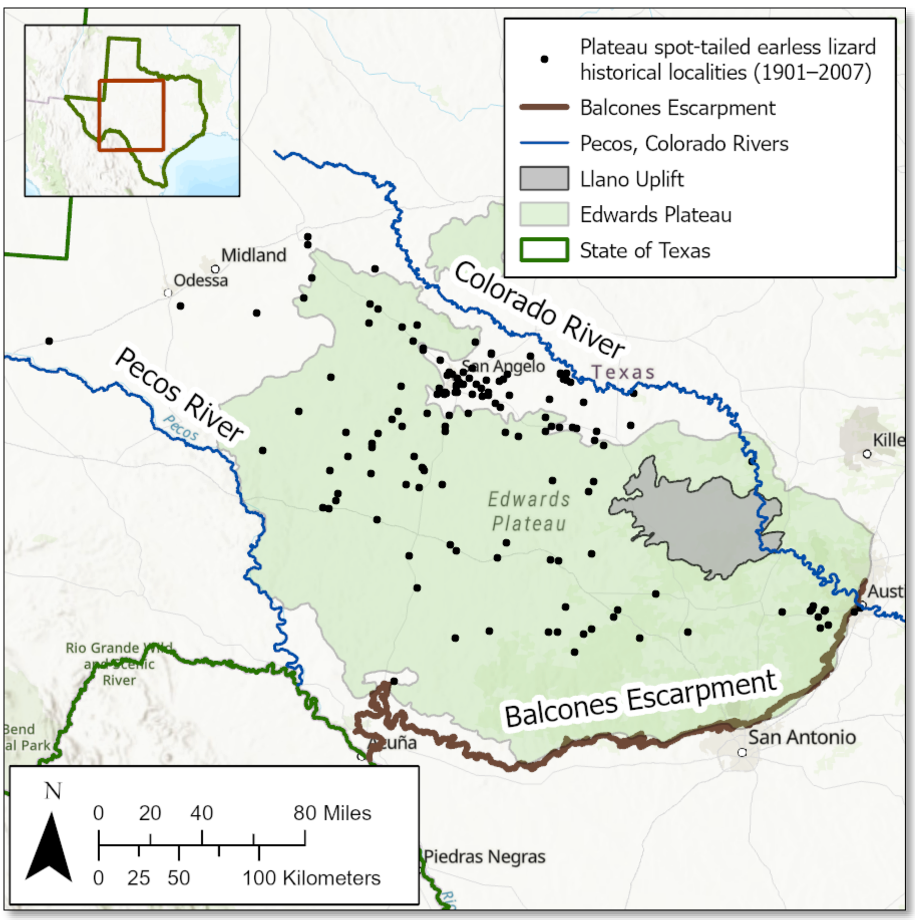

Figure 3.1. Historical localities for the Plateau spot-tailed earless lizard with three major boundary features to the range: the Pecos River, the Colorado River, and the Balcones Escarpment. The Edwards Plateau ecoregion is shown in light green, and the Llano Uplift section of it is shown in grey.

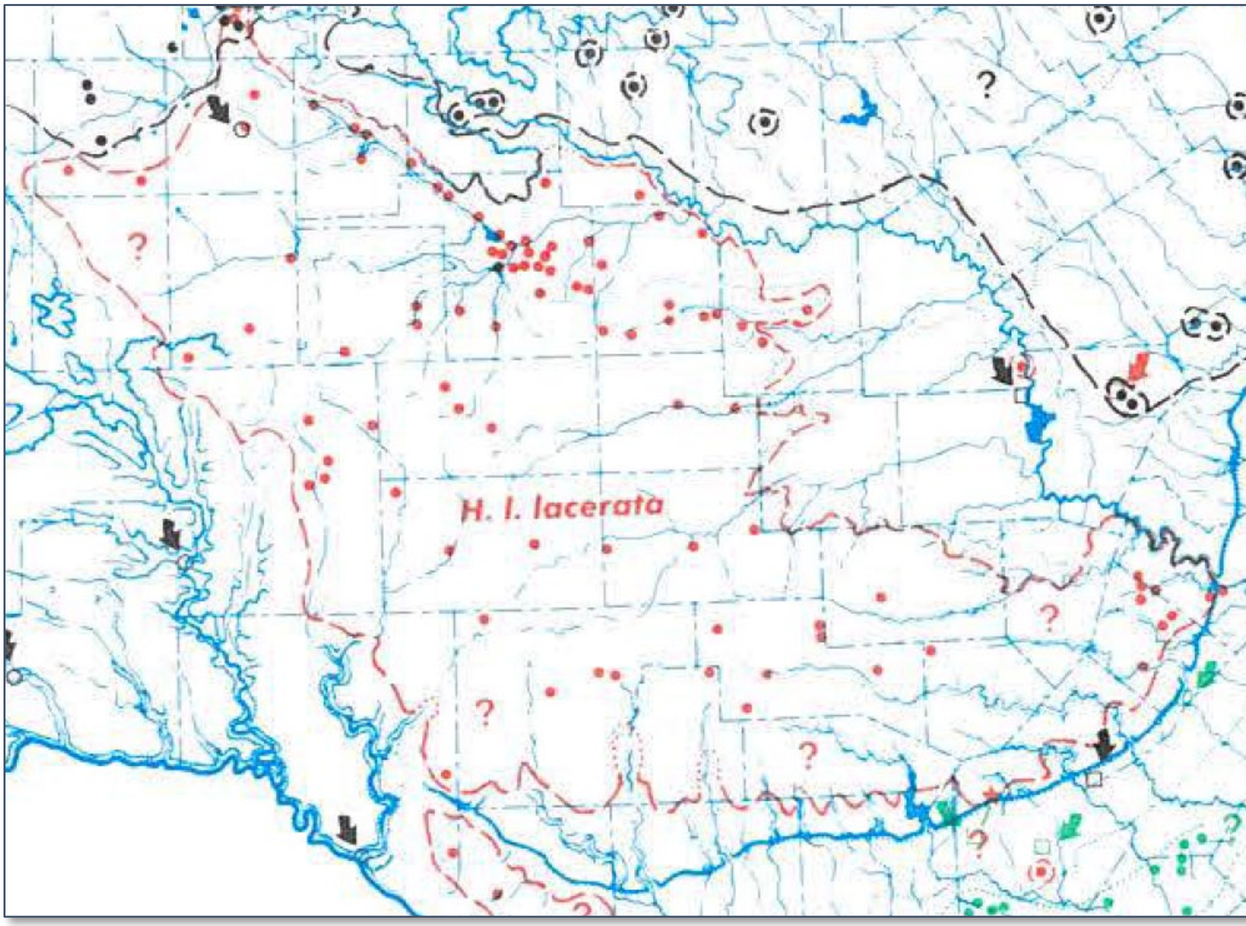

Figure 3.2. Map 11 from Axtell's Interpretive Atlas of Texas Lizards (1998, p. 12), cropped to the extent for the Plateau spot-tailed earless lizard. This map shows the historical range of the species. Note the exclusion of the Llano Uplift and the separation of the edge of this range from the Pecos River.

Current Range and Distribution

Little research on the Plateau spot-tailed earless lizard was completed prior to 2008, when the Texas Parks and Wildlife Department and Texas Comptroller of Public Accounts began funding surveys and other studies (Duran 2017, entire; LaDuc et al. 2018, entire; Hibbitts et al. 2019, entire; 2021, entire; BIO-West Inc 2020, entire; Henke and Eversole 2022; Kahl et al. 2022, entire). One of the first studies focused on developing a dataset including all known historical localities, followed by an effort from 2008 to 2010 to re-locate the Plateau spot-tailed earless lizard at these historical locations (Duran et al. 2010, pp. 4–7, 24–33). Later funding allowed additional survey and inventory work across the species' ranges, resulting in the confirmation that the Plateau spot-tailed earless lizard continue to exist in the vicinity of many historical localities (LaDuc et al. 2018, pp. 18–45; BIO-West Inc 2020, pp. 7, 10; Hibbitts et al. 2021, pp. 499–501). Surveyors also located the Plateau spot-tailed earless lizard in areas lacking historical observations (LaDuc et al. 2018, pp. 18–45; BIO-West Inc 2020, pp. 7, 10; Hibbitts et al. 2021, pp. 499–501). These surveys generally took place along public rights-of-way, due to lack of access to adjacent private lands (Duran 2017, p. 7; LaDuc et al. 2018, p. 41; BIO-West Inc 2020, pp. 6, 36, 46, 54). The surveys were designed to inventory the Plateau spot-tailed earless lizard, identify localities where the species was found, and generate county-level current distribution maps, rather than establish presence-absence (Duran et al. 2010, pp. 4–8; LaDuc et al. 2018, pp. 18–80). Consequently, we emphasize that our occurrence dataset is a presence-only dataset built using positive Plateau spot-tailed earless lizard observations produced by these surveyors and other researchers and citizen scientists. Figure 3.3 shows the historical (1901–2007) and current (2008–2022) Plateau spot-tailed earless lizard observations together.

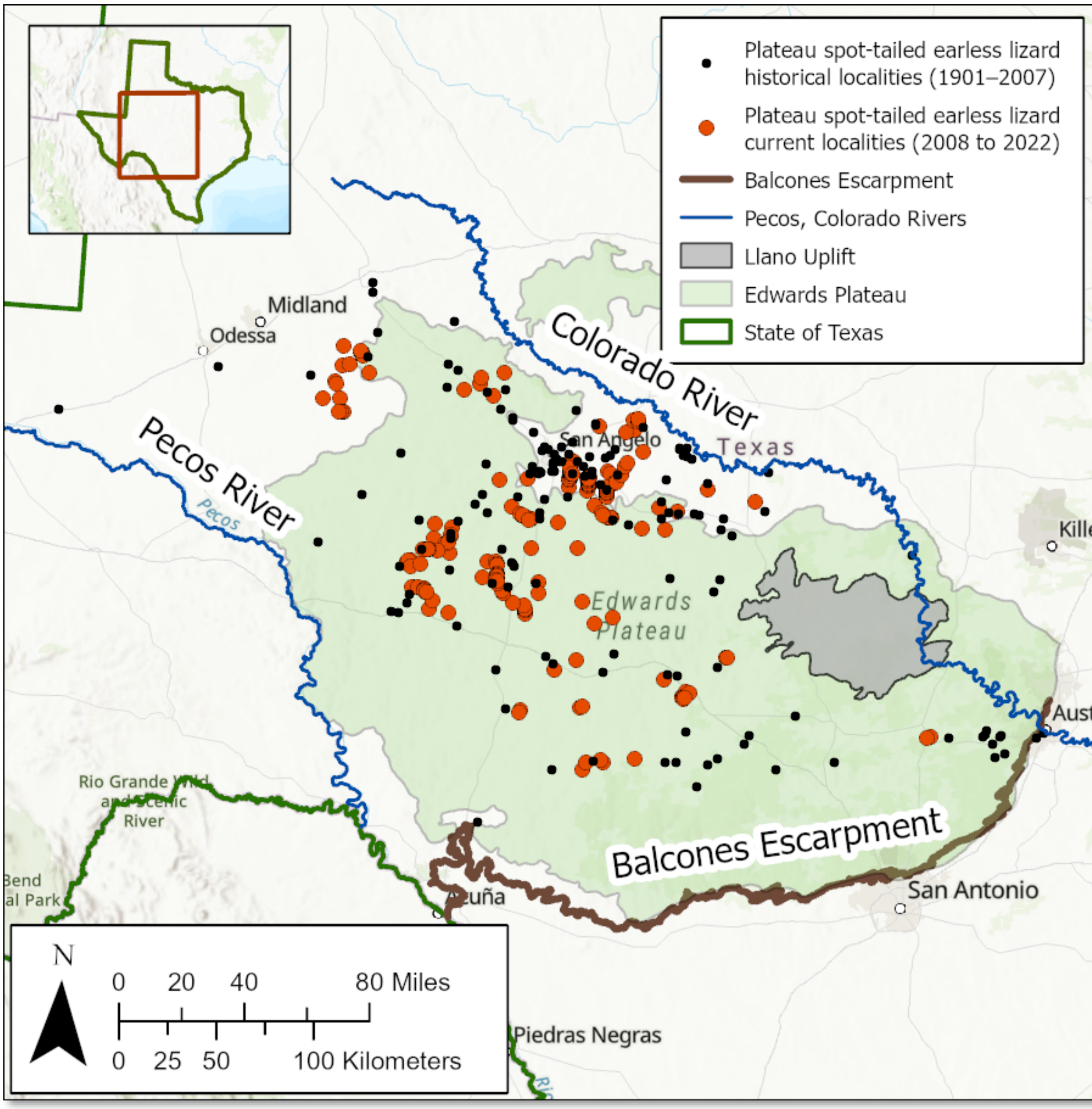

Figure 3.3. Current (orange) and historical (black) occurrence points for the Plateau spot-tailed earless lizard with three major boundary features to the range: the Pecos River, the Colorado River, and the Balcones Escarpment. The Edwards Plateau ecoregion is shown in light green, and the Llano Uplift section of it is shown in grey.

Comparison of Historical and Current Distribution

At the landscape scale, the way the Plateau spot-tailed earless lizard interacts with and moves within its habitats has likely been substantially altered since the arrival of European colonists in Texas (Smeins et al. 1997, entire; Hampton 2014, pp. 25–31; Hibbitts and Hibbitts 2015, pp. 35–39). They brought with them significant changes to disturbance regimes and land use (Hibbitts and Hibbitts 2015, pp. 35–39).

Prior to their arrival, a number of factors, including foraging and migrating American bison (*Bison bison*), the development and maintenance of black-tailed prairie dog (*Cynomys ludovicianus*) colonies, and periodic grass and brush fires, would have frequently reset vegetation succession throughout the range of the Plateau spot-tailed earless lizard (Arthun and Holechek 1982, p. 125; Whicker and Detling 1988, pp. 779–780; Fuhlendorf and Smeins 1997b, pp. 825–826; 1997a, unpaginated; Smeins et al. 1997, pp. 9–17; Detling 1998, p. 440; Hampton 2014, pp. 26–28; Hibbitts and Hibbitts 2015, pp. 35–39; LaDuc et al. 2018, p. 127). If this is correct, then Plateau spot-tailed earless lizard populations may have been constantly shifting within the species' range to areas of appropriate vegetation structure and soils (Hibbitts and Hibbitts 2015, pp. 35–39). We would not necessarily expect a population to naturally be spatially static over many decades. The extirpation of American bison and black-tailed prairie dogs, livestock grazing, fire suppression, and associated shifts in the locations and extent of early successional, grass-dominated ecosystems have combined to alter the landscape of the Plateau spot-tailed earless lizard range. Therefore, it may be the case that Plateau spot-tailed earless lizard populations today are more constrained in their ability to shift on the landscape and thus are more stable spatially today than they were around the time of European settlement.

A visual comparison of the historical and current distribution (Figure 3.3) shows that there are two areas of apparent reduction in the distribution of the Plateau spot-tailed earless lizard. First, in the northwest portion of the species' range, localities along Interstate 20 from Big Spring, Texas, to the border were not re-sighted during the last 15 years. Other isolated points in Irion, Reagan, and Crockett Counties in the western portion of the range also lack more recent confirmation of species persistence. However, surveys in these portions of the range were minimal, and much of the area consists of private land unavailable for inventory (Duran and Axtell 2011, pp. 1, 6–23; LaDuc et al. 2018, pp. 18–45). Therefore, we are unsure whether the range has contracted in the northwest. Second, the Edwards Plateau Hill Country contains numerous historical localities that were not re-sighted. This may be due to a loss of suitable habitat due to increasing forest cover, or reflect the difficulty in accessing private lands and the low detection probability of the Plateau spot-tailed earless lizard (Neuharth et al. 2018, pp. 536–537). In and around Austin, Texas, where extensive urbanization has occurred, we suggest that the apparent reduced distribution likely reflects a true contraction of the species' range (Duran and Axtell 2011, p. 20; LaDuc et al. 2018, p. 81).

Population Analysis Units

In the context of our status assessment, species viability is the ability of the Plateau spot-tailed earless lizard to sustain populations in the wild, over time, and under plausible future scenarios. Therefore, we would ideally identify and describe the historical and current populations of the Plateau spot-tailed earless lizard. However, research efforts on this species to date do not allow us to define true biological populations of the Plateau spot-tailed earless lizard. Given that we lack the detailed demographic study across the range needed to define and analyze biological populations, we instead developed a set of population analysis units to use in our resiliency analysis.

Unit Development

Our population analysis units are based fundamentally on the available occurrence data for the Plateau spot-tailed earless lizard. Because the elevation of the Plateau spot-tailed earless lizard to species from subspecies status occurred relatively recently, we first had to assign all "spot-tailed earless lizard" localities to either the Plateau spot-tailed earless lizard or the Tamaulipan spot-tailed earless lizard. Following the description of the species' range from Hibbitts et al. (2019, p. 147), we used a GIS file of the Balcones Escarpment (as shown in Figure 3.1 and Figure 3.3) to assign localities designated only as "spot-tailed earless lizard" to either the Plateau spot-tailed earless lizard or the Tamaulipan spot-tailed earless lizard. The resulting dataset includes nearly 400 locality records for the Plateau spot-tailed earless lizard for which the observation date was 2008 or later. We consider these to be recent localities.

The next step in developing population analysis units was to buffer the dataset of recent localities. The buffer distance was calculated using a simple unbiased random walk model to estimate the potential annual diffusion of an individual lizard on the landscape (Codling et al. 2008, pp. 813–814). This model has three input parameters: step length, step time, and number of steps. For step length, we used daily movement data from telemetry work conducted on the Plateau spot-tailed earless lizard in Kimble County, Texas (BIO-West Inc. 2020, pp. 38–46). We chose to err on the side of creating units that are too large rather than too small, so the step length in the random walk equation is the maximum daily movement recorded for the Plateau spot-tailed earless lizard (538.8 m [1,767 ft]) (BIO-West Inc. 2020, p. 40; Jackson 2021a, pers. comm.). We defined the step time as one day since we used daily movement values. The number of steps is based on the annual duration of the active period. For this parameter we assumed the longest possible active period based on dates of observations in our database, which spanned March–October, or 245 steps. The result of this equation, the net displacement value, was 11,927 m (7.4 mi).

Next, using ArcGIS, we buffered each current locality point by the net displacement value, and dissolved overlapping circular polygons generated by the buffer, which resulted in a set of nine non-overlapping polygons. One unit was edited so that it did not cross the Colorado River; the river being a range boundary for the species. One unit (Unit 3) was too large and diverse to effectively analyze (nearly ten times the size of the smallest unit). We used buffer distances slightly smaller than the net displacement value to subdivide Unit 3 such that we equalized the distance from a locality point to the edge of the subdivided unit. These are named Unit 3-A, Unit 3-B, etc., and are analyzed independently in the same way as the units that were not subdivided. Ultimately, this process generated 16 population analysis units that we use in our analyses (Figure 3.4). It has been suggested, and is possible, that the Plateau spot-tailed earless lizard is currently present in portions of its historical range that are not covered by these 16 population analysis units (McEachern 2022, pp. 2–3, pers. comm.). It is also possible that individuals move between units, even those that do not share borders. Additional surveys in areas outside the units would be worthwhile and potentially improve our understanding of the species' distribution. For the purposes of the status assessment, however, we limit the extent of the population analysis units to the areas buffering recent localities with confirmed presence of the Plateau spot-tailed earless lizard.

Further details on Plateau spot-tailed earless lizard surveys, occurrence and localities, and information specific to factors influencing viability or our current conditions metrics are discussed in Chapters 4 and 5. In Table 3.1, we provide some basic information about each unit, including its size, the counties overlapped by the unit, the names of any urban areas present within the unit, if any, and most prevalent ecosystems in the unit. The ecosystems are simplified descriptions of the Biophysical Setting types associated the Landfire dataset of the same name (Landfire 2016). Urban areas are drawn from the U.S. Census Bureau Urban Areas dataset (U.S. Census Bureau 2020; 2022b). Table 3.2 provides a brief overview of land use characteristics associated with each population analysis unit. This includes the most significant cultivated crops, the dominant stock animals ranched, including exotic game if important, the primary shrub or tree encroaching on grasslands, and the prevalence of energy development (oil and gas, wind) within the unit. The cultivated row crops noted in the table are defined as those comprising an average of at least 10 km^2 on average over the years 2019–2021 (USDA 2019; 2020; 2021). Information on the dominant stock animal grazed on ranches and the dominant woody plant in each unit is based on information shared by professional wildlife biologists working in those areas (Rains 2022a, p. 1, pers. comm.; McEachern 2022, pp. 1–2, pers. comm.; U.S. Fish and Wildlife Service 2022d, pp. 1–4, pers.

comm.; Hendon 2022, p. 2, pers. comm.; Newberry 2022, pp. 1–2, pers. comm.; Blair 2022, pp. 1–2, pers. comm.; Perlicheck 2022, pp. 1–2, pers. comm.). The prevalence of oil and gas or wind energy development is based on a visual inspection in ArcGIS Pro (ESRI 2021) of spatial datasets on the oil and gas wells, pipelines, and windmills present in population analysis units as of 2022 (IHS 2022a; 2022b; U.S. Geological Survey 2022a). We categorize this prevalence as minimal, moderate, or substantial. In Chapter 4, we delve into detail on these potential influences on Plateau spot-tailed earless lizard viability, discuss how they impact the units across space and time, and share maps depicting these influences across the range of the Plateau spot-tailed earless lizard.

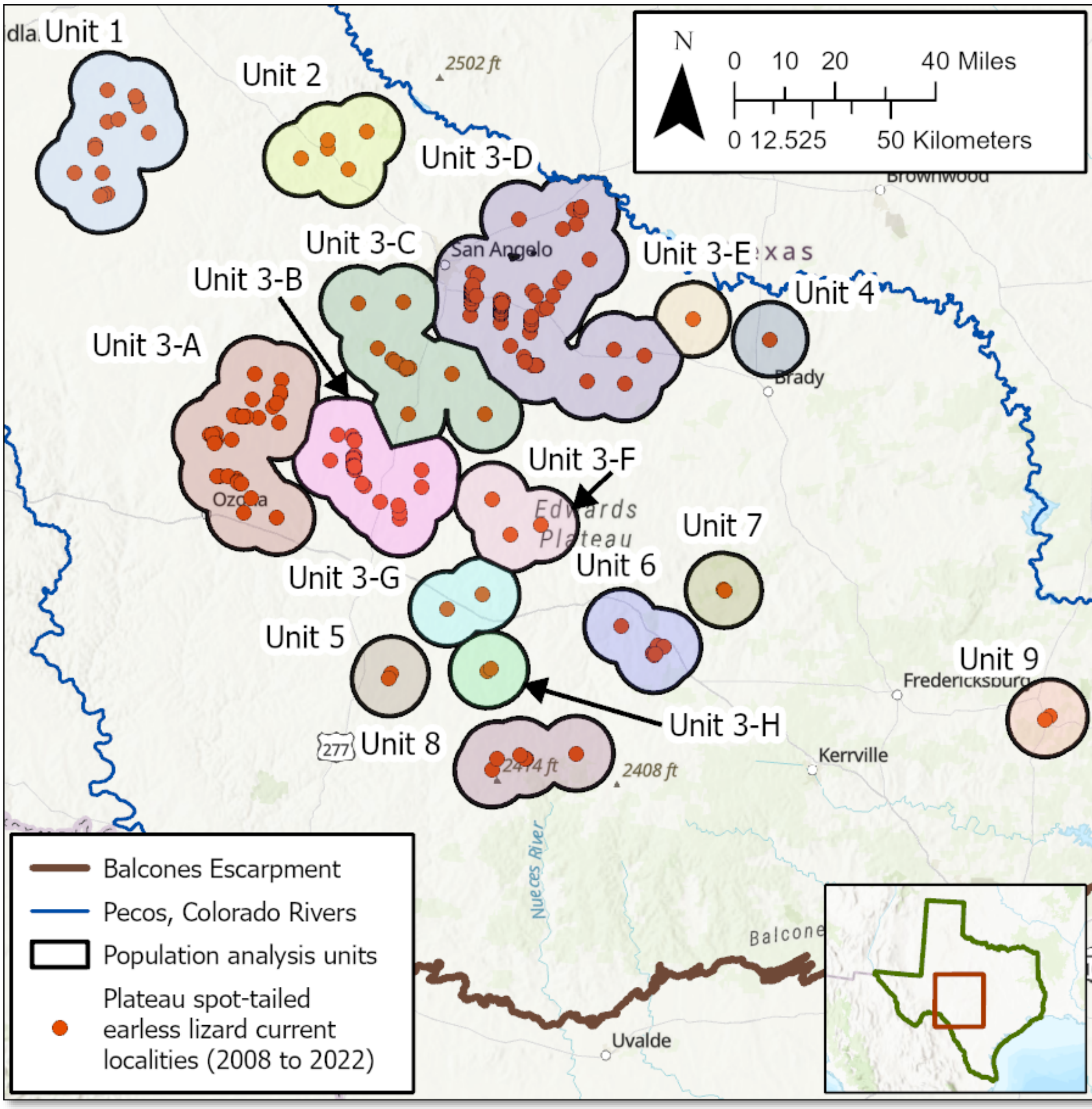

Figure 3.4. Population analysis units used in the Plateau spot-tailed earless lizard species status assessment. Orange circles represent current localities, collected from 2008–2022. The river (shown as a thick blue line) in the western portion of the map is the Pecos River, and the one across the northeast portion of the map is the Colorado River. The Balcones Escarpment is shown as a thick brown line across the southern portion of the map.

Table 3.1. Summary characteristics for Plateau spot-tailed earless lizard population analysis units. For each unit, we describe its area in square kilometers and square miles, the names of any counties or urban areas intersected by the unit, and the most prevalent ecosystems by total area present in the unit.

Population analysis unit	Area (km^2)	Area (mi^2)	Counties	Urban areas	Most prevalent ecosystems
Unit 1	1,823	704	Glasscock, Reagan, Upton, Midland	none	desert grassland, shortgrass prairie
Unit 2	1,152	445	Sterling, Coke, Tom Green	none	mixedgrass prairie, shrubland, shortgrass prairie
Unit 3-A	2,321	896	Crockett, Irion, Schleicher, Sutton	Ozona, TX	shrubland, shortgrass prairie, desert grassland
Unit 3-B	1,686	651	Schleicher, Sutton	none	mixedgrass prairie, savanna-woodland, desert grassland, shrubland, shortgrass prairie
Unit 3-C	2,221	857	Tom Green, Irion, Schleicher	San Angelo, TX	mixedgrass prairie, savanna-woodland, shrubland
Unit 3-D	3,985	1,538	Tom Green, Concho, Menard, Runnels	San Angelo, TX	mixedgrass prairie, savanna-woodland
Unit 3-E	424	164	Concho, McCulloch	none	mixedgrass prairie
Unit 3-F	947	366	Schleicher, Sutton, Kimble, Menard	none	savanna-woodland, mixedgrass prairie, shrubland
Unit 3-G	712	275	Sutton	none	savanna-woodland, mixedgrass prairie, shrubland
Unit 3-H	478	184	Sutton, Edwards	none	savanna-woodland, mixedgrass prairie
Unit 4	447	173	McCulloch County	none	savanna-woodland, mixedgrass prairie
Unit 5	489	189	Sutton, Edwards	none	mixedgrass prairie, savanna-woodland, shrubland
Unit 6	852	329	Kimble, Kerr	Junction, TX	savanna-woodland, shrubland, mixedgrass prairie
Unit 7	458	177	Kimble, Mason	none	mixedgrass prairie, savanna-woodland, shrubland
Unit 8	1,113	430	Edwards, Real	none	savanna-woodland, mixedgrass prairie
Unit 9	494	191	Blanco	none	savanna-woodland, forest-woodland

Table 3.2. Additional summary characteristics for Plateau spot-tailed earless lizard population analysis units. For each unit, we list cultivated crops found on at least 10 km^2 in the unit, the primary livestock grazed on ranchlands (noting if game animals are commonly grazed), the primary shrub or tree species encroaching on grasslands, and the relative prevalence of energy development within the unit (oil and gas well and pipelines, and wind turbines).

Population analysis unit	Primary cultivated crops	Primary animals grazing ranchlands	Primary shrub or tree encroaching on grasslands	Prevalence of energy development: oil and gas	Prevalence of energy development: wind power
Unit 1	cotton and winter wheat	cattle	mesquite	substantial	minimal
Unit 2	winter wheat	cattle	mesquite	minimal	minimal
Unit 3-A	not substantial	sheep and goats	Ashe juniper	substantial	minimal
Unit 3-B	cotton, winter wheat	sheep and goats	Ashe juniper	substantial	minimal
Unit 3-C	winter wheat, cotton	cattle	mesquite	moderate	minimal
Unit 3-D	cotton, winter wheat, sorghum, corn, hay	cattle	mesquite	moderate	minimal
Unit 3-E	winter wheat, cotton, sorghum	cattle	mesquite	minimal	minimal
Unit 3-F	not substantial	sheep and goats	Ashe juniper	minimal	none
Unit 3-G	not substantial	sheep and goats	Ashe juniper	moderate	none
Unit 3-H	not substantial	sheep and goats	Ashe juniper	moderate	none
Unit 4	winter wheat, cotton	cattle	mesquite	minimal	minimal
Unit 5	not substantial	sheep and goats; some deer and exotic game	Ashe juniper	substantial	none
Unit 6	not substantial	cattle; some deer and exotic game	Ashe juniper	minimal	none
Unit 7	not substantial	cattle; some deer and exotic game	Ashe juniper	minimal	none
Unit 8	not substantial	sheep and goats; some deer and exotic game	Ashe juniper	moderate	none
Unit 9	not substantial	cattle	Ashe juniper	minimal	none

4 Influences on Viability

In this chapter, we consider the historical and current anthropogenic and environmental factors influencing Plateau spot-tailed earless lizard resiliency, representation, and redundancy. These influences affect individual, population, or species needs, ultimately affecting the viability of the species—its ability to sustain populations in the wild over time. They may be positive or negative, and some factors may affect the Plateau spot-tailed earless lizard both positively and negatively. This is not a comprehensive review of all the influences that may impact the Plateau spot-tailed earless lizard; for the purposes of this SSA we focus on those factors that are likely to have population or species-level effects.

We developed an influence diagram (Figure 4.1) summarizing the ways in which these factors can influence Plateau spot-tailed earless lizard resiliency through their effects on habitat needs or demographic parameters. The diagram helps to illustrate that the factors can influence resiliency in different ways and to different degrees. As we conducted our analysis, we added detail to the diagram in the form of line thickness to illustrate the relative importance of some factors. For example, we concluded from our research that that Plateau spot-tailed earless lizard abundance and survival are heavily influenced by the presence of suitable habitat and the prevalence of vehicle traffic within that habitat. However, we did not find evidence that predation, pesticides, or the availability of food resources—while relevant to the species (hence their inclusion in the diagram)—are important influences driving Plateau spot-tailed earless lizard abundance and survival. We also completed a cause and effects analysis of factors influencing Plateau spot-tailed earless lizard needs (Appendix A). These tables analyze the pathways by which each stressor affects the species, and each of the causes is examined for its historical, current, and potential future effects on the species' status. Current and potential future effects, along with current expected distribution and abundance, determine present viability and vulnerability to extinction in the future.

Based on our assessment of the Plateau spot-tailed earless lizard needs, the influence diagram, and the cause and effects tables, there are two primary influences on species viability. These are the availability of suitable habitat and presence of vehicular traffic. In this chapter we will discuss the mechanisms, impacts on species needs, and the geographic and temporal scope of these two important influences. We also discuss other factors that were hypothesized to be important early in our analytical process, but which were not found to be significant after further study.

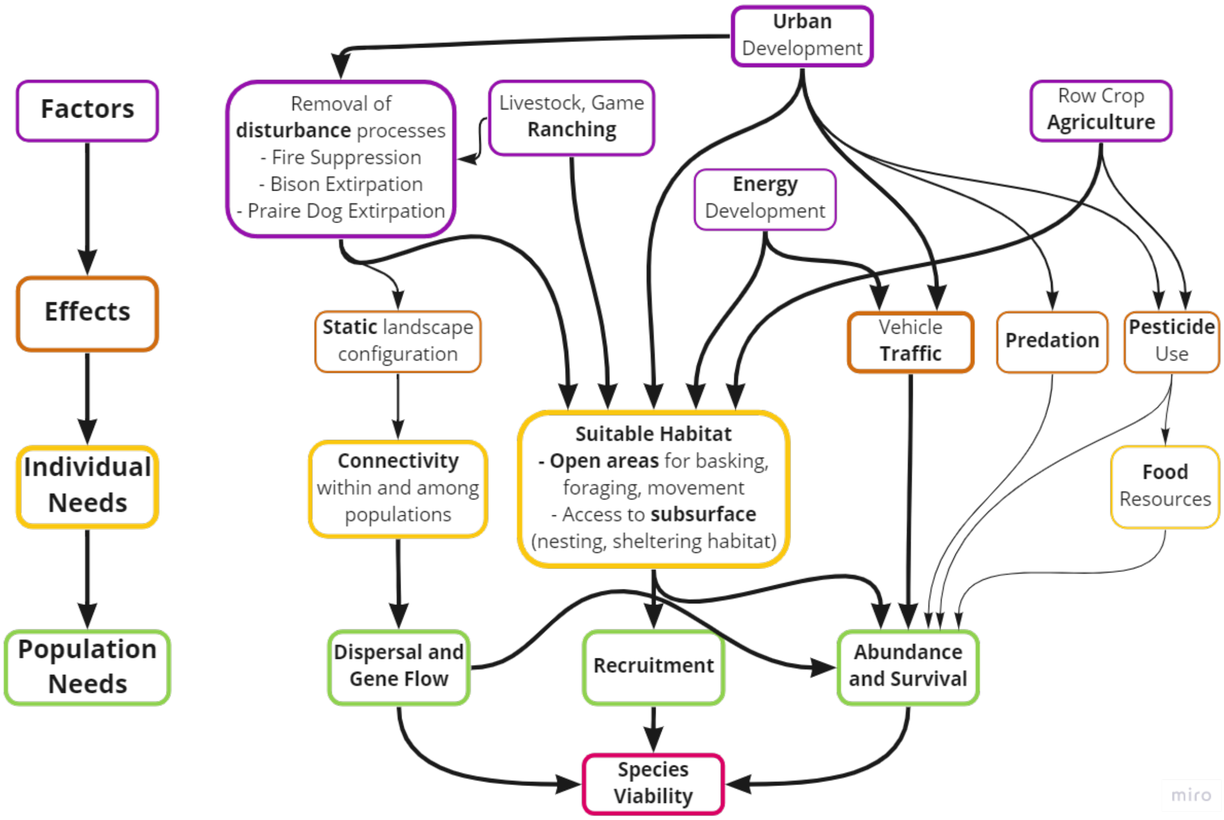

Figure 4.1. Influence diagram that maps the pathways through which environmental and anthropogenic stressors, and conservation efforts, affect demographic parameters and Plateau spot-tailed earless lizard viability. Thicker lines or borders denote relatively more important relationships between items or more impactful influences on the Plateau spot-tailed earless lizard.

Suitable Habitat

As discussed in Chapter 2, the Plateau spot-tailed earless lizard habitat needs include appropriate surface and subsurface habitat. Briefly, this habitat consists of open areas for basking, foraging, and movement, and of access to the subsurface, which is used for sheltering and nesting. Above-ground habitat is characterized by low levels of overstory shrubs and trees, and a density of grasses, forbs, and other plants that allows for patches of bare ground. Subsurface habitat is characterized by the presence of either numerous animal burrows or fissures, or friable soils that allow the Plateau spot-tailed earless lizard to self-bury and to dig nests. There are several ways in which this habitat can be maintained, degraded, or removed from the landscape, and the mechanisms may be either direct or indirect.

Mechanisms

Development

Urbanization involves the conversion of natural or vegetative land cover to impervious cover or nonnative (landscaped) vegetation. Urban, suburban, and exurban development includes the construction of buildings and paved surfaces such as roads and parking lots (McKinney 2002, p. 884). Development is also associated with the planting of turf grass and maintaining specific plant communities (e.g., ornamental landscaping) (McKinney 2002, p. 884).

Inhibition of Disturbance

The inhibition or removal of the sources of resetting successional pathways—especially American bison, black-tailed prairie dogs, and fire—also removes or degrades Plateau spot-tailed earless lizard habitat by allowing open grasslands and savannas to succeed into dense shrublands, woodlands, and even forests, and removing a mechanism that creates patches of bare soil (Frost 1998, pp. 74–75).

American bison were present on the Edwards Plateau at the time of European settlement, although their numbers were likely smaller than further north on the Great Plains; the Edwards Plateau is the edge of their range, and the Balcones Escarpment precludes bison passage (Box 1967, pp. 39–40; Huebner 1991, p. 348; Kimbrell Howell 1999, pp. 109–110; Schmidly 2002, pp. 68–69; Sanderson et al. 2008, pp. 255–256). Where American bison ranged, they would have played a role in maintaining the open grasslands apparently favored by the Plateau spot-tailed earless lizard. Grazing and wallowing behavior by American bison resets successional pathways, creating habitat for not only the Plateau spot-tailed earless lizard but other grassland species, including black-tailed prairie dogs (Sanderson et al. 2008, pp. 253–254; Stambaugh et al. 2014, p. 79).

Black-tailed prairie dogs are important ecosystem engineers where they occur, maintaining shortgrass prairie and creating burrows that other animals can use (Scott 1996, pp. 47–48). Localized extirpations of black-tailed prairie dogs across the Plateau spot-tailed earless lizard range during the first half of the 20th century has allowed for increasing plant density and reduced sheltering opportunities for the Plateau spot-tailed earless lizard (Miller et al. 1994, p. 678). In the portion of the black-tailed prairie dog range where the Plateau spot-tailed earless lizard occurs, the abundance and distribution of the black-tailed prairie dog is likely 5–15% of its historical extent (Singhurst et al. 2010, pp. 253–255). The loss of black-tailed prairie dogs could partially explain the shift on the Edwards Plateau away from grasslands with abundant patches of bare ground towards a denser vegetation with significant shrub and tree encroachment (Weltzin et al. 1997, pp. 758–761; Ceballos et al. 2010, pp. 7–8).

Fire recurred, on average, at very short intervals (every few to several years) across much of Texas and most of the Plateau spot-tailed earless lizard range prior to European settlement (Stambaugh et al. 2014, p. 74). There is not consensus on the exact value of the fire return interval, in large part because the average fire return interval would realistically have varied across the Edwards Plateau based on local soils, topography, vegetation, and indigenous ignitions (Frost 1998, pp. 78–79; Stambaugh et al. 2014, pp. 76–80). However, there is general agreement that historically, grasslands were maintained on the Edwards Plateau by frequent fire, including that set by indigenous peoples (Frost 1998, pp. 78–79; Stambaugh et al. 2014, p. 80). Fire frequency was slightly less in the Mesquite Plains (northeastern Unit 3; Unit 4), which allowed honey mesquite to coexist with grasslands, but precluded invasion by redberry juniper (Arnold et al. 1978, p. 19; Stambaugh et al. 2014, p. 81).

Row-Crop Agriculture

Agricultural development involves the conversion of natural land cover to nonnative crops. We focus here specifically on row-crop agriculture (not pastureland). Cultivated row crops may consist of a wide variety of fruits and vegetables, but the dominant crops in Plateau spot-tailed earless lizard population analysis units with substantial farmland are sorghum, corn, cotton, and winter wheat (USDA 2019; 2020; 2021). Farmers may rotate among these crops in order to improve yields, manage pests, and lower the risk of crop failures (NIPMD 2003, pp. 7–10, 16–17, 20. 24; NIPMD 2008, pp. 2–4, 10–11; NIPMD 2009, pp. 19–21; USDA 2008; 2009; 2010; 2011; 2012; 2013; 2014; 2015; 2016; 2017; 2018; 2019; 2020; 2021; USDA Southern Region Pest Management 2012, pp. 13, 19). Cotton crops are sprayed with a chemical defoliant prior to harvest (NIPMD 2009, p. 4). All of these crops are typically cut down to ground level or plowed under soon after harvest (Blanek 2022, p. 1, pers. comm.). We suggest that this restores, until the next crop grows, the open canopy and bare soils preferred by the Plateau spot-tailed earless lizard. Row crops also typically feature narrow, unpaved roads with low traffic levels that are primarily used by farm equipment.

Grazing

Grazing of livestock such as cattle, sheep, and goats has been a mainstay of the Edwards Plateau economy since the late 1800s (Chambers 1932, p. 67). Their impacts were felt almost immediately, and carrying capacities of livestock on the rangelands have declined more or less continuously since that time (Box 1967, pp. 41–45). A potential consequence of the overutilization of rangelands by livestock is alteration of the vegetative structure of an area (Taylor 1989, p. 297; Ansley and Hart 2012, pp. 2–3). Because livestock preferentially graze on grasses and forbs, they indirectly make shrub and tree seedlings more competitive ecologically (Archer et al. 2017, p. 32). Although livestock sometimes graze these seedlings, because they are not a first choice browse plant for any livestock, control is rarely achieved by grazing (NRCS 1994, pp. 1–2; Krueger et al. 2010, pp. 9–12, 69; U.S. Fish and Wildlife Service 2022d, p. 4, pers. comm.). As a result, when livestock are overstocked in an area, they may remove all of the grasses and forbs, leaving the shrubs and trees to expand in both density and height (NRCS 1994, pp. 1–2; Krueger et al. 2010, pp. 9–12, 69; McEachern 2022, p. 2, pers. comm.). Thus, the short-term impacts of overgrazing may be that open areas are created, but in the long-term, open areas are lost. An additional impact of rangeland overutilization is soil erosion and compaction (Walker et al. 1981, pp. 474–475, 493–494; Taylor 1989, pp. 297–299; Archer and Predick 2014, p. 1402).

Impacts to Species Needs

We assume that the loss or degradation of suitable habitat for sheltering, foraging, and thermoregulation, regardless of the mechanism, leads to a reduction in survival rates and an associated reduction in total abundance. This can occur because of a reduction in the amount of a suitable surface or subsurface habitat or as a result of a decrease in connectivity (corridors) connecting large areas of suitable habitat. As an example, a loss of habitat could lead to increased competition for suitable sheltering locations, and result in some individuals being forced to use less ideal sheltering habitats, which we suggest would lead to decreased survival rates over time. A reduction in the quality of available sheltering habitat could lead to a concentration of lizards within the remaining suitable habitat that allows them to be predated upon more easily or leaves them more vulnerable to local incidents of soil disturbance that kill them while they are buried underground. When loss or degradation of habitat occurs at sufficient levels, local extirpations may result. If the loss or degradation of suitable habitat also results in contiguous habitat being broken up into patches, then a loss of connectivity could also increase the likelihood of local extirpations.

Development

We consider the conversion of natural or vegetative land cover to impervious cover a simple loss of habitat, which negatively impacts Plateau spot-tailed earless lizard survival and abundance.

Inhibition of Disturbance

The loss of fire, American bison, and black-tailed prairie dogs from much of the range of the Plateau spot-tailed earless lizard results in the loss and degradation of its habitat. Frequent fire controls the growth and spread of woody vegetation such as juniper and mesquite; without it, grasslands become shrublands and Plateau spot-tailed earless lizard habitat is lost (Allred et al. 2012, p. 157; Ansley and Hart 2012, pp. 2–4; Hibbitts and Hibbitts 2015, pp. 28–38, 111). American bison create large areas of barren ground or with very short vegetation (Arthun and Holechek 1982, p. 125), which is habitat favored by the Plateau spot-tailed earless lizard. In their absence, this form of disturbance is only partially mimicked by livestock grazing, in part because bison have some behaviors that cattle do not, such as wallowing, and in part because livestock grazing is also associated with smaller, fenced ranges and a lack of fire (Knapp et al.

1999, pp. 45–48). The absence of American bison implies a reduction in bare ground and the loss of a force that resets successional pathways (Knapp et al. 1999, pp. 46–48), degrading or eliminating suitable Plateau spot-tailed earless lizard habitat.

Finally, the range of black-tailed prairie dogs appears to have contracted significantly and continuously for over 100 years. While studies on the relationship between the Plateau spot-tailed earless lizard and black-tailed prairie dogs are lacking, findings from work on congeners (the lesser earless lizard (*H. maculata*) and the keeled earless lizard (*H. propinqua*)) is available. These species have similar habitat requirements and life history characteristics to the Plateau spot-tailed earless lizard and have been found to use features such as prairie dog burrows for cover, especially when fleeing predators (Cooper 2000, pp. 1306–1307; Davis and Theimer 2003, p. 289; Hibbitts and Hibbitts 2015, pp. 112–119). Moreover, lesser earless lizard abundance was found to be positively correlated with the presence of Gunnison's prairie dogs (*Cynomys gunnisoni*) (Davis and Theimer 2003, pp. 284–289). In addition, the Tamaulipan spot-tailed earless lizard has been observed to use and potentially rely on Rio Grande ground squirrel (*Ictidomys parvidens*) burrows in some areas (Duran and Yandell 2014, p. 176). We suggest that the Plateau spot-tailed earless lizard abundance may also be positively correlated with black-tailed prairie dogs' presence and abundance. Black-tailed prairie dogs maintain short grasses, prevent the invasion of tall shrubs and of trees, promote patches of bare ground between grasses, excavate subsurface shelter, and create mounds of dirt that may serve as basking sites – all of which serve the needs of the Plateau spot-tailed earless lizard (Whicker and Detling 1988, pp. 778–780; Detling 1998, p. 440; Cooper 2000, p. 1302; Davis and Theimer 2003, p. 288). Therefore, where black-tailed prairie dogs have been locally extirpated, Plateau spot-tailed earless lizards may have decreased abundance and survival, leading in some cases to local extirpations.

Row-Crop Agriculture

Agricultural fields, particularly row crops, appear to provide suitable habitat for the Plateau spot-tailed earless lizard because surveyors reliably find individuals in and along row crops (LaDuc et al. 2018, pp. 19, 45, 127; BIO-West Inc 2020, p. 94; Hibbitts et al. 2021, pp. 504–505; Henke 2022b, pp. 2–3, pers. comm.). This conclusion reflects a revision of a prior hypothesis that Plateau spot-tailed earless lizards were becoming locally extirpated from areas with concentrated row-crop agriculture (Duran and Axtell 2011, pp. 24–27; Duran 2017, p. 14). In one example in 2018, researchers observed a radio-tagged Tamaulipan spot-tailed earless lizard present in an agriculture field before and after mechanical disking occurred. This indicates that soil disturbance in cultivated crops does not necessarily harm these lizards (BIO-West Inc. 2020, p. 28). The reasons that the Plateau spot-tailed earless lizard inhabit these row crop fields are not well understood, but hypotheses in the literature suggest that row-crop agricultural fields have sufficiently loose soil to allow lizards to easily self-bury or use other animals' burrows, and the open conditions (bare soil, low canopy cover) allow for foraging, thermoregulation, and interactions with conspecifics (Roelke et al. 2018, p. 1024). The roads in between row crops provide an additional open area for the Plateau spot-tailed earless lizard to use, and potential refugia during localized flooding (LaDuc et al. 2018, pp. 22, 45).

Grazing

In the short-term, grazing can create Plateau spot-tailed earless lizard habitat by removing tall vegetation and creating patches of bare soil (Archer et al. 2017, p. 42). However, in the range of the Plateau spot-tailed earless lizard, over the long-term, the synergistic effects of overgrazing (especially coupled with fire suppression) frequently lead to shrub and tree encroachment that degrades or eliminates Plateau spot-tailed earless lizard habitat (NRCS 1994, pp. 1–2; Archer et al. 2017, pp. 42–43). In addition, soil erosion and compaction could make it more difficult for the Plateau spot-tailed earless lizard to successfully bury itself, impeding sheltering behavior, even in areas that otherwise appear to be suitable habitat (Buechner 1944, pp. 718, 728; Taylor 1989, pp. 297–299; Fuhlendorf and Smeins 1997b, p. 825; Van Auken 2000, p. 206; Mysterud 2006, pp. 130–135; Archer et al. 2017, p. 33).

Geographic and Temporal Scope

Development

Overall, the range of the Plateau spot-tailed earless lizard is rural in nature. We looked at the total area in a developed class for each population analysis unit according to the U.S. Environmental Protection Agency's Integrated Climate and Land Use Scenarios (ICLUS) project datasets (U.S. Environmental Protection Agency 2017). Twelve of sixteen population analysis units have less than 1% of their total area in a developed class, and all were over 90% undeveloped. The City of San Angelo, Texas, with a population of approximately 100,000 people (Texas Demographic Center 2022, p. 18), is the only significant urban area within the population analysis units, influencing Unit 3-C and Unit 3-D (96.4% and 95.7% undeveloped, respectively). The only other census-designated urban areas intersecting Plateau spot-tailed earless lizard population analysis units are Ozona, Texas, and Junction, Texas, with populations of approximately 2,700 and 2,500, respectively (Texas Demographic Center 2022, p. 12). These units intersect Unit 3-A (99.5% undeveloped) and Unit 6 (97% undeveloped). Based on conversations with professional wildlife biologists, there is currently a trend toward subdivision of large landholdings in Unit 3-F, Unit 3-G, Unit 3-H, Unit 6, Unit 7, Unit 8, and Unit 9, in which additional roads and housing are being constructed (Blair 2022, p. 1, pers. comm.; Hendon 2022, pp. 1–2, pers. comm.; U.S. Fish and Wildlife Service 2022d, pp. 1–2, pers. comm.). Unit 9 has the lowest proportion of undeveloped land of all the population analysis units, at 91.3%, and appears to be on track for increased residential development in the future (Blair 2022, p. 1, pers. comm.; Hendon 2022, pp. 1–2, pers. comm.). Unit 9 is the only population analysis unit near major urban areas (San Antonio, San Marcos, and Austin, Texas, along the Interstate-35 corridor), and this proximity may explain its increased development pressure.

Available ICLUS projections indicate that most units will not experience significant increases in developed land in the future (Figure 4.2). Under higher development ICLUS scenarios, three units would experience increases of 7–9% in the amount of developed land by 2050: Unit 3-C (decrease to 89.3% undeveloped), Unit 3-D (decrease to 86.7% undeveloped), and Unit 9 (decrease to 82.9% undeveloped). Under such a scenario, seven units would continue to have less than 1% of their area in a developed class, and all would be at least 82% undeveloped. We conclude that the impact of development is relatively small over space and time.

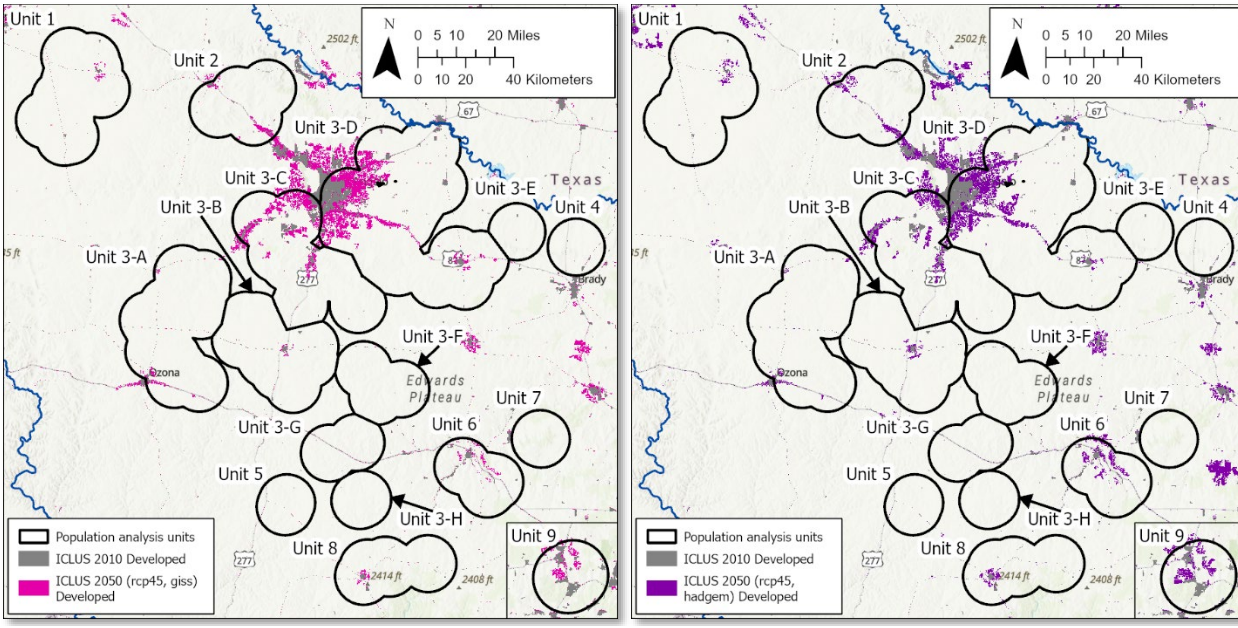

Figure 4.2. Developed area across Plateau spot-tailed earless lizard population analysis units for 2010 and 2050. The two 2050 projections shown are those which led to the greatest increase in developed area for one or more population analysis units. Pixels in grey represent currently developed land. Pink or purple pixels represent projected new developed area in 2050 according to ICLUS projections.

Inhibition of Disturbance

Several disturbance forces that historically would have reset vegetation succession back to bare soil or early successional vegetation have been altered within or eliminated from the range of the Plateau spot-tailed earless lizard. The suppression of frequent fire since European settlement is an impact occurring across the lizard's range (Figure 4.3) (Buechner 1944, pp. 702–704; Fuhlendorf et al. 1996, pp. 246–254; Hampton 2014, pp. 25, 31). The extirpation of black-tailed prairie dogs, whose colonies are associated with early successional communities, has occurred in much of the Plateau spot-tailed earless lizard range (Figure 4.4). While black-tailed prairie dogs are still present in Unit 1, Unit 3-A, and Unit 3-B, their abundance is likely reduced from their historical numbers (Singhurst et al. 2010, pp. 250–260; TPWD 2011). American bison also would have moved through most of the units but have been completely extirpated from the area for about 150 years (Schmidly 2002, pp. 68–69; Sanderson et al. 2008, pp. 255–256; Texas Parks and Wildlife Department n.d.).

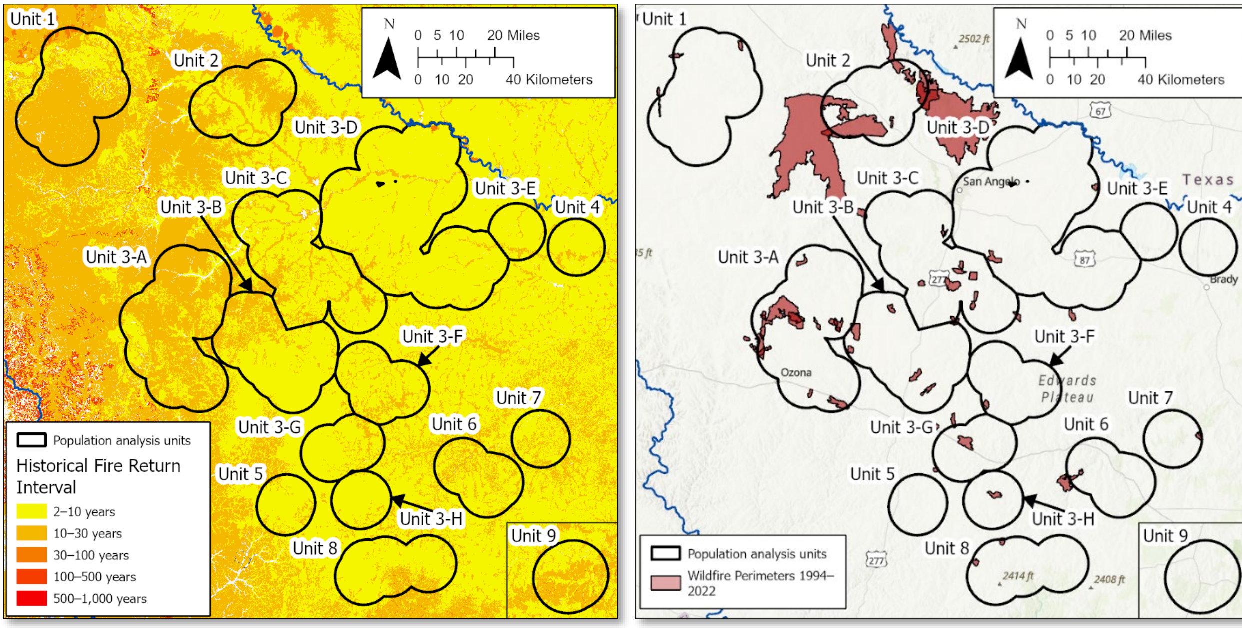

Figure 4.3. Historical fire return interval (left) and wildfire perimeters from the last 20 years. Wildfire frequency is much lower today than historically, due to synergistic factors that include suppression of wildfires.

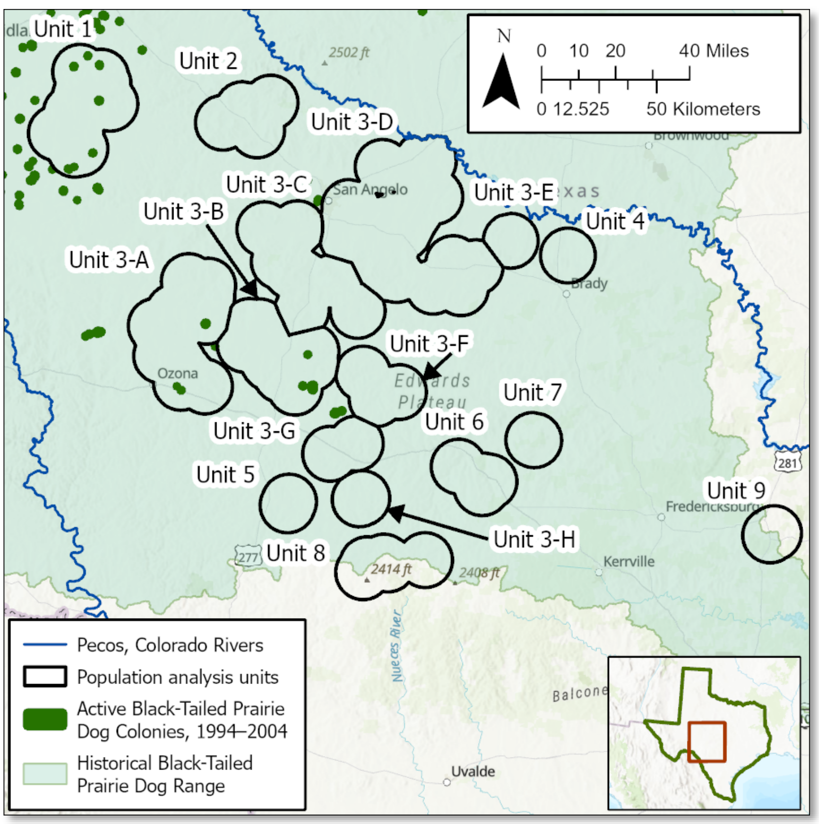

Figure 4.4. Black-tailed prairie dog historical range and active colonies from the period 1994–2004 overlaid onto the Plateau spot-tailed earless lizard population analysis units.

Without these natural disturbances, vegetation on the Edwards Plateau is more likely to succeed into shrublands and forests. In general, the Plateau spot-tailed earless lizard's distribution occurs across temperature and precipitation gradients (Figure 4.5). In addition to soils, these climate factors influence vegetation across the region. The southern portion of the Plateau spot-tailed earless lizard range grades into the Texas Hill Country towards the Balcones Escarpment. Although there are still open areas with Plateau spot-tailed earless lizard habitat on ranches, there are also a lot of juniper-oak forests (U.S. Fish and Wildlife Service 2022c, p. 2, pers. comm.). There are also more shrubs (U.S. Fish and Wildlife Service 2022c, p. 2, pers. comm.). According to people who have surveyed for the Plateau spot-tailed earless lizard, there is less Plateau spot-tailed earless lizard habitat in these areas compared to the more northern portion of the range, and pockets of habitat are fewer and smaller (Blair 2022, p. 1, pers. comm.; Rains 2022a, p. 1, pers. comm.; U.S. Fish and Wildlife Service 2022c, p. 2, pers. comm.). To the north and west, the drier climate and the soils make the persistence of historical grasslands dotted infrequently by trees or shrubs more likely, although Unit 2, Unit 3-D, and Unit 3-E have issues with brush encroachment, primarily by mesquite (Newberry 2022, p. 1, pers. comm.; Rains 2022a, p. 1, pers. comm.).

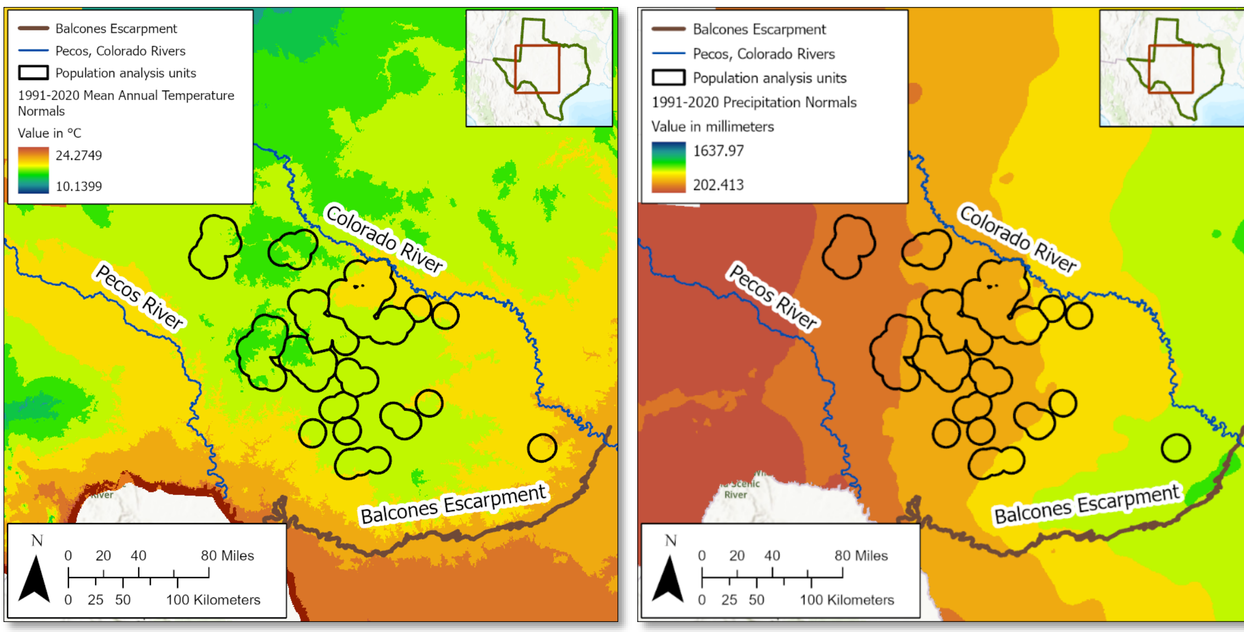

Figure 4.5. Mean annual temperature and precipitation 30-year normals for the period 1990–2020.

Anywhere that there is tree and shrub encroachment on grasslands, there is demand for brush removal (Hendon 2022, p. 2, pers. comm.; Rains 2022a, p. 1, pers. comm.). However, it is very expensive, and therefore must be done selectively (McEachern 2022, p. 1, pers. comm.; U.S. Fish and Wildlife Service 2022d, p. 1, pers. comm.). In Unit 3-A, Unit 3-B, Unit 3-F, Unit 3-G, Unit 3-H, and Units 5–9, the main species targeted in brush removal operations is Ashe juniper (*Juniperus ashei*, locally referred to as cedar) (Blair 2022, p. 1, pers. comm.; Hendon 2022, p. 2, pers. comm.; McEachern 2022, p. 1, pers. comm.; U.S. Fish and Wildlife Service 2022d, p. 1, pers. comm.). To the north, in Unit 1, Unit 2, Unit 3-C, and Unit 3-D, mesquite (*Prosopis* spp.) is targeted for removal (Newberry 2022, p. 1, pers. comm.; U.S. Fish and Wildlife Service 2022d, p. 3, pers. comm.). In Unit 3-G, Unit 3-H, Unit 5, Unit 6, and Unit 8, redberry juniper (*Juniperus pinchotii*) is a problem shrub (U.S. Fish and Wildlife Service 2022d, p. 4, pers. comm.).

In Unit 3-F, Unit 3-G, Unit 3-H, Unit 5, Unit 6, Unit 8, and Unit 9, the majority of the units are comprised of plant communities that naturally succeed into forest (i.e., Conifer and Hardwood Biophysical Setting types) in the absence of disturbance (Figure 4.6), and this process is occurring now and expected to continue into the future in all units (Landfire 2016; University of Montana et al. 2022). The units with the most woody cover currently (based on an average of 2019–2021 data) are Units 6–9. The units with the fastest current rate of increase in woody cover (based on an average area from 1986–2021) are Unit 2, Unit 3-F, Unit 3-G, Unit 6, and Unit 7. The units with the least amount of woody cover currently are Unit 1, Unit 3-A, Unit 3-B, Unit 3-D, and Unit 3-E. The units with the smallest current rate of increase in woody cover are Unit 1, Unit 3-D, and Unit 9. A more detailed explanation of the geoprocessing and calculations used to make these determination is presented in Chapter 6 and in Appendix B. Unit 9's slow rate of increase is likely due to the reduction in available land for the woody species to colonize (Archer et al. 2017, pp. 28–30).

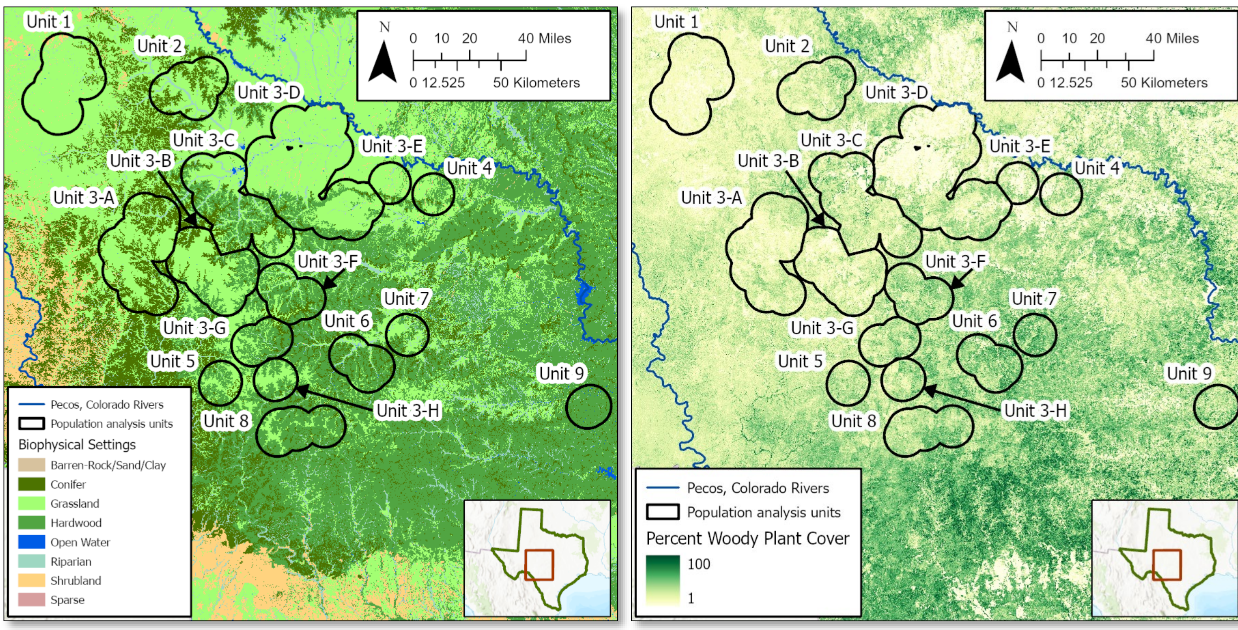

Figure 4.6. Left: Landfire biophysical settings vegetation groups. Darker greens are conifers and hardwoods, while lighter greens are grassland. Right: Rangelands Analysis Project percent woody plan cover for 2020, calculated by combining tree and shrub individual cover layers.

Row-Crop Agriculture

In general, the Plateau spot-tailed earless lizard's distribution occurs across temperature and precipitation gradients (Figure 4.5). In addition to soils, these influence land use across the region. For example, due to both climate and soils, row crop agriculture is only substantial across the northern portion of the species' range. In Unit 1, Unit 2, Unit 3-B, Unit 3-C, Unit 3-D, Unit 3-E, and Unit 4, people grow cotton, winter wheat, sorghum, and corn (USDA 2019; 2020; 2021; Figure 4.7). Four units (Unit 1, Unit 3-D, Unit 3-E, and Unit 4) have significant amounts of area in crops (32%, 34%, 27%, and 17%, respectively). In the remaining twelve units, row-crop agriculture comprises a low proportion (never more than 5%) of each unit.

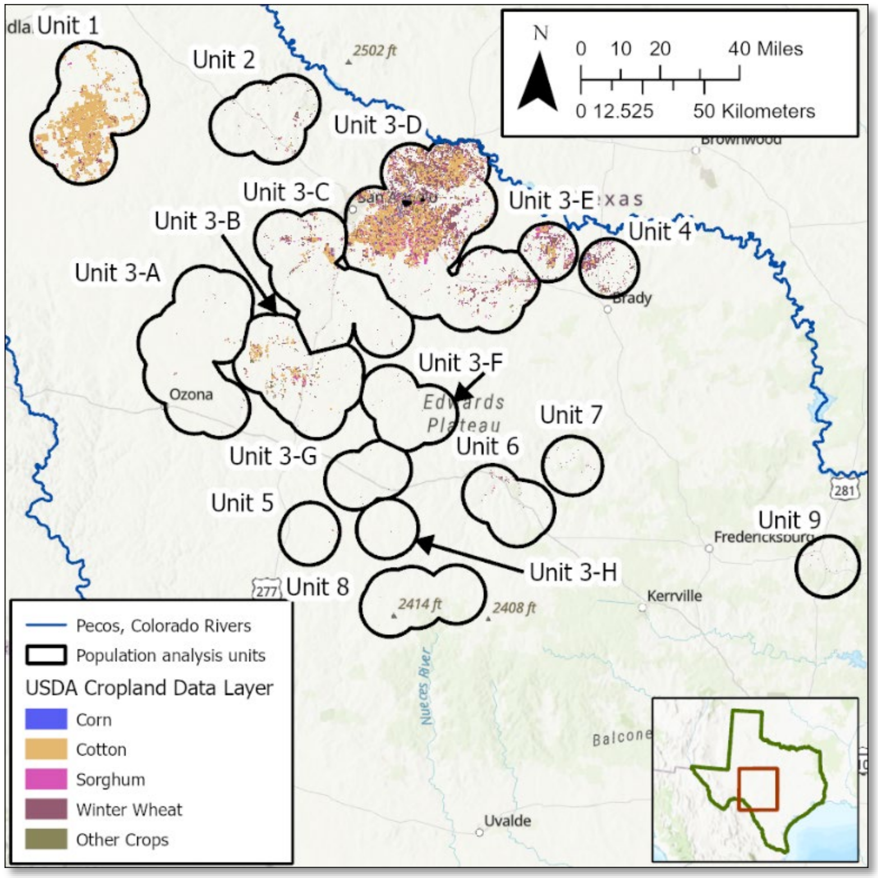

Figure 4.7. USDA National Agriculture Statistics Service Cropland Data Layer for 2021.

Grazing

Ranching occurs in all population analysis units. Units with farming are associated with cattle as the predominant stock animal, although in Units 6, 7, and 9, which do not have substantial farming, cattle are the main livestock (McEachern 2022, p. 2, pers. comm.; U.S. Fish and Wildlife Service 2022d, p. 1, pers. comm.). In the other units, sheep and goats are the primary stock animal grazing rangelands (U.S. Fish and Wildlife Service 2022d, p. 1, pers. comm.). All three types of stock can be found across each unit; here we focus on reporting the dominant stock animal. Because cattle feed primarily on grass, they are found in the parts of the Plateau spot-tailed earless lizard range where rainfall tends to be reliable and soils are reasonably productive (McEachern 2022, p. 2, pers. comm.; U.S. Fish and Wildlife Service 2022d, p. 2, pers. comm.). Sheep and goats are considered hardier and tend to be found in places with more erratic rainfall and more limited natural forage availability (McEachern 2022, p. 2, pers. comm.; U.S. Fish and Wildlife Service 2022d, p. 2, pers. comm.). However, subsidies for wool and mohair were also phased out in the 1990s, removing an important incentive to continue sheep and goat ranching (Wilcox et al. 2012, p. 316).

Overutilization of rangelands has been an ongoing issue throughout most of the range of the Plateau spot-tailed earless lizard since the arrival of European settlers who replaced the American bison with cattle (Buechner 1944, pp. 703–706; Box 1967, entire). The legacy of overutilization of rangelands from the earliest settlements has long-term effects, such that even when stocking densities are lowered, changes to the vegetation community as a result of long-ago overstocking mean that the current stocking capacity of rangelands is lower than many decades ago, and that shifts toward increased woody vegetation are not necessarily reversible (Buechner 1944, pp. 703–078; Walker et al. 1981, pp. 474–475, 493–494; Diamond 2019). We spoke with professional wildlife biologists from across the Plateau spot-tailed earless lizard range, and they confirmed that almost all units have a history of overutilization of the range (Blair 2022, p. 2, pers. comm.; McEachern 2022, p. 2, pers. comm.; Newberry 2022, pp. 1–2, pers. comm.; Perlicheck 2022, p. 2, pers. comm.; Rains 2022a, p. 1, pers. comm.; U.S. Fish and Wildlife Service 2022c, p. 2, pers. comm.; 2022d, pp. 3–4, pers. comm.). However, surveys for the Plateau spot-tailed earless lizard have been successful in heavily overgrazed areas, as long as shrub density is not too high (U.S. Fish and Wildlife Service 2022c, p. 2, pers. comm.). In combination with other factors, overutilization has led to brush encroachment, as discussed above; it is not possible to manually remove all of the brush, and management of the land varies widely among landowners (Blair 2022, pp. 1–2, pers. comm.; Hendon 2022, p. 2, pers. comm.; McEachern 2022, p. 2, pers. comm.; Newberry 2022, pp. 1–2, pers. comm.; Perlicheck 2022, p. 1, pers. comm.; Rains 2022a, p. 1, pers. comm.; U.S. Fish and Wildlife Service 2022c, p. 2, pers. comm.; 2022d, pp. 1–4, pers. comm.).

Several units found within the Texas Hill Country (Units 3-G, 3-H, 5, 6, 7, 8, and 9) have experienced shifts in land use from ranching livestock to promoting wild deer populations or raising exotic wildlife for hunting (Blair 2022, p. 1, pers. comm.; U.S. Fish and Wildlife Service 2022d, p. 1, pers. comm.). Exotic wildlife ranching can be very lucrative (Newberry 2022, p. 1, pers. comm.). Property tax exemptions for wildlife, which includes deer, offer the same financial benefit as those for agriculture, and many new landowners are interested in managing lands for deer and other game species (Blair 2022, p. 1, pers. comm.; U.S. Fish and Wildlife Service 2022d, p. 1, pers. comm.). Deer prefer higher brush cover and taller grasses compared to stock animals, so landowners managing for them promote those conditions, which are not suitable for the Plateau spot-tailed earless lizard (Buechner 1944, pp. 740–741; Hailey 1979, entire; Fulbright and Taylor 2001, entire).

Vehicle Traffic

Mechanisms

Because Plateau spot-tailed earless lizards use roadways for basking, foraging, and interacting with other individuals, they are vulnerable to injury or mortality as a result of being run over by vehicles on those roadways. We assume that as the number of vehicles on a road increases, so does the risk of being hit by a vehicle. Roads may take many forms, from divided multi-lane interstates, with large, frequently mowed rights-of-way, to small, dirt or gravel single-lane pathways on private land (TxDOT 2020a; U.S. Census Bureau 2022a).

Impacts to Species Needs

We did not locate any studies or estimates of road mortality or its impacts on survivals based on empirical data for the Plateau spot-tailed earless lizard or any closely related species. However, researchers conducting field studies on the Plateau spot-tailed earless lizard report road mortalities, and some of our locality database specimens were found dead on a road (Duran and Axtell 2011, p. 7; Hibbitts et al. 2019, p. 141; 2021, pp. 501–502).

Vehicle traffic on roads causes injury and mortality to Plateau spot-tailed earless lizards (Duran and Axtell 2011, p. 27; LaDuc et al. 2018, pp. 42, 123; Hibbitts et al. 2021, pp. 501–502). Injury and mortality from vehicle strike results in reduced survival rates and additive mortality for Plateau spot-tailed earless lizards. We acknowledge that in the cases of some roads, particularly narrow, rural roads with limited traffic, the addition of the roads as a type of impervious cover may have a positive influence on the Plateau spot-tailed earless lizard. If the risk of being run over by a vehicle while using roads is very low, roads can function as habitat. However, if the risk is higher, then roads may function as a sink and a source of increase reduction in survival and abundance, on top of that arising from the loss of natural habitat on its own.

Geographic and Temporal Scope

During surveys for the Plateau spot-tailed earless lizard, surveyors have frequently found Plateau spot-tailed earless lizards using rural roads for basking, foraging, and interacting with conspecifics (Bridegam and Smith 1987, p. 40; Duran et al. 2012, pp. 305–306; Duran 2017, pp. 4, 11–15; LaDuc et al. 2018, pp. 12, 18–22, 257; Hibbitts et al. 2021, pp. 502–507). While roads may sometimes provide basking habitat for the Plateau spot-tailed earless lizard, it is unknown how they compare to naturally open corridors such as washes or other eroded, flat features.

Roads are present throughout the entirety of the species' range. The Texas Department of Transportation (TxDOT) models traffic levels for all roads under its jurisdiction (TxDOT 2018; 2019; 2020a). Unit 2, Unit 3-D, Unit 6, and Unit 9 have highest estimated road densities and traffic levels, while Unit 3-F, Unit 3-H, Unit 5 and Unit 7 have the lowest (TxDOT 2018; 2019; 2020a; Figure 4.8). In some areas, public roads are uncommon. There, most roads are on private property and are privately maintained. We generally assume that traffic on these private roads is very low. However, some areas may experience increased traffic associated with energy development (e.g., oil, natural gas, wind). The construction and maintenance of well pads, pipelines, and wind turbines can lead to increased traffic near those locations (Goodman et al. 2016, pp. 248–250; Astroza et al. 2017, pp. 1–3; Tsapakis 2020, pp. 512–514).

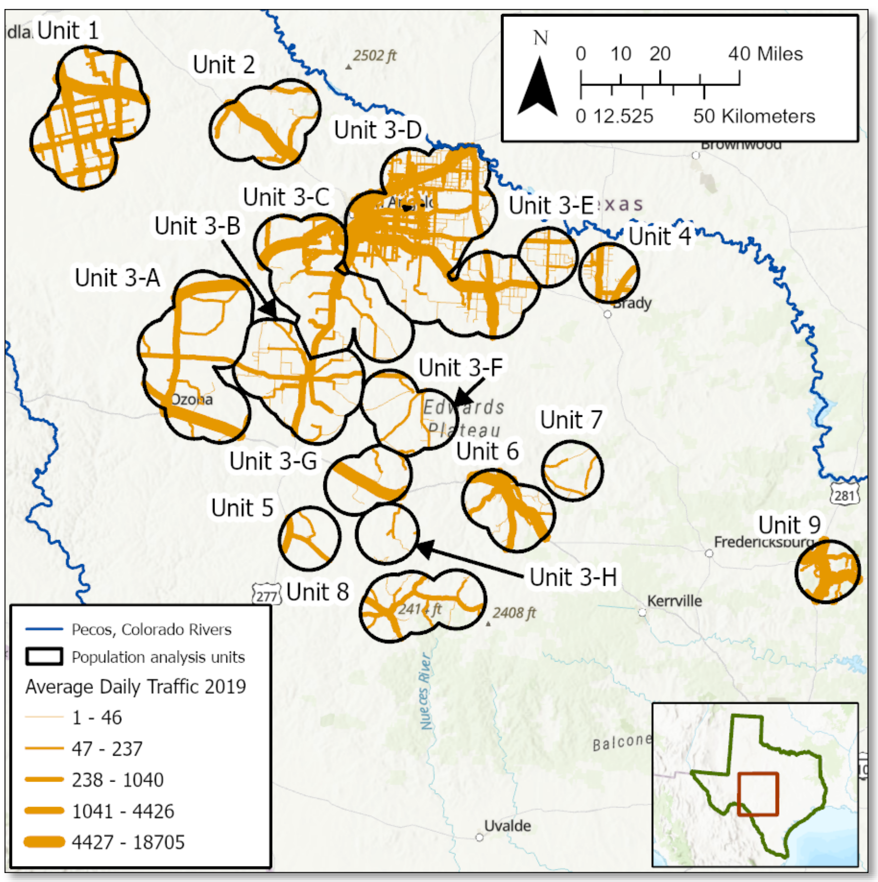

Figure 4.8. TxDOT roadways layer, clipped to the Plateau spot-tailed earless lizard population analysis units and symbolized such that thicker lines indicate higher average daily traffic in 2019.

Other Factors

Energy Development

Development for oil and natural gas extraction is heaviest in Unit 1, Unit 3-A, Unit 3-B, and Unit 5, and is less predominant elsewhere (IHS 2022a; 2022b). Wind farms have been built within the species range, but do not dominate any population analysis unit (U.S. Geological Survey 2022a). Several units have no wind energy footprint at all. Figure 4.9 show the footprint of well and pipelines associated with the oil and gas industry, and Figure 4.10 shows the footprint of wind turbines.

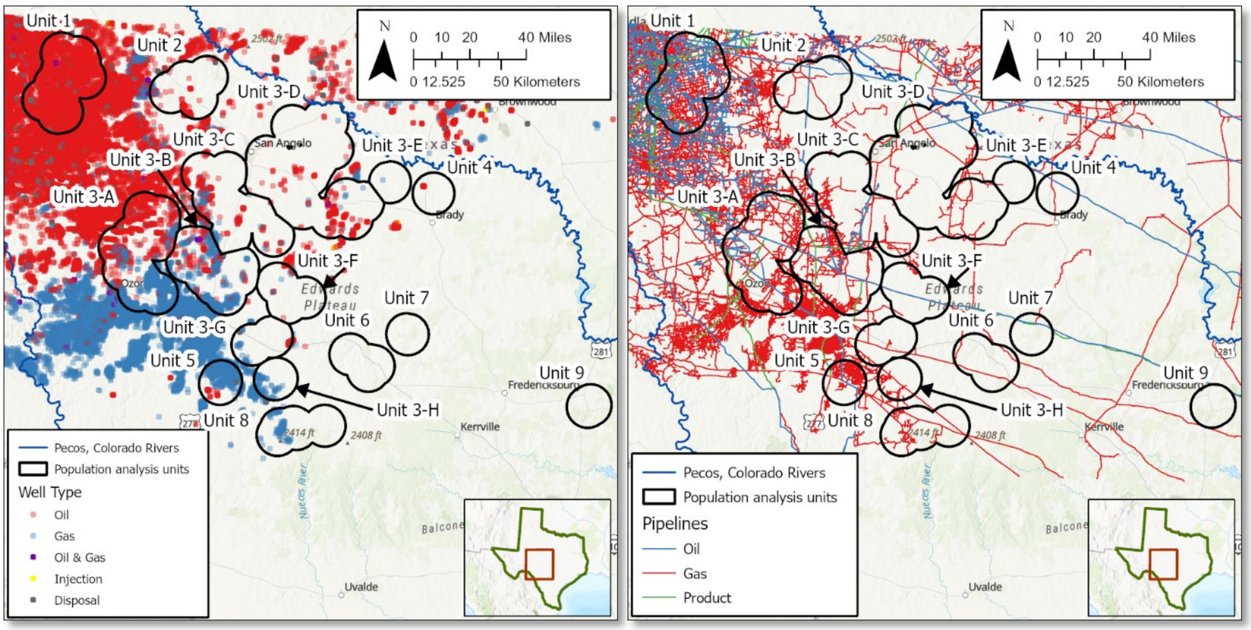

Figure 4.9. Footprint of energy development associated with oil and gas. Map to the left shows wells; map to the right shows pipelines. The Dataset was downloaded using a polygon around all population analysis units; as a result, the underlying dataset does not cover all of the visible area in Texas outside of the population analysis units.

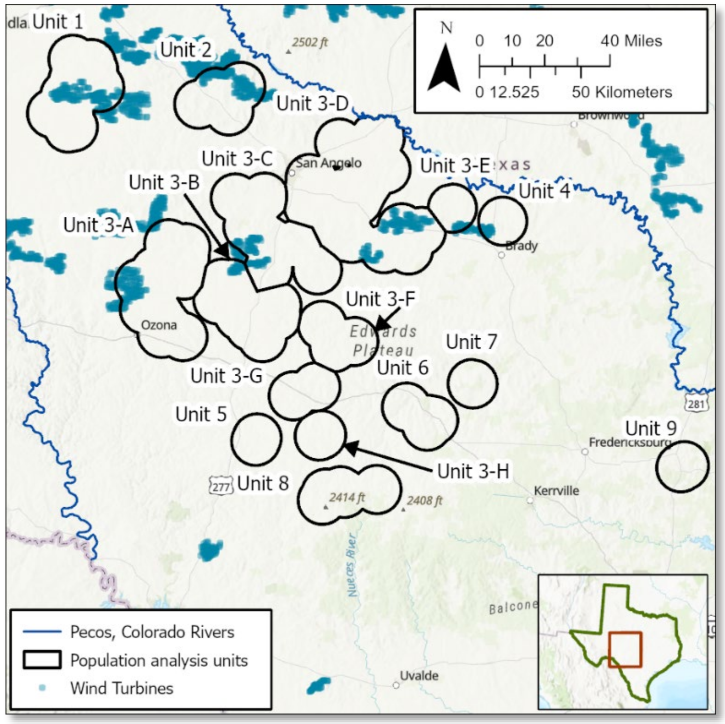

Figure 4.10. Footprint of wind energy development. Rounded blue squares represent individual wind turbines and are shown at 60% transparency in order to demonstrate density.

Energy development is expected to influence Plateau spot-tailed earless lizard habitat due to the construction of oil and gas well pads, pipelines, wind turbine pads, and roads that service them (Wolaver, Pierre, Labay, et al. 2018, p. 170; Pierre et al. 2020, pp. 1–2). Estimates of current and future land cover types most likely to be affected by conversion from an existing use to an energy-associated use identify grasslands and row crops as particularly vulnerable (Wolaver, Pierre, Ikonnikova, et al. 2018, p. 4). Although it is clear that energy development alters Plateau spot-tailed earless lizard habitat, it is not clear whether or to what extent this alteration impacts the species. Plateau spot-tailed earless lizard abundance was sufficiently high in Unit 3-A for researchers to find and capture 15 adult Plateau spot-tailed earless lizard to include in a telemetry study (Hibbitts et al. 2021, p. 501). The study area included energy development, and the telemetry work revealed that the Plateau spot-tailed earless lizard used areas that included oil and gas well pads and associated roads (Hibbitts et al. 2021, p. 506). A different research team working in Unit 3-D also found Plateau spot-tailed earless lizard near oil and gas development, completing telemetry work on nine individuals (BIO-West Inc. 2020, pp. 4, 12, 19). From this we conclude that, at minimum, energy development does not exclude Plateau spot-tailed earless lizard from an area.

Overall, it is not clear exactly how the impacts from energy development on the landscape influence the viability of the Plateau spot-tailed earless lizard. To some degree, the disturbance associated with the construction and maintenance of oil, gas, or wind turbine pads, or pipelines, could potentially benefit the Plateau spot-tailed earless lizard because it creates areas of bare ground or short vegetation. On the other hand, active soil disturbance or the vehicle traffic associated with these activities could cause direct mortality. No clear patterns of Plateau spot-tailed earless lizard presence or abundance are known for areas with or without energy development.

Pesticides

Hammerson et al. (2007, p. 3) suggested that the greatest threats to the Plateau spot-tailed earless lizard are "agricultural herbicides and insecticides." However, there are no studies specifically examining the impact of pesticides on Plateau spot-tailed earless lizards or congeners. We were unable to obtain specific information about the timing or rate of pesticide use on agricultural fields within our population analysis units because this is considered private, proprietary information under Texas regulations. At the broadest level, we suggest that the use of pesticides may impact the Plateau spot-tailed earless lizard directly (from chemical exposure) or indirectly (through suppression of food sources), especially where they inhabit fields used for row-crop agriculture (Gill et al. 2018, pp. 9–11, 17; Møller et al. 2021, pp. 6–8). Studies have demonstrated a wide range of impacts to other lizards from various pesticides (DuRant et al. 2007b, pp. 20–23; 2007a, pp. 446–447; Chang et al. 2018, pp. 221–225; Zhang et al. 2019, pp. 819–823; Freitas et al. 2020, pp. 597–603; Simbula et al. 2021, p. 1024).

We reviewed documents produced by the Texas A&M AgriLife Extension Service and U.S. Department of Agriculture (USDA) on best pest management practices for cotton, corn, sorghum, and winter wheat (National Integrated Pest Management Database 2003, entire; 2008, entire; 2009, entire; USDA Southern Region Pest Management Center 2012, entire). It appears that most pesticides applied to these crops fall under the categories of herbicides and fungicides, which are less likely to impact the Plateau spot-tailed earless lizard than insecticides because of their different mode of action. Still, exposure to multiple pesticides over the course of each growing season could potentially have impacts on Plateau spot-tailed earless lizard body condition, fecundity, sprint speed, endurance, and development, and alter hormone levels, cause organ damage, and impact development (DuRant et al. 2007b, pp. 20–23; 2007a, pp. 446–447; Chang et al. 2018, pp. 221–225; Zhang et al. 2019, pp. 819–823; Freitas et al. 2020, pp. 597–603; Simbula et al. 2021, p. 1024). While it is possible that there are negative impacts to the Plateau spot-tailed earless lizard because of exposure to agricultural pesticides, it is also true that cultivated farm fields are one of the most reliable places to locate the species during surveys (LaDuc et al. 2018, pp. 19, 45, 127; BIO-West Inc 2020, p. 94; Hibbitts et al. 2021, pp. 504–505; Henke 2022b, pp. 2–3, pers. comm.). These fields include areas that have been intensively farmed for decades (Duke 1996, unpaginated). We infer from this that although exposure to pesticides likely has some impact to the Plateau spot-tailed earless lizard, it is not significant enough to drive down survival rates. In addition, as discussed above, row crops occupy a relatively small portion of the total area in population analysis units, which also minimizes the concerns about the effects of pesticides.

Red-imported Fire Ants

The petition to list the Plateau spot-tailed earless lizard and the Tamaulipan spot-tailed earless lizard under the Endangered Species Act included the assertion that the presence and expansion of red-imported fire ant (*Solenopsis invicta*) presented a threat to the persistence of these species (WildEarth Guardians 2010, pp. 3, 10, 13–14, 17, 19). The Service's 90-day finding stated that the information from the petition regarding the threat from the red-imported fire ant was substantial (Department of the Interior 2011, p. 30086). We reviewed information on the red-imported fire ant and its relationship to the Plateau spot-tailed earless lizard for this analysis.

The red-imported fire ant is a South American ant species introduced to the southeastern U.S. sometime in the 1930s or 1940s (Callcott and Collins 1996, p. 241). First documented in Texas in 1953, it has since established populations across most of the state, save the Panhandle and far west Texas (Hung and Vinson 1978, p. 206; APHIS 2022). A modeling effort in 2001 predicted that the ant would become established across most of Texas, and the current federal fire ant quarantine includes (and surrounds) most of the

Plateau spot-tailed earless lizard range, as shown in Figure 4.11 (Korzukhin et al. 2001, p. 649). Thus, it is established that the red-imported fire ant is present in the Plateau spot-tailed earless lizard range.

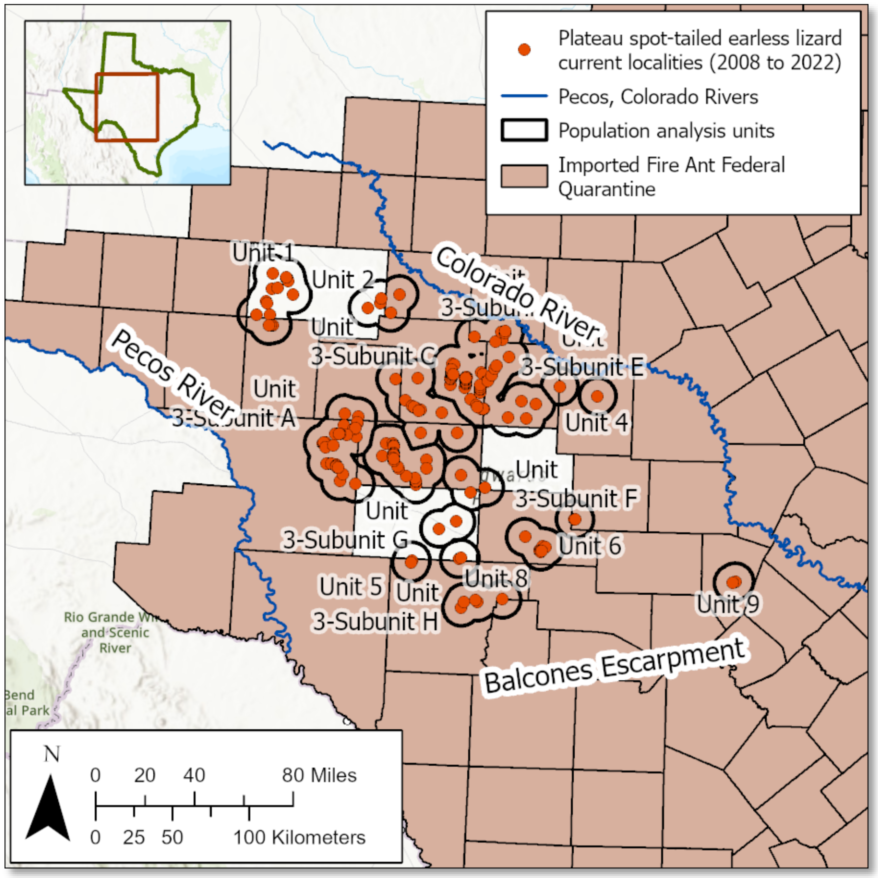

Figure 4.11. Plateau spot-tailed earless lizard population analysis units and current localities overlaid onto the current federal imported fire ant quarantine counties.

It has been hypothesized that the red-imported fire ant could negatively impact Plateau spot-tailed earless lizard populations either by competing with the Plateau spot-tailed earless lizard for prey or by attacking eggs and juveniles, resulting in a reduction in Plateau spot-tailed earless lizard recruitment or survivorship (BIO-West Inc. 2020, Appendix A). Because the Plateau spot-tailed earless lizard's diet is broad, we do not believe that changes to the arthropod community that could be caused by the red-imported fire ant are having a substantial impact on Plateau spot-tailed earless lizard fitness (LaDuc et al. 2018, pp. 81–96). We recognize that other reptiles, such as the Texas horned lizard (*Phrynosoma cornutum*), have been negatively impacted by a reduction in harvester ants caused by red-imported fire ants, but have found no similar impacts for the Plateau spot-tailed earless lizard (Wojcik et al. 2001, p. 21). With respect to a loss of eggs and juveniles, it is theoretically possible for the Plateau spot-tailed earless lizard to be impacted in this way. However, we are unaware of evidence demonstrating that the red-imported fire ant is causing significant mortality to Plateau spot-tailed earless lizard eggs or juveniles, and we are not aware of any local extirpations of the Plateau spot-tailed earless lizard that could be best explained by impacts from the red-imported fire ant.

In discussions with species experts and other professional wildlife biologists, impacts from red-imported fire ants were not identified as primary threats to the Plateau spot-tailed earless lizard (U.S. Fish and

Wildlife Service 2021, p. 8, pers. comm.). Impacts from red-imported fire ants likely occurred primarily during the period of invasion; today the consequences of that invasion have played out and the presence of red-imported fire ants do not pose a significant threat to the Plateau spot-tailed earless lizard (U.S. Fish and Wildlife Service 2021, p. 8, pers. comm.). Moreover, while we know that the red-imported fire ant is present throughout most or potentially all of the Plateau spot-tailed earless lizard range, we do not have data on relative abundance of red-imported fire ant in these areas. It is likely that aridity in the western portion of the Plateau spot-tailed earless lizard range, and colder temperatures in the northern portion, limit the density of red-imported fire ants (Hung and Vinson 1978, p. 210; Korzukhin et al. 2001, pp. 649–652; Sutherst and Maywald 2005, pp. 320–328). Professional wildlife biologists report seeing red-imported fire ants mostly near water, riparian areas, and drainages (Hibbitts et al. 2023, p. 1, pers. comm.; Newberry 2023, p. 1, pers. comm.; Rains et al. 2023, pp. 1–2, pers. comm.). Therefore, another reason why the Plateau spot-tailed earless lizard is not impacted by the red-imported fire ant is that the red-imported fire ant is restricted to a small subset of the habitat occupied by the Plateau spot-tailed earless lizard. In addition, species experts report observing red-imported fire ants in the same general area as healthy Plateau spot-tailed earless lizard populations (Hibbitts et al. 2023, p. 1, pers. comm.). Consequently, we find that the red-imported fire ant is not causing local extirpations of Plateau spot-tailed earless lizard populations and that there is no evidence that it is meaningfully impacting Plateau spot-tailed earless lizard local abundance.

Climate Change

In Texas, climate change has resulted in an increase in mean annual temperatures of about 1˚F (0.6˚ C) since 1950, and both lower and higher future emission scenarios predict "historically unprecedented warming" through 2100 (Runkle et al. 2017, p. 1). The average daily maximum temperature for Tom Green County, Texas, in the heart of the Plateau spot-tailed earless lizard range, is projected to increase 6° F (3.3° C) by 2050 and 10° F (5.5° C) by 2100 under higher emissions scenarios (U.S. Federal Government 2020). Projected future soil temperatures for the western United States indicate that soil temperatures within the range of the Plateau spot-tailed earless lizard are expected to rise by similar amounts by the end of the century under the RCP 8.5 scenario: 6.3–8.1° F (3.5–4.5° C) (Bradford et al. 2019, pp. 3–6).

While the most recent projections still contain significant uncertainty in changes to average annual precipitation, future droughts are expected to be more intense (Runkle et al. 2017, p. 3). This is because increasing temperatures result in increased evapotranspiration, which in turn causes lower soil moisture and higher surface temperatures (Runkle et al. 2017, p. 3; Cheng et al. 2019, pp. 4436–4438). The impacts of drought on the vegetation communities within the species' range are not well understood (Van Auken 2000, p. 206; Archer et al. 2017, pp. 33–36). Drought could reset successional pathways in some areas or promote shrub dominance (Van Auken 2000, p. 206; Archer et al. 2017, pp. 33–36). Thus, drought conditions could promote or inhibit suitable habitat for the Plateau spot-tailed earless lizard.

The Plateau spot-tailed earless lizard could benefit from higher temperatures under climate change. Warmer overnight lows have been shown to have some benefits in studies of other lizards. For example, a series of experiments on the side-blotched lizard (*Uta stansburiana*) found that warmer nighttime temperatures increased the probability that females laid a second clutch (Clarke and Zani 2012, pp. 1120–1121). It also reduced the length of the ovarian cycle, potentially shortening the length of time a gravid female suffers reduced locomotor capacity and consequently improving survival rates during a vulnerable period (Clarke and Zani 2012, p. 1124). The same study also indicated that when eggs are exposed to warmer temperatures, it increases the mass and length of hatchlings, which is related to fitness in the side-blotched lizard and may also be related in the Plateau spot-tailed earless lizard (Clarke and Zani 2012, p.

1125). For clutches laid late in the season, an extended warm fall may also increase the number of late hatchlings that are able to grow enough to successfully overwinter, with downstream effects on populations as a result of high juvenile survival (Clarke and Zani 2012, p. 1125).

However, research also supports the possibility that climate change will negatively impact the Plateau spot-tailed earless lizard. For example, warmer temperatures in general, including warmer overnight lows, could increase the resting metabolic rate of individual lizards, forcing them to increase time spent foraging (Zani 2008, p. 798; Kearney et al. 2009, p. 3838). This could in turn increase their exposure to predation or to extreme high temperatures, which would negatively impact individual survival rates (Zani 2008, p. 798; Kearney et al. 2009, p. 3838). Warmer winters could have a similar effect if the higher temperatures result in increased metabolic rates for individuals that are brumating, either causing them to starve or forcing them to emerge and forage during an atypical time of year, which could suppress overwinter survival (Zani 2008, p. 805). A study on the common lizard (*Zootaca vivipara*), found that juvenile lizards exposed to warmer temperatures grew faster, but did not weigh more and had lower energy reserves and had a lower body condition at the end of the study, indicating a tradeoff between short-term growth and long-term survival that could also be present in the Plateau spot-tailed earless lizard (Rutschmann et al. 2021, p. 1872). Efforts to assess the thermal maximum for the eastern fence lizard (*Sceloporus undulatus*) were successful in establishing these thresholds in laboratory settings, one of which predicted that embryos could not survive in nests when surface temperatures exceed 44° C (Angilletta et al. 2000, pp. 2961–2965; Levy et al. 2016, p. 622). Modeling by Levy et al. (Levy et al. 2016, pp. 621–623) showed that if high midsummer temperatures exceed embryonic tolerances, in the future there will likely be a midsummer gap during which reproduction will not be successful unless the affected species have the behavioral plasticity to adjust when nesting occurs. The Plateau spot-tailed earless lizard presumably also has a soil temperature threshold above which nest failure is likely, although we do not currently know either the temperature threshold for embryos or the range of nest temperatures now or in the past.

The impacts from climate change, especially from warming, are complex and likely vary among species, making it challenging to predict whether the Plateau spot-tailed earless lizard will be a "winner" or "loser" under climate change in the absence of a more detailed behavioral and physiological understanding of the species' needs than we currently have (Zani 2008, p. 807). The impacts of climate change on arthropods (the primary group making up the Plateau spot-tailed earless lizard diet) are projected to vary substantially from species to species (Brantley and Ford 2012, pp. 36–38). Arthropod community composition will likely change in response to climate change and other environmental influences in the future, but the total abundance of arthropods is not expected to decline (Brantley and Ford 2012, pp. 36–38). Because the Plateau spot-tailed earless lizard is an opportunistic feeder that does not specialize on one or a few specific species, we suggest that it will adapt to changing prey availability in the future. In addition, the preferred body temperature of the Plateau spot-tailed earless lizard is broad and includes a maximum exceeding similar lizards by 2° C (Clarke 1963, pp. 91–97). This may indicate behavioral plasticity and a level of tolerance to high temperatures that may also buffer it from the negative consequences associated with increases in air and soil temperatures (Sinervo et al. 2010, p. 897). Decisions by females on where and when to place nests will have important impacts on fecundity, and decisions by all individuals on foraging strategies will have important effects on overall survival and fitness (Clarke and Zani 2012, p. 1125). Behavioral adjustments by the Plateau spot-tailed earless lizard in response to climate change will be a key factor governing whether the net impacts to the species are positive or negative (Kearney et al. 2009, p. 3840; Clarke and Zani 2012, p. 1125).

Studies on various lizards have found conflicting and complex relationships between the warming and drying trends associated with climate change and actual or projected influences on various species (e.g., Flesch et al. 2017, p. 5505). Warmer temperatures may have both positive and negative effects, and may impact a species differently across different life stages or at different times of year (Levy et al. 2016, p. 620; Flesch et al. 2017, p. 5501). Because we currently lack sufficient understanding of the impacts that climate change will have on the Plateau spot-tailed earless lizard, we did not include it in the scenarios used in Chapter 6. However, we present an overview of the potential impacts in this section.

5 Current Condition

In this chapter, we present the results of our Plateau spot-tailed earless lizard current condition analysis in terms of resiliency, redundancy, and representation.

Current Resiliency

Resiliency Analysis Methodology

Resiliency is the ability of a species to withstand environmental and demographic stochasticity: periodic disturbances within the normal range of variation. We gauge resiliency by evaluating population-level characteristics. We sought to include both habitat and demographic factors because our conceptual model (Figure 4.1) identified both as influencing viability. To do this, we assessed available data to quantify or qualitatively describe the intersection between species needs and factors influencing viability. We reviewed online databases, reports, scientific publications, books, spatial datasets concerning land cover, unpublished datasets, and interviewed individual researchers to locate information that could be standardized and applied to Plateau spot-tailed earless lizard population analysis units across the entire species' range.

After considering the available data and the stressors described in Chapter 4, we selected one demographic factor (*Occurrence*) and three habitat factors (*Traffic Intensity, Suitable Habitat,* and *Biophysical Setting*) for our resiliency analysis. We chose these factors based on our understanding of their importance to Plateau spot-tailed earless lizard viability (Chapter 4; Figure 4.1), the availability of quantitative data for use in the current conditions analysis, the availability of data for use in the future conditions analysis (or ability to project metric values into the future), and the potential for differentiating conditions among population analysis units (we assume conditions for the Plateau spot-tailed earless lizard are not identical in each unit). Based on the available data and our understanding of Plateau spot-tailed earless lizard ecology, we developed a basis for assigning a resiliency category for each metric at the population analysis unit level. The resiliency category reflects a qualitative determination of the likelihood that the result of the species' response to the conditions described in each individual metric, over the 20-year period following the year 2022, would be extirpation from a given population analysis unit (Table 5.1). A population analysis unit characterized as high resiliency has a low likelihood of extirpation at the scale of that population analysis unit, while a population analysis unit characterized as low resiliency has a relatively higher likelihood of extirpation. We selected 20 years because the generation time of the Plateau spot-tailed earless lizard is likely relatively short (perhaps as low as 1–2 years, see Chapter 2). A period of ten generations provides a reasonable timeframe to assess the effects of environmental changes.

Table 5.1. The three resiliency categories used in the analysis and the narrative and numerical descriptions corresponding to the estimated probability of extirpation at the population analysis unit level over 20 years that the categories represent.

Resiliency Category	**Estimated probability of extirpation over 20 years: narrative description**	**Estimated probability of extirpation over 20 years: numerical description**	**Estimated probability of survival over 20 years: numerical description**
High Resiliency	Extirpation is very unlikely	<10%	>90%
Moderate Resiliency	Extirpation is unlikely	10–33%	67–90%
Low Resiliency	Extirpation risk ranges from being about as likely as not to being very likely	>33%	<67%

We used a quantitative, repeatable approach to determine an overall resiliency category based on the probability of survival for each population analysis unit considering the impacts to the species across all the demographic and habitat factors and using the results for the individual metrics. The process is as follows: First, we calculated the midpoint value for the range of each resiliency category (see Table 5.1 for the ranges). For example, the High Resiliency category is used for populations deemed very unlikely to become extirpated between 2022 and 2042. We use 90-100% as the quantitative analogue to this statement; thus, the midpoint value for metrics assigned High Resiliency is 95%, Moderate Resiliency is 78.5% and Low Resiliency is 33.5%. After assigning a numeric value to each combination of metric and population analysis unit, we calculated the geometric mean of those values across all the metrics. Because probabilities combine multiplicatively, we use the geometric mean rather than arithmetic mean. The result of this formula was a value between 33.5% (if all metrics were in Low) and 95% (if all metrics were High). Finally, we converted that value back to the matching resiliency category. For example, if the geometric mean for a given population analysis unit was 73.2%, it would be assigned a final resiliency category of Moderate Resiliency in the current resiliency analysis because it falls between 67% and 90%.

Metrics

In this section we describe the rationale, sources, and calculations used to derive numerical values for each of the resiliency metrics and the rules used to categorize those results into High, Moderate, or Low Resiliency status at the metric level. Additional technical detail on the steps to calculate each of the metrics, for both current and future resiliency, can be found in Appendix B.

Occurrence over Space and Time

Attempts to estimate abundance, even for very small areas, have been complicated by very low capture and recapture rates, especially year-to-year (LaDuc et al. 2018, pp. 14, 38–39; BIO-West Inc. 2020, pp. 71–72; Hibbitts et al. 2021, pp. 499–500). Consequently, point estimates for attributes such as population abundance or apparent annual survival, which have been successfully completed on one study unit, approximately 43 acres (17. 4 ha) in size, have large confidence intervals (BIO-West Inc. 2020, pp. 77–78; Jackson 2021b, pers. comm.). In order to use a simpler and more repeatable methodology, we focus on the presence-only dataset compiled during the development of this SSA. This methodology still requires assumptions; specifically, we assume that that larger numbers of observations over more years in the recent past are positively correlated with underlying populations that are larger or have better habitat conditions and that are, therefore, more resilient. We acknowledge that factors such as search effort and detection probability may vary within and across population analysis units. We attempted to partially correct for this by soliciting feedback from species experts for any borderline cases; for example, if true observations were much greater than recorded observations, or if extensive search efforts have yielded very few observations, experts could recommend a specific categorical outcome based on this additional information.

The majority of available Plateau spot-tailed earless lizard data, and the only data available across the entire range of the species, consists of presence-only occurrence data. We obtained these data from a wide range of source material, including museum records, citizen science databases, grant and contract reports, journal articles, and personal communications reporting observations of the species. These data were collected both systematically (i.e., as part of a formal research study) and opportunistically. While limited data are available on abundance or population size, density, or sex ratios for small areas within a couple of population analysis units (BIO-West Inc. 2020, pp. 38, 63–78), our resiliency analysis is intended to evaluate population analysis units using the same criteria in each unit to the maximum extent possible.

Our *Occurrence* metric is based on the set of observations of the Plateau spot-tailed earless lizard from 2008 to 2022, based on the recommendation of the producers of the data and the fact that the GPS data from 2008 or later have high levels of locational accuracy. We reviewed each point in our dataset and removed likely duplicates based on available information about precise location and date of collection. The quantitative rules that follow are based on the total number of observations within a given analysis unit, the number of years with an observation, and expert judgement by researchers with extensive experience surveying for the Plateau spot-tailed earless lizard. This expert judgement was used to select the final category for three units in which the number of observations and the number of years with an observation conflicted in a way that made the most appropriate final category unclear.

The basis for assigning population analysis units into resiliency categories for the *Occurrence* metric are as follows:

High Resiliency: Observations are from at least five years during the 2008–2022 timeframe. Estimated number of unique observations is 20 or more. Expert surveyors characterize the unit as one in which Plateau spot-tailed earless lizards are reliably encountered when searching appropriate habitat under good conditions. It is uncommon to fail to locate any Plateau spot-tailed earless lizards if searching within the unit with reasonable survey effort.

Moderate Resiliency: Observations are from two to four years during the 2008–2022 timeframe. Estimated number of unique observations is five to 19. Expert surveyors characterize the unit as one in which Plateau spot-tailed earless lizards are found in appropriate habitat under good conditions, but not reliably. It may take many hours of survey effort to locate and catch a Plateau spot-tailed earless lizard.

Low Resiliency: Observations are from one year during the 2008–2022 timeframe. Estimated number of unique observations is fewer than five. Expert surveyors characterize the unit as one in which Plateau spot-tailed earless lizards are not usually found, even in apparently appropriate habitat and good conditions.

Traffic Intensity

Plateau spot-tailed earless lizards are commonly detected on roads and roadsides, and may use them for basking, travel, and interacting with conspecifics (Duran 2017, pp. 4, 8–9; Hibbitts et al. 2021, pp. 502–

507). The lizards appear to be less wary of vehicles as compared to people on foot during surveys, suggesting that they do not exhibit vehicle avoidance adaptations (Axtell 1956, p. 176; Duran 2013, p. 1; Hibbitts et al. 2021, pp. 500, 505–507). In addition, participants in surveys for the Plateau spot-tailed earless lizard report that the lizards commonly run across the road in front of moving cars and that it can be challenging to avoid hitting them in these circumstances (McEachern 2022, p. 3, pers. comm.). Our occurrence database contains approximately 20 "Dead on Road" observations (GBIF.org 2021; iNaturalist 2021; Texas Parks and Wildlife Department 2021b). Two out of 15 adult Plateau spot-tailed earless lizard fitted with radio transmitters by Hibbitts et al. (2021, pp. 501–502) experienced road mortality during the period under study, which varied from one to 40 days for each lizard. Therefore, there is evidence that the Plateau spot-tailed earless lizard is at risk of being hit by vehicles while in roadways and along roadsides.

Although the potential for mortality from vehicle strikes has been documented, its magnitude and variation across the landscape has not been measured. We developed a road exposure index for this assessment using public roads datasets from TxDOT that serves as a relative measure of the risk to the Plateau spot-tailed earless lizard from vehicle mortality across its range. It assumes that, in general, more roads with more traffic results in an increased likelihood that a Plateau spot-tailed earless lizard will be struck and injured or killed by a vehicle, with the potential to impact population abundance and survival rates (Forman and Alexander 1998, pp. 212–214; Jochimsen et al. 2004, pp. 8–11, 17–18, 22–23; Fahrig and Rytwinski 2009, pp. 3, 6, 10–11; Bennett 2017, pp. 3–4).

We used ArcGIS Pro software (ESRI 2021) and R statistical software (R Core Team 2022) to calculate the traffic intensity index for each population analysis unit. A more detailed description of the methodology and results is included in Appendix B. The traffic intensity index is calculated for each unit separately. Using a single year of data, the traffic intensity index is computed by summing the total kilometer-length of roads in a unit, multiplying that by the average annual daily traffic per kilometer in that unit, and then dividing by the area of the unit in square kilometers. To derive the current resiliency value, we calculated the index for each of the past three years of available data (2018, 2019, and 2020) and then took the average traffic intensity value over those three years in order to reduce the potential influence of any unusual values over that time.

We also considered the fact that the construction and maintenance of oil wells, gas wells, and wind turbines could generate additional traffic that would not be accounted for in the initial analysis, in part because some of this traffic and associated mortality occurs on private roads (Goodman et al. 2016, pp. 248–250; Astroza et al. 2017, p. 1; Keehn and Feldman 2018, pp. 384, 392). We attempt to account for this additional traffic by modifying the traffic density index. We did this by calculating the total number of oil and gas wells or wind turbines in a given population analysis unit and dividing this value by the square root of the area of the unit in square kilometers (effectively quantifying the number of well and windmills per kilometer, in order to maintain compatibility with the original metric's units). The final traffic intensity value is the sum of the traffic intensity calculated above, and the well and windmill adjustment just described.

We use the final traffic intensity index to assign population analysis units to either High Resiliency or Moderate Resiliency conditions (Figure 5.1). While we are confident that exposure to vehicular traffic constitutes a stressor for the Plateau spot-tailed earless lizard, because we do not have any indications that exposure to vehicular traffic alone results in local extirpations, we do not include low resiliency as a potential outcome of traffic intensity values. The break point of 10,000,000 as the traffic intensity index value for dividing High Resiliency from Moderate Resiliency population analysis units was chosen based on an assumption that population-level effects of road mortality would arise only in the units with the greatest traffic intensity. This break point represents an order of magnitude value that separates the four (of 16) units with the highest traffic intensity index values. We reviewed our data on where road mortalities have been observed, but our sample was too small and too uncorrelated with the traffic intensity data to base the breakpoint on that information.

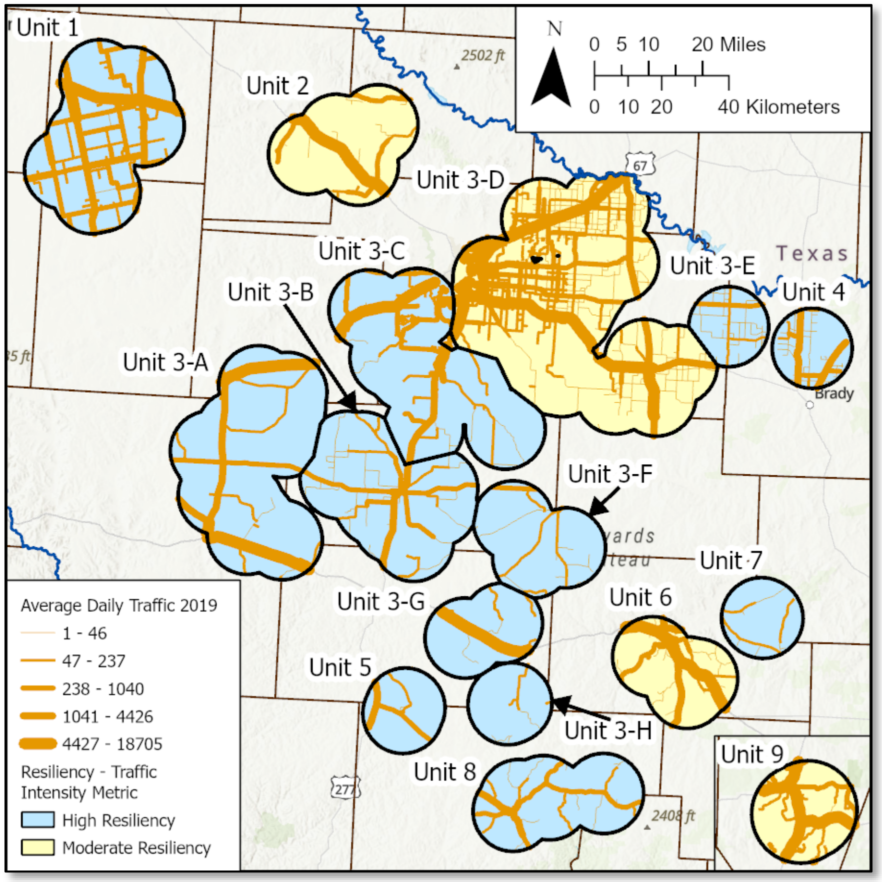

Figure 5.1. Plateau spot-tailed earless lizard population analysis units shaded according to the resiliency category determination for this metric under the current conditions. TxDOT Roadway Inventory average daily traffic values from 2019 are shown as an example; thicker lines indicate higher average daily traffic.

The road length and daily traffic parameters are extracted from the TxDOT Roadway Inventory datasets (TxDOT 2018; 2019; 2020a). We excluded roads associated with urban areas (U.S. Census Bureau 2010; as defined by 2022c, p. 16715) in our calculations because we assume that Plateau spot-tailed earless lizards are excluded from these areas based on a lack of available habitat and are therefore not impacted by those roads. The number of active oil and gas wells was obtained from the S&P Global Enerdeq Browser (IHS 2022a). The number of wind turbines was obtained from a U.S. Geological Survey dataset (U.S. Geological Survey 2022a). Maps showing oil and gas wells and wind turbines are included in Chapter 4.

The final rules are as follows:

High Resiliency: Final traffic intensity index value less than 10,000,000

Moderate Resiliency: Final traffic intensity index value greater than 10,000,000

Suitable Habitat

The Plateau spot-tailed earless lizard is an ectotherm that requires open, sunny areas for basking and foraging, and it has a relatively high preferred body temperature during its active periods (Axtell 1954, p. 47; Clarke 1963, p. 94; Hibbitts et al. 2019, p. 150). Its habitat has consistently been described as relatively open, flatter areas with friable soils, which are soils loose enough to allow the Plateau spot-tailed earless lizard to shimmy underground in self-burial (Axtell 1968, p. 56.1; Duran and Axtell 2011, p. 24; Hibbitts and Hibbitts 2015, p. 110). Because it is adapted to burrow underground or take shelter in soil fissures or animal burrows, it is not dependent on overstory canopy cover to hide from predators (Axtell 1954, p. 42). Research suggests that the Plateau spot-tailed earless lizard is best adapted to open grasslands, which were common across the Edwards Plateau prior to European settlement of Texas (Duran and Axtell 2011, pp. 25–26; Hibbitts and Hibbitts 2015, pp. 25–41; Hibbitts et al. 2021, pp. 505–507). Woody plant encroachment on historical grasslands has occurred to varying degrees across the range of the Plateau spot-tailed earless lizard due to a variety of factors, including long-term overutilization of grasses by livestock, fire suppression, fuel load reduction, and shrubland succession dynamics (Box 1967, entire; Taylor 2007, pp. 52–54; Wilcox et al. 2008, pp. 1686–1687; 2012, p. 316; Fowler and Simmons 2009, pp. 23–25; Wilcox and Huang 2010, pp. 3–4; Archer et al. 2017, entire).

We developed a spatially explicit habitat suitability model for the Plateau spot-tailed earless lizard that covers its entire current range (U.S. Fish and Wildlife Service 2022a, entire). The model includes two abiotic soils variables (depth to bedrock and percent sand at 30 cm) and two land cover variables (percent tree canopy cover and percent shrub cover). The soils variables are constant over time, whereas the land cover variables are available for each year from 1986–2021 (University of Montana 2022); the model draws from 2020 data for these, and so represents habitat suitability as a snapshot in time. The model output is an average of the results from an ensemble of five algorithms (boosted regression trees, generalized additive models, generalized linear models, MAXENT, and random forests) and consists of a raster with 30-m pixels. We simplified this output into a binary raster where each raster pixel was classified as either meeting or not meeting the minimum habitat suitability needs of the species. The threshold value for this reclassification is the lowest habitat suitability value associated with an occurrence point (omission rate = 0, sensitivity = 1) (Pearson 2010, p. 77). We then calculated the proportion of each unit that met minimum habitat suitability for the Plateau spot-tailed earless lizard. Figure 5.2 shows the classified habitat suitability model results.

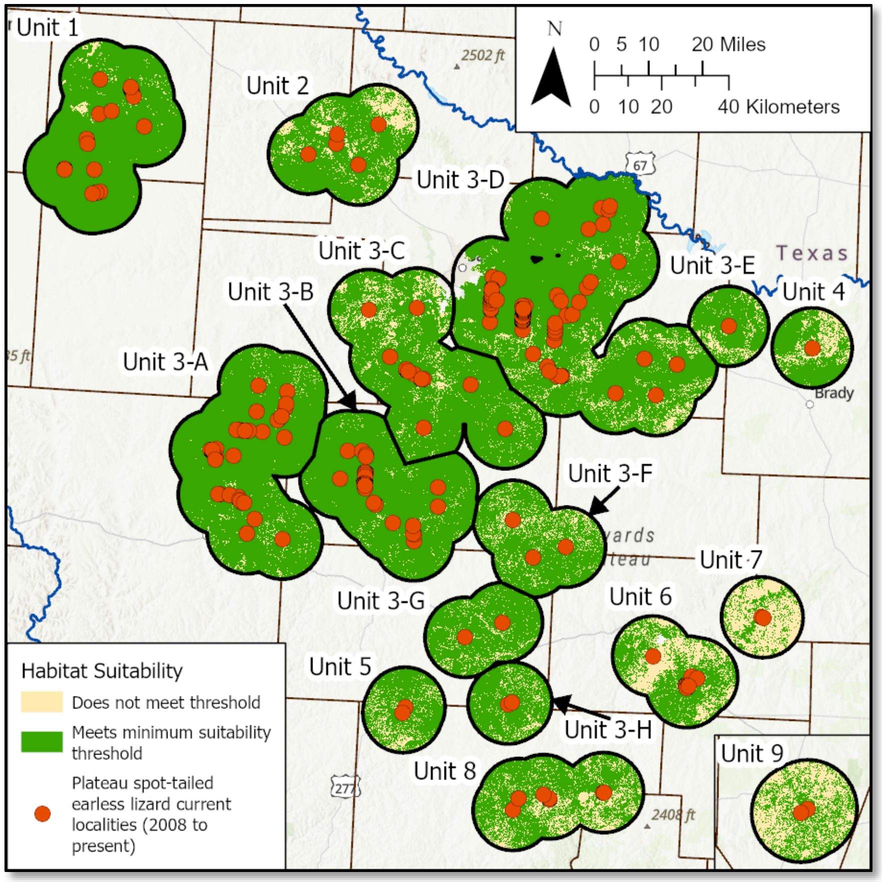

Figure 5.2. Results of habitat suitability model for the Plateau spot-tailed earless lizard clipped to the extent of our population analysis units. Recent localities are shown as orange dots. Dark green areas are those where the results of the habitat suitability model met the minimum suitability threshold; light tan areas are those where the results did not meet this threshold.

To inform our categorization of the analysis units based on proportion of modeled suitable habitat, we reviewed the literature for thresholds of habitat coverage at which species abundance declines. A study on the Arapaho Prairie in western Nebraska on the common lesser earless lizard (*Holbrookia maculata*) and the eastern fence lizard (*Sceloporus undulatus*) found steep declines as habitat declined from 75% to 38% to 15%; the common lesser earless lizard nearly disappearing at the lowest threshold (Ballinger and Watts 1995, pp. 413–416). A study of bird species response to canopy cover found a negative impact on the probability of occurrence for grassland birds when suitable habitat fell below 75-90% (Grant et al. 2004, p. 812). In desert grasslands to the southwest of the Plateau spot-tailed earless lizard's range, banner-tailed kangaroo rats (*Dipodomys spectabilis*) were found to decline when suitable habitat fell below 85% (Cosentino et al. 2014, p. 671; Bestelmeyer et al. 2018, p. 684). A draft Species Status Assessment for Texas kangaroo rat (*Dipodomys elator*) used 90% open habitat as a threshold below which the species declines, and 50% open habitat as a threshold below which habitat is not compatible with that species (U.S. Fish and Wildlife Service 2021, p. 53). A study on forest songbirds found support for thresholds affecting species occurrence where a rapid decline was observed after landscape-scale habitat levels declined below 5–30% (Betts et al. 2007, pp. 1052–1055; 2014, p. 519).

We also reviewed descriptions of grassland, shrubland, and forest cover types ascribed to the Plateau spot-tailed earless lizard range by the Landfire project (Landfire 2020a, entire; 2020b, entire; 2020c, entire; 2020d, entire; 2020e, entire; 2020f, entire; 2020g, entire; 2020h, entire; 2020i, entire; 2020j, entire). These descriptions document state-and-transition models for ecosystems without considering the influence on wildlife species. In general, shrub or forest cover above 50% is considered “closed” (Landfire 2020e, pp. 5–8; 2020f, pp. 3–4; 2020g, pp. 2–4), which we assume is associated with lower Plateau spot-tailed earless lizard resiliency, given its dependence on open conditions. Finally, we took into account the overall habitat conditions of each unit, including our understanding of land cover changes from conversations with wildlife biologists working in federal government, state government, and the private sector (Blair 2022, pp. 1–2, pers. comm.; Hendon 2022, pp. 1–4, pers. comm.; McEachern 2022, pp. 1–2, pers. comm.; Newberry 2022, pp. 1–2, pers. comm.; Perlicheck 2022, pp. 1–2, pers. comm.; Rains 2022a, pp. 1–2, pers. comm.; U.S. Fish and Wildlife Service 2022c, p. 2, pers. comm.; 2022d, pp. 1–5, pers. comm.).

In the studies we summarized above, grassland-obligates experienced declines when the proportion of the landscape comprising suitable habitat was below 75–90%. However, we chose to use a threshold of 60% or greater of suitable habitat for assigning a unit to the High Resiliency category, because the habitat suitability model results for Unit 6, which has a relatively abundant lizard population, were 61% suitable habitat. In the studies above, severe declines or the absence of species were observed when suitable habitat declined below 5–50%. To account for uncertainty in the best threshold level, and to accommodate the possibility that the Plateau spot-tailed earless lizard can persist even when canopy cover exceeds 50%, we made the threshold level for Low Resiliency to below 40% suitability habitat.

The basis for assigning population analysis units into resiliency categories for the *Suitable Habitat* metric are as follows:

High Resiliency: At least 60% of the population analysis unit has a habitat suitability value above the minimum threshold.

Moderate Resiliency: Between 40% and 60% of the population analysis unit has a habitat suitability value above the minimum threshold.

Low Resiliency: Less than 40% of the population analysis unit has a habitat suitability value above the minimum threshold.

Biophysical Setting

As discussed, the Plateau spot-tailed earless lizard needs open canopy habitat for basking and foraging. Grasslands and savannah-like habitats are best, and too much woody plant (shrub and tree) encroachment reduces the suitability of potential habitat. We assume that Plateau spot-tailed earless lizard populations are more resilient in places where the underlying habitat is more likely to be compatible. Based on this assumption, we developed a metric based on the Landfire biophysical setting (BPS) types dataset in which higher proportions of resilient BPS types within a population analysis unit are associated with higher population resiliency.

BPS types, as defined by the Landscape Fire and Resource Management Planning Tools (Landfire) program, is a spatially explicit data product identifying the vegetation communities present prior to colonization that incorporates information about climate, soils, topography, plant competition, and best scientific estimates of the historical disturbance regime (Rollins 2009, pp. 240–241; Blankenship et al. 2021, p. 4). By comparing BPS type classification across the Plateau spot-tailed earless lizard range to the ecological communities currently present, we can gain an understanding of how resilient the underlying ecosystems on which the Plateau spot-tailed earless lizard depends are based on how much they have changed in the presence of post-settlement activities. For example, some grasslands within the Plateau spot-tailed earless lizard range are unlikely to ever support dense shrub or tree cover because of their climate and soils characteristics (Landfire 2020b, pp. 5–6; 2020c, pp. 2–3; 2020j). In other areas, the open, grassy ecosystems are dependent on regular disturbance that inhibits the growth of woody plants (Landfire 2020i, pp. 3–4; 2020f, pp. 2–3; 2020g, pp. 2–3). In the absence of factors such as prairie dog colonies, grazing of woody plants, and frequent fire, woody plants may increase to the point where they can no longer be controlled, and a shift in the fundamental basic ecological structure occurs (Fuhlendorf et al. 1996, pp. 250–252; Bestelmeyer et al. 2018, pp. 680–684; Landfire 2020a, pp. 4–5). And in some areas, the natural setting is forested, and shifts to a more open canopy structure in the last 100–200 years represent an anomalous condition, with the current vegetation conditions representing a reversion to the historical mean (O'Donnell 2019, pp. 35–36; Landfire 2020d, pp. 2–3; 2020e, pp. 1–5).

We reviewed the 45 BPS models that intersect Plateau spot-tailed earless lizard population analysis units (Landfire 2016). We collapsed the individual BPS types into resiliency categories based on their vegetation group classification, creating a binary raster similar in concept to what we did for the *Habitat Suitability* metric. The more resilient category is virtually entirely comprised of Grassland BPSs (it also includes about 2 km^2 [0.8 mi^2] total of Barren and Sparse vegetation groups). The less resilient category includes BPSs falling into the Conifer, Hardwood, Shrubland, and Riparian vegetation groups (and also includes about 29 km^2 [11 mi^2] of Open Water). We calculated the proportion of each population analysis unit (again, omitting the urban area) comprised of more resilient BPSs. We binned the results into High Resiliency, Moderate Resiliency, and Low Resiliency categories, using the same breakpoints as for the Suitable Habitat metric for consistency. Figure 5.3 illustrates the distribution of BPS vegetation groups across all the Plateau spot-tailed earless lizard population analysis units.

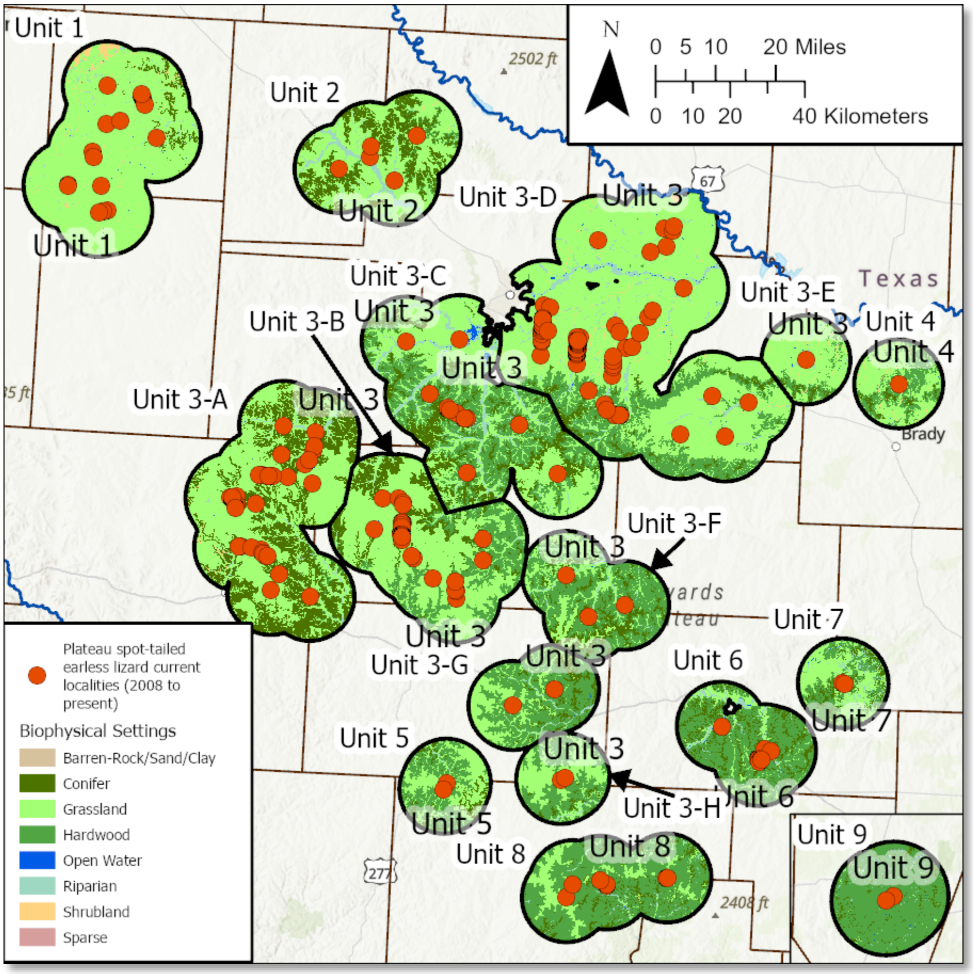

Figure 5.3. Landfire biophysical settings vegetation groups clipped to the Plateau spot-tailed earless lizard population analysis units, less urban areas. Darker greens are conifers and hardwoods, while lighter greens are grassland. Biophysical settings vegetation groups that are not readily apparent on the map (e.g., shrubland, sparse) occur at very low frequencies.

The basis for assigning population analysis units into resiliency categories for the *Suitable Habitat* metric are as follows:

High Resiliency: At least 60% of the population analysis unit is comprised of Landfire BPS types considered more resilient to maintaining open conditions appropriate for the Plateau spot-tailed earless lizard.

Moderate Resiliency: Between 40% and 60% of the population analysis unit is comprised of Landfire BPS types considered more resilient to maintaining open conditions appropriate for the Plateau spot-tailed earless lizard.

Low Resiliency: Less than 40% of the population analysis unit is comprised of Landfire BPS types considered more resilient to maintaining open conditions appropriate for the Plateau spot-tailed earless lizard.

Summary

Table 5.2 describes the basis for assigning resiliency to each population analysis unit, by metric, for the resiliency analysis. We calculated metric values for each population analysis unit (a summary of these methods precedes this section within this chapter, but additional detail may be found in Appendix B) and assigned each unit the appropriate resiliency category based on those values. The remainder of the chapter presents the metric values calculated for each unit, as well as each unit's metric-level and population analysis unit-level resiliency category.

Table 5.2. This table summarizes the information presented in the preceding section on the methods used to assign resiliency category rating for each metric used in the resiliency analysis.

Metric	High Resiliency	Moderate Resiliency	Low Resiliency
Occurrence	Twenty or more observations across five or more years, 2008–2022; expert surveyor concurrence.	Five to nineteen observations across two to four years, 2008–2022; expert surveyor concurrence or opinion.	Fewer than five observations from one year, 2008–2022; expert surveyor concurrence or opinion.
Traffic Intensity	Final traffic intensity index value less than 10,000,000	Final traffic intensity index value greater than 10,000,000	Not used
Suitable Habitat	At least 60% of a unit meets minimum suitable habitat threshold.	Between 40% and 60% of a unit meets minimum suitable habitat threshold.	Less than 40% of a unit meets minimum suitable habitat threshold.
Biophysical Setting	At least 60% of a unit is comprised of biophysical settings resilient to maintaining open vegetation cover regardless of human activities.	Between 40% and 60% of a unit is comprised of biophysical settings resilient to maintaining open vegetation cover regardless of human activities.	Less than 40% of a unit is comprised of biophysical settings resilient to maintaining open vegetation cover regardless of human activities.

Current Resiliency Results

Unit 1

At least 17 inventory surveys in which 11 lizards were observed were conducted in Glasscock and Reagan, Upton, and Midland Counties in 2015 and 2016 (LaDuc et al. 2018, pp. 25–30). The data shared with us from this effort included six localities (Texas Comptroller 2021), all of which were also posted to public databases. Other localities within this unit come from other inventory efforts and observations shared to public databases (Duran et al. 2010, pp. 32–33; GBIF.org 2021; Texas Parks and Wildlife Department 2021b). Overall, we located 28 observations across five years, spanning the period 2009–2017, when compiling our occurrence database. Therefore, we assigned a rating of **High Resiliency** for the *Occurrence* metric. The average traffic intensity index value for 2018–2020 fell within the range considered **High Resiliency** for the *Traffic Intensity* metric (for the specific value of the index for this and all other units, refer to Appendix B, Table B.7). The proportion of Unit 1 meeting the minimum suitable habitat threshold is 98%, putting it in the **High Resiliency** category for the *Habitat Suitability* metric. Approximately 92% of the unit is comprised of Landfire BPS types likely to remain in open, grassy conditions, so we assigned a rating of **High Resiliency** for the *Biophysical Setting* metric.

The overall conditions in this unit currently indicate that the Plateau spot-tailed earless lizard population is characterized as having **High Resiliency**.

Unit 2

Twenty inventory surveys in which five lizards were observed were conducted in Sterling and Coke Counties in 2015 (LaDuc et al. 2018, pp. 25–30). The data shared with us from this effort included four localities (Texas Comptroller 2021), two of which were also available from public databases. We obtained other localities from observations shared to public databases (GBIF.org 2021; iNaturalist 2021; Texas Parks and Wildlife Department 2021b). Overall, we located five observations, all from 2015, when compiling our occurrence database. By our initial quantitative rules, this would put the unit into the Low Resiliency category; however, experts who conducted the surveys in 2015 recommended a higher resiliency category because of how easy it was to find Plateau spot-tailed earless lizards while surveying (Hibbitts et al. 2022, p. 1, pers. comm.). These experts did not return to the unit in future years to conduct additional surveys because they were confident about the occupancy of the unit after the successful survey year in 2015 (Hibbitts et al. 2022, p. 1, pers. comm.). Consequently, we assigned a rating of **Moderate Resiliency** for the *Occurrence* metric. The average traffic intensity index value for 2018–2020 fell within the range considered **Moderate Resiliency** for the *Traffic Intensity* metric. The proportion of Unit 2 meeting the minimum suitable habitat threshold is 80%, putting it in the **High Resiliency** category for the *Habitat Suitability* metric. Approximately 61% of the unit is comprised of Landfire BPS types likely to remain in open, grassy conditions, so we assigned a rating of **High Resiliency** for the *Biophysical Setting* metric.

The overall conditions in this unit currently indicate that the Plateau spot-tailed earless lizard population is characterized as having **Moderate Resiliency**.

Unit 3-A

Fifty-two inventory surveys in which 11 lizards were observed were conducted in Irion and Crockett Counties in 2015, 2016, and 2017 (LaDuc et al. 2018, pp. 29–30). The data shared with us from this effort included six localities occurring within this unit (Texas Comptroller 2021), two of which were also available from public databases. Other localities within this unit come from other inventory efforts and observations shared to public databases (Duran et al. 2010, pp. 32–33; GBIF.org 2021; Texas Parks and Wildlife Department 2021b; Rains 2022b, pp. 1–2, pers. comm.). A telemetry study was done in Crockett County in 2017 and 2018 (Hibbitts et al. 2021, p. 501). Overall, we located 41 observations across ten years, spanning the period 2008–2022, when compiling our occurrence database. Therefore, we assigned a rating of **High Resiliency** for the *Occurrence* metric. The average traffic intensity index value for 2018–2020 fell within the range considered **High Resiliency** for the *Traffic Intensity* metric. The proportion of Unit 3-A meeting the minimum suitable habitat threshold is 97%, putting it in the **High Resiliency** category for the *Habitat Suitability* metric. Approximately 58% of the unit is comprised of Landfire BPS types likely to remain in open, grassy conditions, so we assigned a rating of **Moderate Resiliency** for the *Biophysical Setting* metric.

The overall conditions in this unit currently indicate that the Plateau spot-tailed earless lizard population is characterized as having **High Resiliency**.

Unit 3-B

Twenty-two inventory surveys in which 50 lizards were observed were conducted in Schleicher County in 2015, 2016, and 2017 (LaDuc et al. 2018, pp. 25–30). The data shared with us from this effort included 40 localities occurring within this unit (Texas Comptroller 2021), none of which were found in public databases. Based on the number of observations found within the unit, we believe most of the surveys and observations reported by LaDuc et al. (2018, pp. 25–30) took place within this unit, but because at least one observation from this dataset occurs in another unit, we believe that some of the surveys likely took place outside of it. Other localities within this unit come from other inventory efforts and observations shared to public databases (GBIF.org 2021; Hibbitts 2021, pers. comm.; Texas Parks and Wildlife Department 2021b). Overall, we located 63 observations across six years, spanning the period 2009–2019, when compiling our occurrence database. Therefore, we assigned a rating of **High Resiliency** for the *Occurrence* metric. The average traffic intensity index value for 2018–2020 fell within the range considered **High Resiliency** for the *Traffic Intensity* metric. The proportion of Unit 3-B meeting the minimum suitable habitat threshold is 98%, putting it in the **High Resiliency** category for the *Habitat Suitability* metric. Approximately 63% of the unit is comprised of Landfire BPS types likely to remain in open, grassy conditions, so we assigned a rating of **Moderate Resiliency** for the *Biophysical Setting* metric.

The overall conditions in this unit currently indicate that the Plateau spot-tailed earless lizard population is characterized as having **High Resiliency**.

Unit 3-C

Seventy-one inventory surveys in which 156 lizards were observed were conducted across Irion, Tom Green, and Schleicher Counties in 2015, 2016, and 2017 (LaDuc et al. 2018, pp. 25–30). The data shared with us from this effort included two localities occurring within this unit (Texas Comptroller 2021), neither of which was found in public databases. Because only two localities from the LaDuc et al. (2018, pp. 25–30) effort are found in this unit, and the fact that two other units overlap Schleicher and Tom Green Counties, we believe that most of the observations and surveys took place outside of this unit. We obtained other localities from observations shared to public databases (GBIF.org 2021; Texas Parks and Wildlife Department 2021b). Overall, we located 16 observations across four years, spanning the period 2009–2016, when compiling our occurrence database. Therefore, we assigned a rating of **Moderate Resiliency** for the *Occurrence* metric. The average traffic intensity index value for 2018–2020 fell within the range considered **High Resiliency** for the *Traffic Intensity* metric. The proportion of Unit 3-C meeting the minimum suitable habitat threshold is 88%, putting it in the **High Resiliency** category for the *Habitat Suitability* metric. Approximately 43% of the unit is comprised of Landfire BPS types likely to remain in open, grassy conditions, so we assigned a rating of **Moderate Resiliency** for the *Biophysical Setting* metric.

The overall conditions in this unit currently indicate that the Plateau spot-tailed earless lizard population is characterized as having **Moderate Resiliency**.

Unit 3-D

Fifty-three inventory surveys in which 134 lizards were observed were conducted across Concho and Tom Green Counties in 2015, 2016, and 2017 (LaDuc et al. 2018, pp. 25–30). The data shared with us from this effort included 88 localities occurring within this unit (Texas Comptroller 2021), 39 of which were also available from public databases. We obtained other localities from observations shared to public databases (GBIF.org 2021; iNaturalist 2021; Texas Parks and Wildlife Department 2021b). Overall, we located 150 observations across six years, spanning the period 2009–2021, when compiling our occurrence database. Therefore, we assigned a rating of **High Resiliency** for the *Occurrence* metric.

The average traffic intensity index value for 2018–2020 fell within the range considered **Moderate Resiliency** for the *Traffic Intensity* metric. The proportion of Unit 3-D meeting the minimum suitable habitat threshold is 92%, putting it in the **High Resiliency** category for the *Habitat Suitability* metric. Approximately 77% of the unit is comprised of Landfire BPS types likely to remain in open, grassy conditions, so we assigned a rating of **High Resiliency** for the *Biophysical Setting* metric.

The overall conditions in this unit currently indicate that the Plateau spot-tailed earless lizard population is characterized as having **High Resiliency**.

Unit 3-E

Sixteen inventory surveys in which 30 lizards were observed were conducted in Concho and McCulloch Counties in 2015 (LaDuc et al. 2018, pp. 25–30). The data shared with us from this effort included two localities occurring within this unit (Texas Comptroller 2021), both of which were also available from public databases (GBIF.org 2021). Overall, we located two observations from 2015 when compiling our occurrence database. Therefore, we assigned a rating of **Low Resiliency** for the *Occurrence* metric. The average traffic intensity index value for 2018–2020 fell within the range considered **High Resiliency** for the *Traffic Intensity* metric. The proportion of Unit 3-E meeting the minimum suitable habitat threshold is 84%, putting it in the **High Resiliency** category for the *Habitat Suitability* metric. Approximately 81% of the unit is comprised of Landfire BPS types likely to remain in open, grassy conditions, so we assigned a rating of **High Resiliency** for the *Biophysical Setting* metric.

The overall conditions in this unit currently indicate that the Plateau spot-tailed earless lizard population is characterized as having **Moderate Resiliency**.

Unit 3-F

Fifty inventory surveys in which 52 lizards were observed were conducted in Menard, Schleicher, and Sutton Counties in 2015, 2016, and 2017 (LaDuc et al. 2018, pp. 25–30). The data shared with us from this effort didn't include any localities occurring within this unit (Texas Comptroller 2021), and so we believe that these surveys and observed lizards likely occurred in other units, as detailed above. We obtained localities from observations shared to public databases (GBIF.org 2021; Texas Parks and Wildlife Department 2021b). Overall, we located three observations from 2016 and 2017 when compiling our occurrence database. The number of observations would indicate Low Resiliency, while the number of years would indicate Moderate Resiliency. We assigned a rating of **Moderate Resiliency** for the *Occurrence* metric because the observation points are well distributed in space across the unit. The average traffic intensity index value for 2018–2020 fell within the range considered **High Resiliency** for the *Traffic Intensity* metric. The proportion of Unit 3-F meeting the minimum suitable habitat threshold is 82%, putting it in the **High Resiliency** category for the *Habitat Suitability* metric. Approximately 25% of the unit is comprised of Landfire BPS types likely to remain in open, grassy conditions, so we assigned a rating of **Low Resiliency** for the *Biophysical Setting* metric.

The overall conditions in this unit currently indicate that the Plateau spot-tailed earless lizard population is characterized as having **Moderate Resiliency**.

Unit 3-G

Ten inventory surveys in which no Plateau spot-tailed earless lizards were observed were conducted in Sutton County in 2015 (LaDuc et al. 2018, pp. 25–30). In 2016, two lizards were observed during one survey (LaDuc et al. 2018, pp. 25–30). The data shared with us from this effort didn't include any localities occurring within this unit (Texas Comptroller 2021), potentially because the observation occurred on private land and the landowner did not give permission for the location to be shared with us. We obtained localities from observations shared to public databases and shared directly with us

(GBIF.org 2021; Moore 2022, p. 1, pers. comm.). Overall, we located two observations from 2016 and 2022 when compiling our occurrence database. The number of observations would indicate Low Resiliency, while the number of years would indicate Moderate Resiliency. We assigned a rating of **Moderate Resiliency** for the *Occurrence* metric because the observation points are well distributed in space across the unit. The average traffic intensity index value for 2018–2020 fell within the range considered **High Resiliency** for the *Traffic Intensity* metric. The proportion of Unit 3-G meeting the minimum suitable habitat threshold is 89%, putting it in the **High Resiliency** category for the *Habitat Suitability* metric. Approximately 29% of the unit is comprised of Landfire BPS types likely to remain in open, grassy conditions, so we assigned a rating of **Low Resiliency** for the *Biophysical Setting* metric.

The overall conditions in this unit currently indicate that the Plateau spot-tailed earless lizard population is characterized as having **Moderate Resiliency**.

Unit 3-H

Ten inventory surveys in which no Plateau spot-tailed earless lizards were observed were conducted in Sutton County in 2015 (LaDuc et al. 2018, pp. 25–30). In 2016, two lizards were observed during one survey (LaDuc et al. 2018, pp. 25–30). The data shared with us from this effort didn't include any localities occurring within this unit (Texas Comptroller 2021), potentially because the observations occurred on private land and the landowner did not give permission for the locations to be shared with us. We obtained localities from observations shared to public databases (Texas Parks and Wildlife Department 2021b). Overall, we located three observations from 2016 when compiling our occurrence database. Therefore, we assigned a rating of **Low Resiliency** for the *Occurrence* metric. The average traffic intensity index value for 2018–2020 fell within the range considered **High Resiliency** for the *Traffic Intensity* metric. The proportion of Unit 3-H meeting the minimum suitable habitat threshold is 87%, putting it in the **High Resiliency** category for the *Habitat Suitability* metric. Approximately 46% of the unit is comprised of Landfire BPS types likely to remain in open, grassy conditions, so we assigned a rating of **Moderate Resiliency** for the *Biophysical Setting* metric.

The overall conditions in this unit currently indicate that the Plateau spot-tailed earless lizard population is characterized as having **Moderate Resiliency**.

Unit 4

Eight inventory surveys were conducted in McCulloch County in 2015 and 2016; one survey from 2015 observed one lizard (LaDuc et al. 2018, pp. 25–30). The data shared with us from this effort included two localities occurring within Unit 3-E (Texas Comptroller 2021), so we are not sure whether any surveys took place within Unit 4. This population analysis unit is based on one observation, from 2016, obtained from a public database (GBIF.org 2021). Therefore, we assigned a rating of **Low Resiliency** for the *Occurrence* metric. The average traffic intensity index value for 2018–2020 fell within the range considered **High Resiliency** for the *Traffic Intensity* metric. The proportion of Unit 4 meeting the minimum suitable habitat threshold is 72%, putting it in the **High Resiliency** category for the *Habitat Suitability* metric. Approximately 57% of the unit is comprised of Landfire BPS types likely to remain in open, grassy conditions, so we assigned a rating of **Moderate Resiliency** for the *Biophysical Setting* metric.

The overall conditions in this unit currently indicate that the Plateau spot-tailed earless lizard population is characterized as having **Moderate Resiliency**.

Unit 5

At least eight inventory surveys in which seven lizards were observed were conducted in Edwards County in 2015 and 2016 (LaDuc et al. 2018, pp. 25–30, 43–44). The data shared with us from this effort didn't include any localities occurring within this unit (Texas Comptroller 2021), which could be because those localities are in Unit 8, or because the observations occurred on private land and the landowner did not give permission for the locations to be shared with us. We obtained localities from observations shared to public databases (iNaturalist 2021; Texas Parks and Wildlife Department 2021b). Overall, we located two observations from 2020 and 2021 when compiling our occurrence database. We assigned a rating of **Moderate Resiliency** for the *Occurrence* metric because the metadata for the points suggests that more lizards were observed than were actually recorded (iNaturalist 2021; Texas Parks and Wildlife Department 2021b). The average traffic intensity index value for 2018–2020 fell within the range considered **High Resiliency** for the *Traffic Intensity* metric. The proportion of Unit 5 meeting the minimum suitable habitat threshold is 80%, putting it in the **High Resiliency** category for the *Habitat Suitability* metric. Approximately 44% of the unit is comprised of Landfire BPS types likely to remain in open, grassy conditions, so we assigned a rating of **Moderate Resiliency** for the *Biophysical Setting* metric.

The overall conditions in this unit currently indicate that the Plateau spot-tailed earless lizard population is characterized as having **Moderate Resiliency**.

Unit 6

At least nine inventory surveys were conducted in Kimble County in 2015 and 2016 (LaDuc et al. 2018, pp. 25–30, 43–44). One survey in 2015 recorded observing one lizard (LaDuc et al. 2018, pp. 25–30, 43–44). The data shared with us from this effort didn't include any localities occurring within this unit (Texas Comptroller 2021), which could be because the observations occurred on private land and the landowner did not give permission for the locations to be shared with us. Bio-West et al. (2020, pp. 4, 91) completed telemetry work in Kimble County from 2015–2017 under a grant from the Texas Comptroller's Office, but we do not have localities from that work because it took place on private property. We obtained localities from observations shared to public databases (GBIF.org 2021; Texas Parks and Wildlife Department 2021b). Overall, we located ten observations from 2014, 2017, and 2018 when compiling our occurrence database. Therefore, we assigned a rating of **Moderate Resiliency** for the *Occurrence* metric. The average traffic intensity index value for 2018–2020 fell within the range considered **Moderate Resiliency** for the *Traffic Intensity* metric. The proportion of Unit 6 meeting the minimum suitable habitat threshold is 61%, putting it in the **High Resiliency** category for the *Habitat Suitability* metric. Approximately 12% of the unit is comprised of Landfire BPS types likely to remain in open, grassy conditions, so we assigned a rating of **Low Resiliency** for the *Biophysical Setting* metric.

The overall conditions in this unit currently indicate that the Plateau spot-tailed earless lizard population is characterized as having **Low Resiliency**.

Unit 7

Mason County was not part of the inventory effort from 2015–2017 (LaDuc et al. 2018, pp. 25–30). Our observation localities are the result of opportunistic sightings. We obtained localities from observations shared to public databases (GBIF.org 2021). Overall, we located two observations from 2008 and 2010 when compiling our occurrence database. Therefore, we assigned a rating of **Low Resiliency** for the *Occurrence* metric. The average traffic intensity index value for 2018–2020 fell within the range considered **High Resiliency** for the *Traffic Intensity* metric. The proportion of Unit 7 meeting the minimum suitable habitat threshold is 30%, putting it in the **Low Resiliency** category for the *Habitat Suitability* metric. Approximately 47% of the unit is comprised of Landfire BPS types likely to remain in open, grassy conditions, so we assigned a rating of **Moderate Resiliency** for the *Biophysical Setting* metric.

The overall conditions in this unit currently indicate that the Plateau spot-tailed earless lizard population is characterized as having **Low Resiliency**.

Unit 8

At least eight inventory surveys in which seven lizards were observed were conducted in Edwards County in 2015 and 2016 (LaDuc et al. 2018, pp. 25–30, 43–44). The data shared with us from this effort included two localities occurring within this unit (Texas Comptroller 2021), both of which were also available from public databases. It is possible that the other observation occurred on private land and the landowner did not give permission for the locations to be shared with us. We obtained other localities from observations shared to public databases (GBIF.org 2021; Texas Parks and Wildlife Department 2021b). Overall, we located nine observations, all from 2015, when compiling our occurrence database. By our initial quantitative rules, this would put the unit into the Low Resiliency category; however, experts who conducted the surveys in 2015 recommended a higher resiliency category because of how easy it was to find Plateau spot-tailed earless lizards while surveying. These experts did not return to the unit in future years to conduct additional surveys because they were confident about the occupancy of the unit after the successful survey year in 2015. Consequently, we assigned a rating of **Moderate Resiliency** for the *Occurrence* metric. The average traffic intensity index value for 2018–2020 fell within the range considered **High Resiliency** for the *Traffic Intensity* metric. The proportion of Unit 8 meeting the minimum suitable habitat threshold is 72%, putting it in the **High Resiliency** category for the *Habitat Suitability* metric. Approximately 17% of the unit is comprised of Landfire BPS types likely to remain in open, grassy conditions, so we assigned a rating of **Low Resiliency** for the *Biophysical Setting* metric.

The overall conditions in this unit currently indicate that the Plateau spot-tailed earless lizard population is characterized as having **Moderate Resiliency**.

Unit 9

Nine inventory surveys were conducted in Blanco County in 2015 and 2016, but no Plateau spot-tailed earless lizard were observed (LaDuc et al. 2018, pp. 25–30). We obtained localities from observations shared to public databases (GBIF.org 2021). Overall, we located two observations from 2015 and 2016 when compiling our occurrence database. The number of observations would indicate Low Resiliency, while the number of years would indicate Moderate Resiliency. We assigned a rating of **Low Resiliency** for the *Occurrence* metric because experts who conducted the surveys in 2015 suggested that because the ratio of survey effort to observations is high, Low Resiliency is the more appropriate determination (Hibbitts et al. 2022, p. 1, pers. comm.). The average traffic intensity index value for 2018–2020 fell within the range considered **Moderate Resiliency** for the *Traffic Intensity* metric. The proportion of Unit 9 meeting the minimum suitable habitat threshold is 45%, putting it in the **Moderate Resiliency** category for the *Habitat Suitability* metric. Approximately 1% of the unit is comprised of Landfire BPS types likely to remain in open, grassy conditions, so we assigned a rating of **Low Resiliency** for the *Biophysical Setting* metric.

The overall conditions in this unit currently indicate that the Plateau spot-tailed earless lizard population is characterized as having **Low Resiliency**.

Summary of Current Resiliency

The current resiliency of Plateau spot-tailed earless lizard population analysis units based on demographic and habitat factors is presented in Figure 5.4, Table 5.3, Table 5.4, and Table 5.5. Generally, resilient population analysis units are characterized by having enough individuals within habitat patches to survive and reproduce despite disturbance. Based on our analysis of the 16 population analysis units evaluated across the Plateau spot-tailed earless lizard's presumed current range, we determined that four of these units (50% of the total area) have a current overall condition of **High Resiliency,** nine (41% of the total area) have a current overall condition of **Moderate Resiliency**, and three (9% of the total area in all population analysis units) have a current overall condition of **Low Resiliency** (The proportion of area value given in this context is rounded to the nearest whole number.). We assume that the units with High or Moderate *Overall Resiliency* are maintaining reasonable populations and habitat. While land management has changed over time, with the exception of succession into tree and shrub-dominated areas, this land management has not resulted in substantial changes to habitat conditions across the full species' range. Overall, given the current conditions of the population analysis units for the Plateau spot-tailed earless lizard, the majority of population analysis units and a majority of the area in population analysis units are characterized by populations with the ability to withstand stochastic events (e.g., disturbance).

As discussed in Chapter 3 on the species' range, the area of the current population analysis units is 64% of the area that would have been in population analysis units if we had constructed them using only the historical localities. Although we lack sufficient surveys to indicate that the species is absent from these historical areas, it is possible that the current range of the species may be reduced from what it historically was. However, without information supporting such a range reduction, we did not incorporate this information into the resiliency metric results.

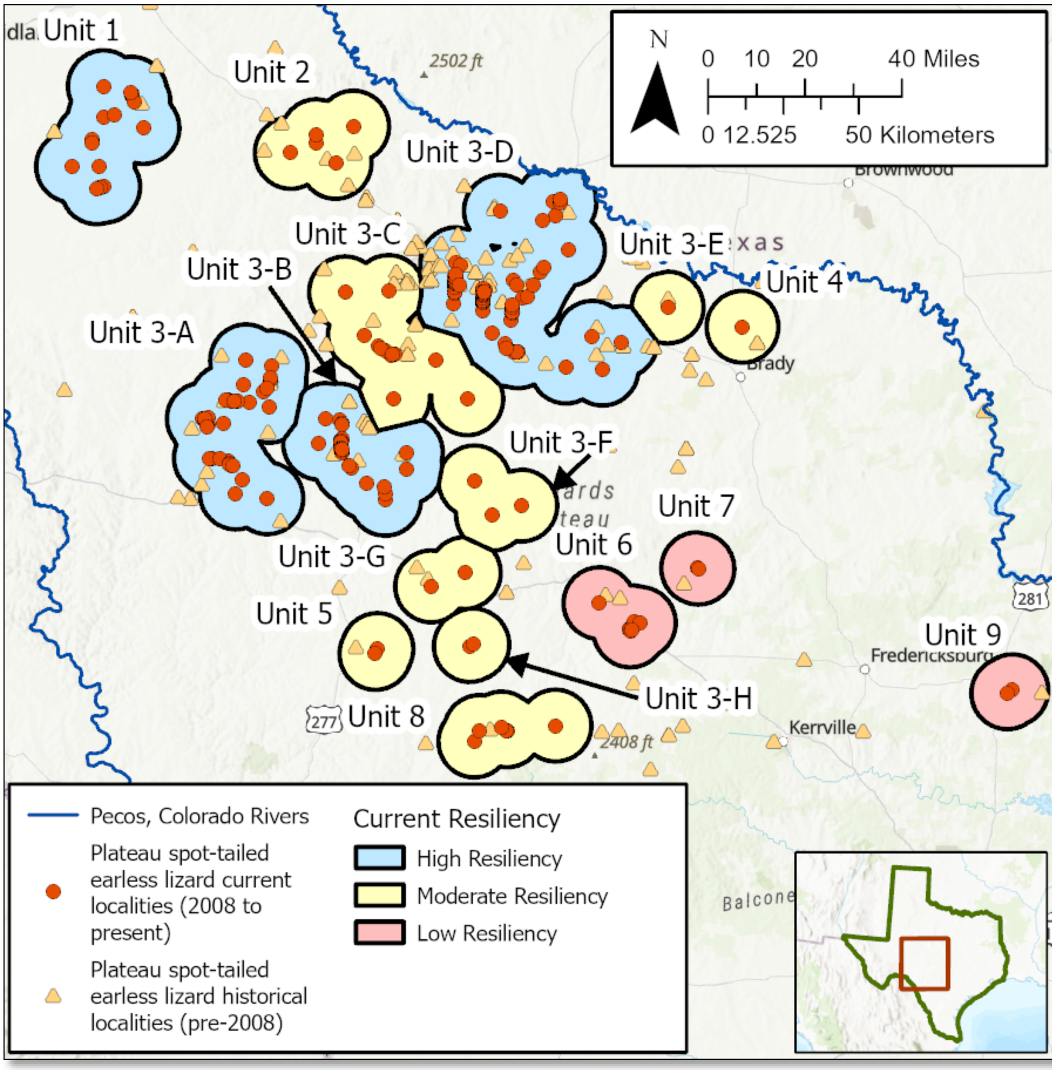

Figure 5.4. Plateau spot-tailed earless lizard population analysis units colored by the results of the current resiliency analysis (blue for high resiliency, yellow for moderate resiliency, and red for low resiliency). Dark orange circles represent recent localities. Light orange triangles represent historical localities.

Table 5.3. Current condition analysis results by population analysis unit, individual metrics, and overall resiliency. The *Occurrence* metric is our demographic factor, while the other three metrics are associated with habitat factors. The factor-level resiliency rating is presented in addition to our determination of the overall resiliency important for species viability. The order of the population analysis units is roughly north to south and west to east.

Population Analysis Unit	**Occurrence**	**Traffic Intensity**	**Suitable Habitat**	**Biophysical Setting**	**Overall Resiliency**
Unit 1	High	High	High	High	High
Unit 2	Moderate	Moderate	High	High	Moderate
Unit 3-A	High	High	High	Moderate	High
Unit 3-B	High	High	High	High	High
Unit 3-C	Moderate	High	High	Moderate	Moderate
Unit 3-D	High	Moderate	High	High	High
Unit 3-E	Low	High	High	High	Moderate
Unit 3-F	Moderate	High	High	Low	Moderate
Unit 3-G	Moderate	High	High	Low	Moderate
Unit 3-H	Low	High	High	Moderate	Moderate
Unit 4	Low	High	High	Moderate	Moderate
Unit 5	Moderate	High	High	Moderate	Moderate
Unit 6	Moderate	Moderate	High	Low	Low
Unit 7	Moderate	High	Low	Moderate	Low
Unit 8	Moderate	High	High	Low	Moderate
Unit 9	Low	Moderate	Moderate	Low	Low

Table 5.4. Population analysis units by area in square kilometers, proportion of area relative to the total area in all population analysis units, and Overall Resiliency for the current conditions analysis. The proportion of area value given in this context is rounded to the nearest whole number.

Population Analysis Unit	Unit Area (km^2)	Contribution of Unit to Total Area in all Population Analysis Units	Overall Resiliency
Unit 1	1,823	9%	High
Unit 2	1,152	6%	Moderate
Unit 3-A	2,321	12%	High
Unit 3-B	1,686	9%	High
Unit 3-C	2,221	11%	Moderate
Unit 3-D	3,985	20%	High
Unit 3-E	424	2%	Moderate
Unit 3-F	947	5%	Moderate
Unit 3-G	712	4%	Moderate
Unit 3-H	478	2%	Moderate
Unit 4	447	2%	Moderate
Unit 5	489	2%	Moderate
Unit 6	852	4%	Low
Unit 7	458	2%	Low
Unit 8	1,113	6%	Moderate
Unit 9	494	3%	Low

Table 5.5. Summary of Overall Resiliency under current conditions across all currently occupied Plateau spot-tailed earless lizard population analysis units. For each resiliency category, the table identifies the number of population analysis units assigned to that category, the sum of the area of the units assigned to that category, and the proportion of the area across all the population analysis units assigned to that category. The proportion of area value given in this context is rounded to the nearest whole number.

Overall Resiliency	Number of Units	Area in km^2	Proportion of Area in All Units
High Resiliency	4	9,814	50%
Moderate Resiliency	9	7,982	41%
Low Resiliency	3	1,805	9%

Current Redundancy

Redundancy is the ability of a species to withstand catastrophes (Smith et al. 2018, p. 304). Catastrophes are stochastic events that are expected to lead to population collapse regardless of population health and for which adaptation is unlikely (Mangel and Tier 1993, p. 1083). When sufficient numbers of populations are well distributed in space, a species has redundancy and a decreased risk of extinction across the range as a whole (Smith et al. 2018, pp. 306–307). In a typical SSA, we gauge redundancy by analyzing the number and distribution of populations relative to the timing and intensity of anticipated species-relevant catastrophic events that could act on one or more entire populations simultaneously (U.S. Fish and Wildlife Service 2016, p. 13). The primary threats to the Plateau spot-tailed earless lizard arise from the additive mortality presumed to occur from vehicle mortality and the loss of habitat due to land use change and vegetation succession. Road traffic, land use change, and vegetation succession do not impact the Plateau spot-tailed earless lizard in the same way simultaneously over large extents; thus, they have no catastrophic analogue. We evaluated several potential events that are known to have catastrophic impacts on some species but were unable to identify a catastrophe that would be relevant to the Plateau spot-tailed earless lizard.

Droughts and heat waves are events that could be catastrophes, but the Plateau spot-tailed earless lizard's biology shields this species from being severely impacted by them. Because they are ectothermic, their metabolism slows when their body temperature is lowered, during which time their metabolism may also slow, conserving both water and the energy produced from feeding (Pianka and Vitt 2003, pp. 37–39). The area inhabited by the Plateau spot-tailed earless lizard is already characterized by periods of drought and by heat waves, with no observed impact to the lizard. We know that the Plateau spot-tailed earless lizard has a higher optimal body temperature than other related species (Clarke 1963, pp. 91–94). In addition, it spends most of its time underground, providing an opportunity for it to stay cooler than other reptiles who merely take shelter in shade (Axtell 1956, p. 177; Clarke 1963, p. 113; Neuharth et al. 2018, p. 536; Hibbitts et al. 2021, p. 506; U.S. Fish and Wildlife Service 2022b, pp. 3–4, pers. comm.).

High intensity rainfall events can easily lead to flooding around the streams and rivers intersecting the Plateau spot-tailed earless lizard range (Texas Water Development Board 2019, p. 7), but the species is not known to be particularly prevalent in floodplains. Riparian areas make up a small proportion of each population analysis unit (Figure 5.3). Even if a downpour caused temporary ponding in areas where the Plateau spot-tailed earless lizard was buried, it is not clear that this would result in high levels of individual mortality; there is some evidence that earless lizards in that situation would be able to slow their metabolism further in order to survive some period of inundation (Meyer 1967, entire).

We might envision that extreme cold would also cause mortality in this species, but we have no evidence to support this, and the available research suggests that they normally retreat underground when temperatures are low, including when it is very cold (LaDuc et al. 2018, p. 90; BIO-West Inc. 2020, pp. 9, 62). We are not aware of any past freezes that caused mortality to either the Plateau spot-tailed earless lizard or any of its congeners that would serve as the basis to evaluate cold temperatures as a plausible catastrophic event.

Wildfires are another event that can have a catastrophic impact on many species. However, in the context of the Plateau spot-tailed earless lizard, it is the lack of frequent fire that has resulted in changes to habitat that negatively impact the species (Fuhlendorf and Smeins 1997b, p. 246). Wildfires themselves may kill some Plateau spot-tailed earless lizards, but others are likely safe underground when low severity fires pass by (Jolly et al. 2022, pp. 2058–2060). The Plateau spot-tailed earless lizard is also mobile and potentially able to retreat from slower-moving fires. Most wildfires that occur within the species' range today are contained quickly and do not grow very large relative to the size of our population analysis units, again excluding them from being a plausible catastrophic event of concern (ESRI 2022; WFM RD&A 2022).

Because we cannot analyze redundancy through the lens of catastrophic events, we instead characterize redundancy as having multiple resilient populations within ecoregions and across the species' geographic range (Smith et al. 2018, pp. 306–307). Considering the status of populations spatially serves as a measure of how well distributed the risk of local extirpations is geographically. This allows for the possibility that there may be future catastrophic events that impacts the Plateau spot-tailed earless lizard that is unanticipated at the time of this analysis. In addition, there should be some plausible means of connectivity between population analysis units to support recolonization after a catastrophic event (Smith et al. 2018, pp. 306–307). In the absence of a clear species-centered method to delineate relevant units for assessing redundancy, we use Bailey's Level 4 Ecoregions to divide the range into units for tallying (USDA Forest Service 2022). Figure 5.5 shows the ecoregions in relation to the population analysis units. Where a population analysis unit crosses an ecoregion boundary, we assign it to the ecoregion where most observations within the unit occur. Unit 3-D crosses, and has observations, in four ecoregions. Most of the observations from this unit fall into the Red Prairie or the Edwards Plateau Woodland ecoregions, so in Table 5.4 below we assigned a value of 0.5 for each of these.

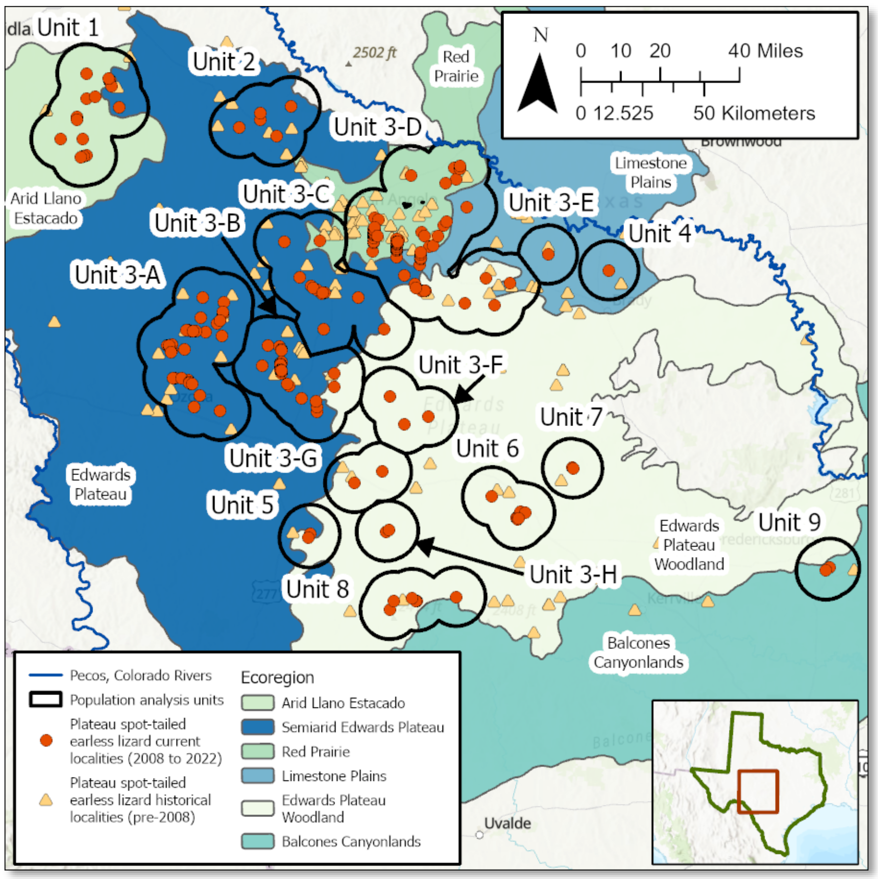

Figure 5.5. Plateau spot-tailed earless lizard population analysis units overlaid on Bailey's Level 4 Ecoregions (USDA Forest Service 2022). Dark orange circles represent recent localities. Light orange triangles represent historical localities.

We evaluated Plateau spot-tailed earless lizard redundancy rangewide and at the ecoregion scale. The ecoregions used for this assessment are those intersecting current and historical Plateau spot-tailed earless lizard localities. Currently, the Plateau spot-tailed earless lizard occurs in population analysis units considered **High** or **Moderate Resiliency** in five of the six ecoregions, supporting redundancy across most of the historical range (Table 5.4). At the ecoregion scale, there is more than one analysis unit in a **High** or **Moderate Resiliency** condition for three of the ecoregions (Semiarid Edwards Plateau, Edwards Plateau Woodland, and Limestone Plains), all within the central part of range. The Plateau spot-tailed earless lizard lacks redundancy in the Arid Llano Estacado and Red Prairie ecoregions, but we note that these ecoregions are on the edge of the Plateau spot-tailed earless lizard range and are bisected by the Colorado River, which forms the northern boundary of the species' range. The condition of the only population analysis unit in the Balcones Canyonlands ecoregion is **Low Resiliency**, indicating a lack of redundancy at the southern edge of the range.

Table 5.6. Current conditions analysis results by ecoregion and count of population analysis units in each resiliency category.

Bailey's Level 4 Ecoregion	High Resiliency Units	Moderate Resiliency Units	Low Resiliency Units	Total Units
Arid Llano Estacado	1	0	0	1
Semiarid Edwards Plateau	2	2	0	4
Red Prairie	0.5	0	0	0.5
Edwards Plateau Woodland	0.5	5	2	7.5
Limestone Plains	0	2	0	2
Balcones Canyonlands	0	0	1	1
All Ecoregions	4	9	3	16

Current Representation

Representation is the ability of the Plateau spot-tailed earless lizard to adapt to both near-term and long-term changes in its physical and biological environments (Smith et al. 2018, p. 304). This ability to adapt to new environments—referred to as adaptive capacity—is essential for viability, as all species need to continually adapt to changing environments (Nicotra et al. 2015, p. 1269). The Plateau spot-tailed earless lizard may adapt to novel changes in their environment by moving to new, suitable environments or by altering its physical or behavioral traits to match the new environmental conditions through either plasticity or genetic change (Nicotra et al. 2015, p. 1270; Beever et al. 2016, p. 132). In contrast to redundancy, which characterizes how a species may response to short-term events, representation characterizes the species' response over longer time scales (Smith et al. 2018, pp. 306–307).

We can best gauge representation by examining the breadth of genetic, phenotypic, and ecological diversity found within a species and its ability to disperse and colonize new areas (Smith et al. 2018, pp. 306–307). In assessing the breadth of variation, it is important to consider both larger-scale variation (such as morphological, behavioral, or life history differences which might exist across the breadth of environmental and ecological variation across the species range), and smaller-scale variation (which might include measures of interpopulation genetic diversity) (Smith et al. 2018, pp. 306–307).

We are unaware of any spatial patterning in the behavior, morphology, or life history of the Plateau spot-tailed earless lizard. The only study we know of relevant to these factors was focused at resolving the taxonomic question of the Plateau spot-tailed earless lizard and the Tamaulipan spot-tailed earless lizard and did not discuss differences within or among Plateau spot-tailed earless lizard populations (Hibbitts et al. 2019, entire). Thus, to assess representation, we focused on whether the species exists across a large area with diversity of environmental conditions (e.g., climatic conditions, geology, climax vegetation community), and we assume that the risk of loss of adaptive potential can be minimized by maintaining a broad distribution of the species across its known historical range (Smith et al. 2018, pp. 306–307). For the Plateau spot-tailed earless lizard, because of the lack of spatial patterning and a lack of established catastrophic events impacting the species, there is some overlap with our method for assessing redundancy. As with the redundancy analysis, we evaluated Plateau spot-tailed earless lizard representation rangewide and at the ecoregion scale. We again evaluate how many ecoregions have more than one population in high or moderate resiliency. However, while in the redundancy analysis this data is used to inform the species' ability to recovery from a large perturbation, in representation this informs the species' ability to adapt to changing conditions over time (Smith et al. 2018, p. 304). We also evaluate the total number of populations in high or moderate resiliency, which was not a component of the redundancy analysis. Having multiple populations in an ecoregion and numerous populations across the full extent of the species' range functions as a proxy for genetic or behavioral adaptations present within that region that may enhance the ability of the Plateau spot-tailed earless lizard to persist over the long term (Smith et al. 2018, pp. 306–307).

Current representation for the Plateau spot-tailed earless lizard is characterized by its occurrence in **High** or **Moderate Resiliency** condition within five of the six of the historically occupied ecoregions (Figure 5.5 and Table 5.5), and that 13 of 16 population analysis units are in either **High** or **Moderate Resiliency** from our current condition resiliency analysis. In terms of area on the landscape, the units in either **High** or **Moderate Resiliency** condition account for 91% of the total area across all the currently occupied population analysis units (Table 5.5). Units currently determined to be in **High Resiliency** conditions make up 50% of the total area, while units in **Moderate Resiliency** conditions make up 41%. Although the range of the species has contracted, including within some of the ecoregions, we assume that the Plateau spot-tailed earless lizard retains some capacity to adapt to changing future conditions because it remains geographically widespread, the majority of population analysis units are classified as **High** or **Moderate Resiliency**, and the majority of the area in population analysis units is classified as **High** or **Moderate Resiliency**.

6 Species Viability

In this chapter, we describe how the current viability of the Plateau spot-tailed earless lizard may change from the conditions outlined in our future scenarios. We consider the potential contributions of sources of stressors in the future, and correspondingly, how those stressors may negatively impact the species' habitat and demographic needs. As in the current conditions chapter, we evaluate the species' viability in terms of resilience at the population scale, and in terms of redundancy and representation at the species scale. We describe two plausible future scenarios and project the response of the Plateau spot-tailed earless lizard to the environmental conditions at one future timestep in terms of the three Rs, and ultimately, species viability.

Future Resiliency

Future Resiliency Analysis Methodology

As with the current conditions analysis, the future conditions resiliency assessment reflects our judgement of the likelihood that the species' response to the conditions described in each individual metric, over the 20-year period following a given timestep, would be extirpation from a given population analysis unit. We selected 20 years because the generation time of the Plateau spot-tailed earless lizard is likely relatively short (perhaps as low as 1–2 years, see Chapter 2). A period of ten generations provides a reasonable timeframe to assess the effects of environmental changes. We carry forward the framework used in the current resiliency analysis with respect to the resiliency categories and associated estimates of extirpation and survival. As a starting point, we sought to evaluate the species' response to the conditions in each scenario using the same metrics and basis for assigning resiliency that were used in the current condition resiliency analysis. We also used the quantitative, repeatable approach to determine an overall resiliency category for each population analysis unit considering the impacts to the species across all the demographic and habitat factors that was used in the current resiliency analysis.

Future Timestep

We consider one future timestep: 2050. Resiliency categories assigned to each scenario at this timestep reflect a qualitative determination of the likelihood that the species response to the conditions described in each individual metric, from 2050 to 2070, would be extirpation from a given population analysis unit. Thus, the full projection time for the species response presented in this SSA report encompasses the period from 2022–2070. The future condition of the Plateau spot-tailed earless lizard is expected to be driven predominantly by the persistence and availability of adequate amounts of suitable habitat, as this appears to best correlate with Plateau spot-tailed earless lizard occupancy and relative abundance. Vehicle traffic, with its ability to cause harm and mortality to individual lizards, further influences the future condition of the species.

Metrics

Occurrence and Biophysical Setting

The *Occurrence* metric is based on observational, presence-only data that we compiled into a database and mapped on the landscape. Past trends in abundance or occupancy are not available due to a lack of long-term field data. Consequently, we are unable to project increases or decreases in *Occurrence* based on the other metrics. The goal of the metric is to measure the influence of each factor on its own, while the overall population analysis unit resiliency category rating reflects the totality of conditions. Therefore, for the year 2050, we used the same values from 2022 when making the future resiliency determination for this metric; that is, we assume that resiliency for the *Occurrence* metric is stable rather than assuming a change in its future value. Similarly, the *Biophysical Setting* metric is also not expected to change in the future because its purpose is to capture the underlying resiliency of the vegetation communities owing to abiotic and biological influences. Because the overall mean resiliency value is an average, the values for *Occurrence* and *Biophysical Setting* from the current resiliency analysis serve as null values for calculating the overall mean for the future timestep. This was done to allow any changes in the other two metrics to appropriately modify the mean value and allow the current and future conditions to be comparable to one another.

Traffic Intensity

The population of the State of Texas is growing rapidly; this growth is expected to continue into the future, and is associated with increased traffic (TxDOT 2020b, p. 56). Increased traffic and roadway use is heaviest, and projected to increase the most, in the urbanized parts of the state (TxDOT 2020b, pp. 56, 67). However, TxDOT anticipates increases in rural road traffic volume as well, especially in areas associated with agricultural or energy production (TxDOT 2020b, pp. 39, 56, 67), which applies to portions of the Plateau spot-tailed earless lizard range. Both truck and auto traffic are expected to increase substantially in rural areas over the next few decades, continuing an existing trend (TxDOT 2020b, pp. 39, 67).

We were unable to locate suitable datasets containing projections of public roads and their traffic levels. Therefore, to bring the *Traffic Intensity* metric forward, we developed our own projections. We extracted the road length and daily traffic parameters from TxDOT Roadway Inventory datasets from 2013–2020 (TxDOT 2013; 2014; 2015; 2016; 2017; 2018; 2019; 2020a). We extracted windmills in production by year over the same timeframe (2013–2020) from the U.S. Wind Turbine Database (U.S. Geological Survey 2022a; 2022b). We did not have the historical data needed to determine the number of active wells in previous years, so we held that value constant at the number present at the time we acquired the dataset in 2022 (IHS 2022a). The geoprocessing and data manipulation steps are otherwise the same as described in Chapter 5. For each year from 2013–2020 we calculated a *Traffic Intensity* value. We input that metric value and the past year into a linear regression and calculated the 80% prediction interval for Traffic Intensity in the future at timestep 2050. We used an 80% prediction interval because a 95% prediction interval resulted in nonsensical (below 0) values for the lower boundary. The upper and lower values for the prediction interval are used to parameterize two future scenarios (Table 6.1).

Suitable Habitat

Our habitat suitability model includes abiotic soils and vegetation cover predictor variables, as discussed in Chapter 5. While we do not anticipate changes to soil characteristics in the future, vegetation cover is almost certain to change. As discussed in Chapters 4 and 5, woody plant encroachment is occurring across much of the Plateau spot-tailed earless lizard range (Fowler and Simmons 2009, pp. 23–24; Rains 2022a, p. 1, pers. comm.). According to our habitat suitability model, higher levels of tree and shrub cover are negatively correlated with observations of the Plateau spot-tailed earless lizard (U.S. Fish and Wildlife Service 2022a, pp. 1–2). Several conditions that promote woody plant encroachment are present within the Plateau spot-tailed earless lizard range, making it likely that current trends toward increasing woody plant cover will continue (Fulbright et al. 1991, p. 15; Fuhlendorf and Smeins 1997b, pp. 825–826; Van Auken 2000, p. 207; Fowler and Simmons 2009, pp. 23–24; Archer et al. 2017, pp. 28, 32–36, 41–45; O'Donnell 2019, pp. 35–36).

For example, the grazing of cattle, sheep, and goats continues across the range, and the overutilization of rangelands is generally accepted as a cause of woody plant encroachment (Van Auken 2000, p. 206; Archer et al. 2017, pp. 26, 32–33, 43–44; Blair 2022, pp. 1–2, pers. comm.; Hendon 2022, pp. 1–2, pers. comm.; McEachern 2022, p. 2, pers. comm.; Newberry 2022, pp. 1–2, pers. comm.; Perlicheck 2022, pp. 1–2, pers. comm.; Rains 2022a, p. 1, pers. comm.; U.S. Fish and Wildlife Service 2022c, p. 2, pers. comm.; 2022d, pp. 1–4, pers. comm.). Where grazing is being discontinued, it is often replaced by management for game species, especially white-tailed deer (Rains 2022a, p. 1, pers. comm.; U.S. Fish and Wildlife Service 2022d, pp. 1–2, pers. comm.). Game species like deer use brushy areas as habitat, so management for game typically allows the presence of more woody plants than would be desirable under a livestock grazing regime (McEachern 2022, p. 1, pers. comm.; Newberry 2022, pp. 1–2, pers. comm.; U.S. Fish and Wildlife Service 2022d, pp. 1–2, pers. comm.). Therefore, regardless of whether land is managed for livestock or game, the result is likely to be a continuation of existing trends in increasing woody plant cover.

In addition, wildfire frequency and extent are generally low in this area, and while there are some efforts to restore prescribed fire to the landscape, these efforts occur across small extents (Van Auken 2000, p. 204; ESRI 2022; Hendon 2022, p. 2, pers. comm.; Newberry 2022, p. 2, pers. comm.; U.S. Fish and Wildlife Service 2022d, p. 2, pers. comm.). With trends in this area of Texas toward the subdivision of larger ranches, restoring prescribed fire across large areas will remain challenging (Blair 2022, pp. 1–2, pers. comm.; Hendon 2022, p. 2, pers. comm.; Newberry 2022, p. 2, pers. comm.; U.S. Fish and Wildlife Service 2022d, p. 2, pers. comm.). The addition of more rural housing may increase the risk of wildfire, but it will also increase the pressure to quickly extinguish any wildfire or escaped prescribed burns.

The decline and extirpation of black-tailed prairie dogs from the Plateau spot-tailed earless lizard range also promotes shrub encroachment (Whicker and Detling 1988, pp. 779–781; Detling 1998, p. 440; Van Auken 2000, p. 205; Ceballos et al. 2010, p. 2). While conservation efforts to enhance black-tailed prairie dog populations were vigorous in the early 2000s (Van Pelt 1999, entire; Singhurst et al. 2010, entire), we found no recent efforts to monitor black-tailed prairie dogs or to restore their habitat in the portion of Texas overlapping the Plateau spot-tailed earless lizard range.

Finally, in some portions of the Plateau spot-tailed earless lizard range, shrub and tree cover is already fairly high and may be close to or past the tipping point for a vegetative regime shift in which feedback loops promoting tree and shrub cover are difficult to stop. And the continued loss of more grassland—and with it, suitable habitat for the Plateau spot-tailed earless lizard—is likely to continue into the future (Van Auken 2000, pp. 200–206; Bestelmeyer et al. 2018, pp. 678–683; University of Montana et al. 2022).

In the current conditions analysis, the *Suitable Habitat* metric is based on the proportion of a population analysis unit meeting apparent minimum habitat suitability based on an ensemble model. The habitat suitability model was created for a point in time (2020), and the available information did not allow us to project future habitat suitability using the same methods. Therefore, we altered our approach to habitat suitability for the future conditions analysis.

We obtained the vegetation cover data from 2020 that was used as predictor variables for the habitat suitability model (University of Montana et al. 2022). We computed the average amount of woody cover per pixel at the population analysis unit scale, then took the inverse to obtain an average area without woody cover for each analysis unit. We then compared these values to the proportion of the unit meeting the minimal habitat standard and its associated resiliency category to establish correlations. We determined that an average area without woody cover greater than 65% was correlated with High Resiliency based on the habitat suitability model values, and an average area without woody cover less than 55% was correlated with Low Resiliency based on the habitat suitability model values. Next, we obtained historical data on vegetation cover (University of Montana et al. 2022) and quantified the average area in each population analysis unit without woody plant cover for each year from 1986–2021. We input that value and the year into a linear regression and calculated the 95% prediction interval and mean value for area without woody plant cover at timestep 2050. We use the lower boundary of this interval for Scenario 1, and the mean value of future projection for Scenario 2. We use the mean value instead of the upper boundary because we suspect that the linear model likely overpredicts future woody plant cover over the long term; that is, that woody plant cover has some upper edaphic limit in terms of its total percent cover. However, we did not have the capacity to attempt to estimate that limit for woody plants in each population analysis unit (Archer et al. 2017, pp. 38–39, 45).

Scenarios

We use a single, relatively near-term future timestep of 2050 to reduce the uncertainty in our future projections, given the short lifespan in the wild of the Plateau spot-tailed earless lizard and the fact that the most important factors influencing species viability do not have externally developed projections or models. A short projection time is prudent because our confidence in the underlying relationships and projections is not high enough to extrapolate out over a longer time period. Given that the Plateau spot-tailed earless lizards in the wild are unlikely to live longer than three years, using this timestep projection encompasses on the order of 10–20 generations for this species. When constructing future scenarios, considering metrics that change in the future, we grouped the outcomes from projections that were more favorable for the Plateau spot-tailed earless lizard into Scenario 1 and the outcomes that were less favorable into Scenario 2.

In general, conditions for the Plateau spot-tailed earless lizard are projected to become less favorable in the future. The *Traffic Intensity* index value is expected to increase in the future for all population analysis units except Unit 7 in Scenario 1. In Scenario 2, it increases in all units. The degree of increase is larger in Scenario 2 compared to Scenario 1. The average area without woody plant cover is expected to decline in the future for most, but not all population analysis units under Scenario 1. Under Scenario 2, all but one population analysis unit will experience a decline in the average area without woody plant cover at timestep 2050. In combination, these two scenarios represent the full potential range of projected outcomes we analyzed for the Plateau spot-tailed earless lizard (Table 6.1).

Table 6.1. Description of the conditions projected to occur for each influencing factor in the two future scenarios. We also identify the primary metric impacted by a given influencing factor.

Habitat Metric	Influencing Factor	Scenario 1	Scenario 2
Traffic Intensity	Road Mortality	Lower boundary for the 80% prediction interval for the Traffic Intensity index at timestep 2050.	Upper boundary for the 80% prediction interval for the Traffic Intensity index at timestep 2050.
Habitat Suitability	Shrub and Tree Encroachment	Lower boundary for the 95% prediction interval for the average area without woody plant cover at timestep 2050.	Projected average area without woody plant cover at timestep 2050.

Our scenarios do not include conservation measures. We are not aware of any future conservation efforts planned for the Plateau spot-tailed earless lizard. We attempted to gather information that would allow us to consider efforts to maintain suitable habitat for the Plateau spot-tailed earless lizard and use it in our future scenarios, such as existing and future planned prescribed fires or brush removal efforts. However, we were unable to obtain information on precisely where and when these types of habitat maintenance efforts are taking place now or will take place in the future. Consequently, we have no information to base a projection on or to design a future scenario around. Moreover, a significant amount of conservation effort in the region is for species that prefer habitats that are not suitable or not the best habitat for the Plateau spot-tailed earless lizard. For example, the golden-cheeked warbler (*Setophaga chrysoparia*) prefers old-growth Ashe juniper and oak forests (Groce et al. 2010, p. 17; Dreiss et al. 2022, p. 1); the Plateau spot-tailed earless lizard does not occur in this habitat. The black-capped vireo (*Vireo atricapilla*) and white-tailed deer (*Odocoileus virginianus*) both prefer higher brush and shrub cover than the Plateau spot-tailed earless lizard (Hailey 1979, entire; U.S. Fish and Wildlife Service 2018, pp. 15–21). Thus, land managed for conservation purposes is not necessarily being managed for the Plateau spot-tailed earless lizard or its habitat requirements. We are not aware of any lands that are managed specifically for the Plateau spot-tailed earless lizard.

Scenario 1

Changes to Resiliency at the Metric Level

Compared to the current conditions, there was no change in the resiliency category determination for the *Occurrence* or *Biophysical Setting* metrics for any population analysis unit. When we considered projected changes to *Traffic Intensity* over time, we found that although the drivers behind this metric, especially traffic volume, are increasing, for most population analysis units the changes were not large enough to shift population analysis units into a different resiliency category. The exceptions were Unit 1, Unit 3-A, and Unit 3-C. These units shifted from **High Resiliency** to **Moderate Resiliency** for this metric. When we considered projected changes to *Suitable Habitat* over time, we again found that although we generally expect woody plant cover to increase, the level of change by 2050 did not result in a change in the resiliency category for most of the population analysis units. However, we project a shift from **High Resiliency** to **Moderate Resiliency** for Unit 3-F, Unit 3-G, and Unit 8, and a shift from **High Resiliency** to **Low Resiliency** for Unit 6.

Summary of Scenario 1 Resiliency

After evaluating each metric for a given scenario, we projected an overall future resiliency level for each population analysis unit (Table 6.2). Compared to the results of the current resiliency analysis, under Scenario 1 we project changes to the *Overall Resiliency* of the Plateau spot-tailed earless lizard in four of the population analysis units (Figure 6.1). The *Overall Resiliency* for Unit 3-A is projected to decrease from **High Resiliency** to **Moderate Resiliency**. The *Overall Resiliency* for Unit 3-F, Unit 3-G, and Unit 8 is projected to decrease from **Moderate Resiliency** to **Low Resiliency**. We did not project an improvement to any of the metrics or overall rating for any population analysis unit.

Under this scenario, at timestep 2050, the overall resiliency of the Plateau spot-tailed earless lizard is characterized by having three population analysis units (38% of the total area) in the **High Resiliency** category, seven population analysis units (38% of the total area) in the **Moderate Resiliency** category, and six population analysis units (23% of the total area) in the **Low Resiliency** category (Table 6.2; The proportion of area value given in this context is rounded to the nearest whole number.). The *Overall Resiliency* designation decreases for four units; the others remain the same as under the current conditions. Overall, under this scenario, the majority of population analysis units (10 of 16) and the majority of the area in population analysis units (77%) are categorized as either **High Resiliency** or **Moderate Resiliency** and are generally assumed to have the ability to withstand stochastic events (e.g., disturbance).

Table 6.2. Summary of future resiliency analysis for Scenario 1 at timestep 2050 Resiliency categories reflect the outcomes from the species response to the conditions present in 2050 over the period 2050–2070. Arrows pointing down indicate declines compared to the current resiliency.

Population Analysis Unit	Occurrence	Traffic Intensity	Habitat Suitability	Biophysical Setting	Overall Resiliency
Unit 1	High	Moderate ↓	High	High	High
Unit 2	Moderate	Moderate	High	High	Moderate
Unit 3-A	High	Moderate ↓	High	Moderate	Moderate ↓
Unit 3-B	High	High	High	High	High
Unit 3-C	Moderate	Moderate ↓	High	Moderate	Moderate
Unit 3-D	High	Moderate	High	High	High
Unit 3-E	Low	High	High	High	Moderate
Unit 3-F	Moderate	High	Moderate ↓	Low	Low ↓
Unit 3-G	Moderate	High	Moderate ↓	Low	Low ↓
Unit 3-H	Low	High	High	Moderate	Moderate
Unit 4	Low	High	High	Moderate	Moderate
Unit 5	Moderate	High	High	Moderate	Moderate
Unit 6	Moderate	Moderate	Low ↓	Low	Low
Unit 7	Moderate	High	Low	Moderate	Low
Unit 8	Moderate	High	Moderate ↓	Low	Low ↓
Unit 9	Low	Moderate	Moderate	Low	Low

Table 6.3. Summary of Overall Resiliency under Scenario 1 across all Plateau spot-tailed earless lizard population analysis units. For each resiliency category, the table identifies the number of population analysis units assigned to that category, the sum of the area of the units assigned to that category, and the proportion of the area across all the population analysis units associated with that category. The proportion of area value given in this context is rounded to the nearest whole number.

Overall Resiliency	Number of Units	Area in km^2	Proportion of Area in All Units
High Resiliency	3	7,493	38%
Moderate Resiliency	7	7,531	38%
Low Resiliency	6	4,577	23%

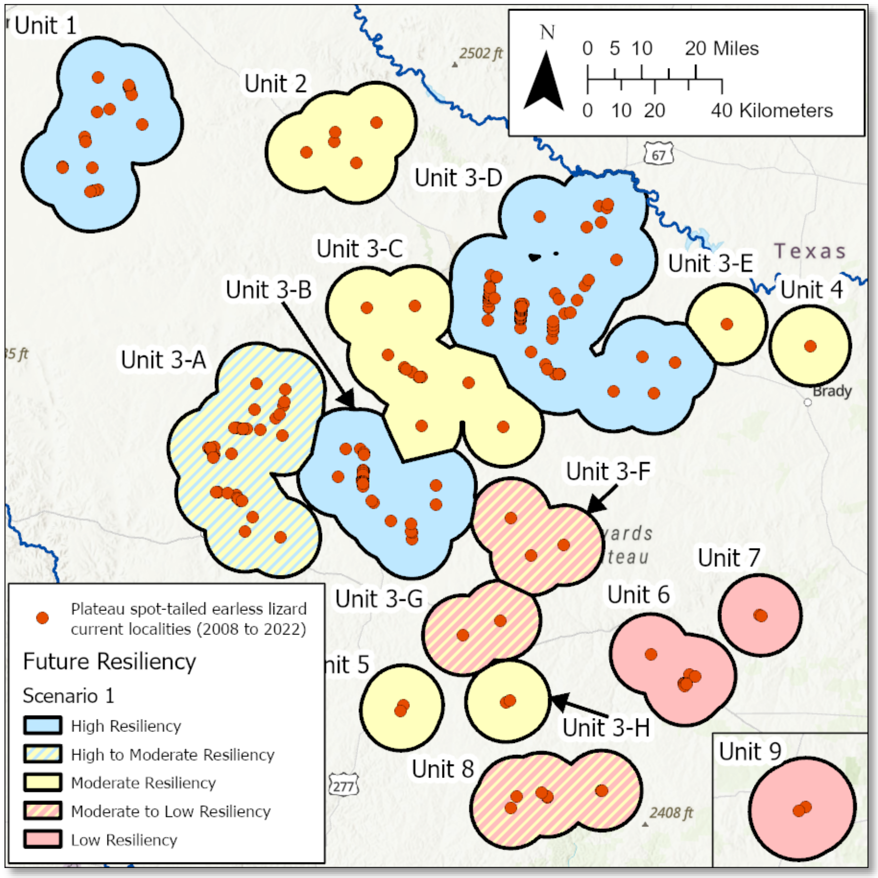

Figure 6.1. Results of future resiliency analysis for Scenario 1 at 2050. Population analysis units in blue are High Resiliency, those in yellow are Moderate Resiliency, and those in red are Low Resiliency. Population analysis units that are yellow with blue diagonal lines shifted from High Resiliency in the current conditions analysis to Moderate Resiliency in the future conditions analysis. Population analysis units that are red with yellow diagonal lines shifted from Moderate Resiliency in the current conditions analysis to Low Resiliency in the future conditions analysis. Orange circles represent current Plateau spot-tailed earless lizard localities (2008–2022).

Scenario 2

Changes to Resiliency at the Metric Level

Compared to the current conditions, there was no change in the resiliency category determination for the *Occurrence* or *Biophysical Setting* metrics for any population analysis unit. When we considered projected changes to *Traffic Intensity* over time, we found that although the drivers behind this metric, especially traffic volume, are increasing, for most population analysis units the changes were not large enough to shift population analysis units into a different resiliency category. The exceptions were Unit 1, Unit 3-A, Unit 3-C, and Unit 3-G. These units shifted from **High Resiliency** to **Moderate Resiliency** for this metric. When we considered projected changes to *Suitable Habitat* over time, the higher rate of loss of area without woody plant cover resulted in a change in the resiliency category for most of the population analysis units. Compared to the current conditions, six population analysis units currently considered **High Resiliency** shifted to **Moderate Resiliency**: Unit 2, Unit 3-A, Unit 3-C, Unit 3-E, Unit 3-H, and Unit 4. Five units shifted from **High Resiliency** to **Low Resiliency**: Unit 3-F, Unit 3-G, Unit 5, Unit 6, and Unit 8.

Summary of Scenario 2 Resiliency

After evaluating each metric for a given scenario, we projected an overall future resiliency level for each population analysis unit (Table 6.4). Compared to the results of the current resiliency analysis, under Scenario 2 we project changes to the *Overall Resiliency* of the Plateau spot-tailed earless lizard in seven of the population analysis units (Figure 6.2). The *Overall Resiliency* for Unit 3-A shifts from **High Resiliency** to **Moderate Resiliency.** The *Overall Resiliency* for six units (Unit 3-F, Unit 3-G, Unit 3-H, Unit 4, Unit 5, and Unit 8) shifts from **Moderate Resiliency** to **Low Resiliency** at timestep 2050. We did not project an improvement to any of the metrics or overall rating for any population analysis unit.

Under this scenario, at timestep 2050, the overall resiliency of the Plateau spot-tailed earless lizard is characterized by having three population analysis units (38% of the total area) in the **High Resiliency** category, four population analysis units (31% of the total area) in the **Moderate Resiliency** category, and nine population analysis units (31% of the total area) in the **Low Resiliency** category (Table 6.5). The *Overall Resiliency* designation decreases for seven units; the others remain the same as under the current conditions. Overall, under this scenario, fewer than half (7 of 16) of population analysis units, but the majority of the area in population analysis units (69% of the total area) are categorized as either **High Resiliency** or **Moderate Resiliency** and are generally assumed to have the ability to withstand stochastic events (e.g., disturbance).

Table 6.4. Summary of future resiliency analysis for Scenario 2 at timestep 2050 Resiliency categories reflect the outcomes from the species response to the conditions present in 2050 over the period 2050–2070. Arrows pointing down indicate declines compared to the current resiliency.

Population Analysis Unit	Occurrence	Traffic Intensity	Suitable Habitat	Biophysical Setting	Overall Resiliency
Unit 1	High	Moderate ↓	High	High	High
Unit 2	Moderate	Moderate	Moderate ↓	High	Moderate
Unit 3-A	High	Moderate ↓	Moderate ↓	Moderate	Moderate ↓
Unit 3-B	High	High	High	High	High
Unit 3-C	Moderate	Moderate ↓	Moderate ↓	Moderate	Moderate
Unit 3-D	High	Moderate	High	High	High
Unit 3-E	Low	High	Moderate ↓	High	Moderate
Unit 3-F	Moderate	High	Low ↓	Low	Low ↓
Unit 3-G	Moderate	Moderate ↓	Low ↓	Low	Low ↓
Unit 3-H	Low	High	Moderate ↓	Moderate	Low ↓
Unit 4	Low	High	Moderate ↓	Moderate	Low ↓
Unit 5	Moderate	High	Low ↓	Moderate	Low ↓
Unit 6	Moderate	Moderate	Low ↓	Low	Low
Unit 7	Moderate	High	Low	Moderate	Low
Unit 8	Moderate	High	Low ↓	Low	Low ↓
Unit 9	Low	Moderate	Moderate	Low	Low

Table 6.5. Summary of Overall Resiliency under Scenario 2 across all Plateau spot-tailed earless lizard population analysis units. For each resiliency category, the table identifies the number of population analysis units assigned to that category, the sum of the area of the units assigned to that category, and the proportion of the area across all the population analysis units associated with that category. The proportion of area value given in this context is rounded to the nearest whole number.

Overall Resiliency	Number of Units	Area in km²	Proportion of Area in All Units
High Resiliency	3	7,493	38%
Moderate Resiliency	4	6,118	31%
Low Resiliency	9	5,990	31%

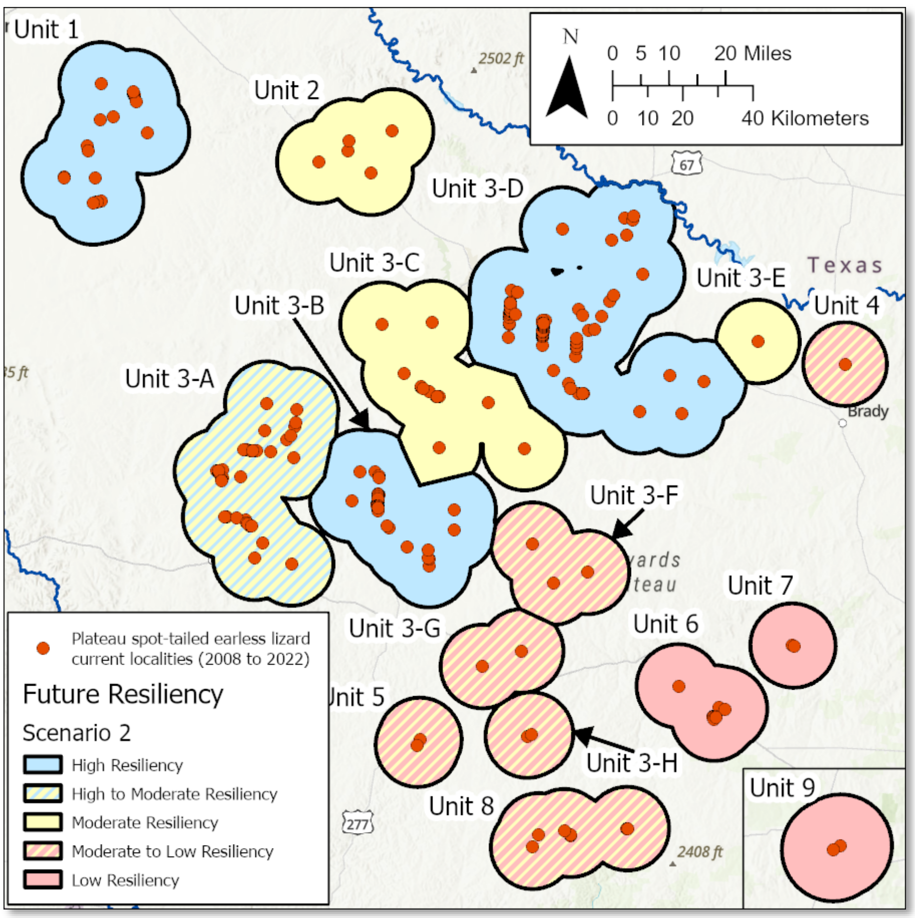

Figure 6.2. Results of future resiliency analysis for Scenario 2 at 2050. Population analysis units in blue are High Resiliency, those in yellow are Moderate Resiliency, and those in red are Low Resiliency. Population analysis units that are yellow with blue diagonal lines shifted from High Resiliency in the current conditions analysis to Moderate Resiliency in the future conditions analysis. Population analysis units that are red with yellow diagonal lines shifted from Moderate Resiliency in the current conditions analysis to Low Resiliency in the future conditions analysis. Orange circles represent current Plateau spot-tailed earless lizard localities (2008–2022).

Summary/Synthesis

Overall, after projecting the response of the Plateau spot-tailed earless lizard to changing habitat conditions under the two plausible future scenarios, the resiliency of Plateau spot-tailed earless lizard individual population analysis units is declining under both scenarios, but to different degrees (Table 6.6 and Table 6.7). Specifically, estimates of current resiliency for the Plateau spot-tailed earless lizard population analysis units categorize four units (50% of the total area) as **High Resiliency**, nine units (41% of the area) as **Moderate Resiliency**, and three units (9% of the area) as **Low Resiliency** (The proportion of area value given in this context is rounded to the nearest whole number.). Under Scenario 1, at timestep 2050, the future resiliency of the Plateau spot-tailed earless lizard is characterized by having three units (38% of the area) in the **High Resiliency** category, seven units (38% of the area) in the **Moderate Resiliency** category, and six units (23% of the area) in the **Low Resiliency** category. Under Scenario 2, at timestep 2050, the overall resiliency of the Plateau spot-tailed earless lizard is characterized by having three units (38% of the area) in the **High Resiliency** category, four units (31% of the area) in the **Moderate Resiliency** category, and nine units (31% of the area) in the **Low Resiliency** category. The number of population analysis units categorized as **High** or **Moderate Resiliency** is ten under Scenario 1 (majority of the units and 77% of the area) and seven under Scenario 2 (fewer than half of the units but 69% of the area)). Populations in **High** or **Moderate Resiliency** are generally assumed to have the ability to withstand stochastic events (e.g., disturbance).

Table 6.6. *Overall Resiliency* categories for Plateau spot-tailed earless lizard population analysis units under current and future projections in 2050. Compared to the current conditions, future projections in Scenario 1, four units have lower resiliency, while in Scenario 2, seven units have lower resiliency. Arrows pointing down indicate declines compared to the current resiliency.

Population Analysis Unit	Current	Scenario 1	Scenario 2
Unit 1	High	High	High
Unit 2	Moderate	Moderate	Moderate
Unit 3-A	High	Moderate ↓	Moderate ↓
Unit 3-B	High	High	High
Unit 3-C	Moderate	Moderate	Moderate
Unit 3-D	High	High	High
Unit 3-E	Moderate	Moderate	Moderate
Unit 3-F	Moderate	Low ↓	Low ↓
Unit 3-G	Moderate	Low ↓	Low ↓
Unit 3-H	Moderate	Moderate	Low ↓
Unit 4	Moderate	Moderate	Low ↓
Unit 5	Moderate	Moderate	Low ↓
Unit 6	Low	Low	Low
Unit 7	Low	Low	Low
Unit 8	Moderate	Low ↓	Low ↓
Unit 9	Low	Low	Low

Table 6.7. Summary of Overall Resiliency under current conditions and two future scenarios across all Plateau spot-tailed earless lizard population analysis units. For each resiliency category, the table identifies the number of population analysis units assigned to that category and the proportion of the area across all the population analysis units associated with that category. The proportion of area value given in this context is rounded to the nearest whole number.

Overall Resiliency	Current		Future Scenario 1		Future Scenario 2	
	Number of Units	Proportion of Area in All Units	Number of Units	Proportion of Area in All Units	Number of Units	Proportion of Area in All Units
High Resiliency	4	50%	3	38%	3	38%
Moderate Resiliency	9	41%	7	38%	4	31%
Low Resiliency	3	9%	6	23%	9	31%

Future Redundancy

Currently, the Plateau spot-tailed earless lizard has redundancy rangewide and has some redundancy at the ecoregion level. We project that under our future scenarios, redundancy for the Plateau spot-tailed earless lizard will decline at the ecoregion scale but will be maintained rangewide (see the current redundancy analysis section in Chapter 5 for more details on how we determine redundancy at the ecoregion level).

Under Scenario 1, the condition of Plateau spot-tailed earless lizard population analysis units is considered **High** or **Moderate Resiliency** in five of the six ecoregions (Table 6.5; for a map showing the population analysis units overlaid on the ecoregions, see Figure 6.1). Therefore, it has redundancy rangewide. At the ecoregion scale, there is more than one analysis unit in a **High** or **Moderate Resiliency** condition for three of the ecoregions (Semiarid Edwards Plateau, Edwards Plateau Woodland, and Limestone Plains). The Plateau spot-tailed earless lizard has redundancy in these ecoregions. The Plateau spot-tailed earless lizard lacks redundancy in the Arid Llano Estacado and Red Prairie ecoregions, although we note that these are on the edge of the Plateau spot-tailed earless lizard range, and are bisected by the Colorado River, which forms the northern boundary of the species' range. The condition of the only population analysis unit in the Balcones Canyonlands ecoregion is **Low Resiliency**, indicating a lack of redundancy. Under Scenario 1, the Plateau spot-tailed earless lizard experiences some decline in redundancy compared to the current conditions. In Scenario 1, redundancy declines for the Edwards Plateau Woodland ecoregion because units decline in resiliency, increasing the risk of extirpation from a catastrophic event. However, redundancy is still maintained within this ecoregion because there are still multiple population analysis units in **High** or **Moderate Resiliency**.

Under Scenario 2, the condition of Plateau spot-tailed earless lizard population analysis units is considered **High** or **Moderate Resiliency** in five of the six ecoregions (Table 6.6). Therefore, it has redundancy rangewide. At the ecoregion scale, there is more than one analysis unit in a **High** or **Moderate Resiliency** condition for one of the ecoregions (Semiarid Edwards Plateau). Therefore, the Plateau spot-tailed earless lizard has some redundancy in this ecoregion. The Plateau spot-tailed earless lizard lacks redundancy in the Arid Llano Estacado and Red Prairie ecoregions, although we note that these are on the edge of the Plateau spot-tailed earless lizard range, and are bisected by the Colorado

River, which forms the northern boundary of the species' range. It also lacks redundancy in the Edwards Plateau Woodland, Limestone Plains Balcones Canyonlands ecoregions, with 1 or fewer units in either **High** or **Moderate Resiliency** condition. Compared to the current conditions, the number of units in either **High Resiliency** or **Moderate Resiliency** in Scenario 1 differs for the Edwards Plateau Woodland and Limestone Plains ecoregions because several units decline to **Low Resiliency** conditions, increasing the risk of extirpation from catastrophic event, and leading to our determination that these ecoregions lack redundancy.

Table 6.8. Future conditions analysis results by ecoregion and count of population analysis units in each resiliency category for Scenario 1. Changes from the current conditions analysis indicated with arrows; see Table 5.4.

Bailey's Level 4 Ecoregion	High Resiliency Units	Moderate Resiliency Units	Low Resiliency Units	Total Units
Arid Llano Estacado	1	0	0	1
Semiarid Edwards Plateau	1 ↓	3 ↑	0	4
Red Prairie	0.5	0	0	0.5
Edwards Plateau Woodland	0.5	2 ↓	5 ↑	7.5
Limestone Plains	0	2	0	2
Balcones Canyonlands	0	0	1	1
All Ecoregions	3	7 ↓	6 ↑	16

Table 6.9. Future conditions analysis results by ecoregion and count of population analysis units in each resiliency category for Scenario 2. Changes from the current conditions analysis indicated with arrows; see Table 5.4.

Bailey's Level 4 Ecoregion	High Resiliency Units	Moderate Resiliency Units	Low Resiliency Units	Total Units
Arid Llano Estacado	1	0	0	1
Semiarid Edwards Plateau	1 ↓	3 ↑	0	4
Red Prairie	0.5	0	0	0.5
Edwards Plateau Woodland	0.5	0 ↓	7 ↑	7.5
Limestone Plains	0	1 ↓	1 ↑	2
Balcones Canyonlands	0	0	1	1
All Ecoregions	3	4 ↓	9 ↑	16

Future Representation

As with our analysis of current representation, we assume that the risk of loss of adaptive potential (i.e., representation) can be minimized by maintaining a broad distribution of the Plateau spot-tailed earless lizard across its known historical range into the future. Representation for the Plateau spot-tailed earless lizard under Scenario 1 is characterized by its occurrence in **High** or **Moderate Resiliency** condition within five of the six historically occupied ecoregions, and by the fact that the resiliency analysis determined that the future conditions under Scenario 1 are of either **High** or **Moderate Resiliency** for 10 of 16 population analysis units (Table 6.7). In terms of area on the landscape, the units in either **High** or **Moderate Resiliency** condition each account for 38% of the total area across all the population analysis units, adding up to 77% in all.

Under Scenario 2, representation for the Plateau spot-tailed earless lizard is characterized by its occurrence in **High** or **Moderate Resiliency** condition within five of the six historically occupied ecoregions, and by the fact that the resiliency analysis determined that the future conditions under Scenario 2 are of either **High** or **Moderate Resiliency** for 7 of 16 population analysis units (Table 6.8). In terms of area on the landscape, the units in either **High** or **Moderate Resiliency** condition account 69% of the total area across all the population analysis units. Units currently determined to be in **High Resiliency** conditions make up 38% of the total area, while units in **Moderate Resiliency** conditions make up 31%.

Although we project declines in resiliency and redundancy under our future scenarios, the Plateau spot-tailed earless lizard will continue to have representation because it will continue to occur throughout its historic range. Overall, we assume that the Plateau spot-tailed earless lizard retains some capacity to adapt to changing future conditions because it remains geographically widespread in both scenarios, the majority of population analysis units are classified as **High** or **Moderate Resiliency** in one scenario, and the majority of the area in population analysis units is classified as **High** or **Moderate Resiliency** in both scenarios.

Summary of Species Viability

This assessment describes the viability of the Plateau spot-tailed earless lizard in terms of resiliency, redundancy, and representation using the best available commercial and scientific information. We used these concepts to describe current and potential future conditions regarding the species' viability. To address the uncertainty associated with potential future impacts and how they will affect the species' resource needs, we assessed potential future conditions using two plausible scenarios. These scenarios were based on identified influences on the species across its range, allowing us to predict potential changes in population and habitat parameters.

Prior to 2010, little research was done on this species, which limits our understanding of the trajectory of this species and its populations over the past several decades. In the past decade, large efforts to inventory the species across its range and conduct research to fill in gaps in knowledge have been completed. For example, telemetry work added to our understanding of movement and time spent above ground, a diet study identified the range and most common types of prey consumed by the Plateau spot-tailed earless lizard, and wide-ranging surveys established that Plateau spot-tailed earless lizard continue to be found at many historical localities. That said, large portions of the likely range of the species could not be surveyed due to factors such as a refusal by landowners to allow surveyors onto their land (or to allow that information to be shared with the Service) and the enormous time and resources needed for qualified surveyors to search the full species range. We have uncertainty in whether or not the Plateau spot-tailed earless lizard is present outside of our population analysis units because most of this area has not been surveyed or has not been surveyed sufficiently for us to have confidence that the species is absent.

Similarly, research to date has shown little conclusive evidence about the relationship between the needs of the Plateau spot-tailed earless lizard and conditions on the ground. In this assessment, we make inferences and draw conclusions based on our understanding of the dynamics present in the underlying ecosystems (e.g., shrub encroachment), descriptions of better and worse habitat from the literature and from species experts, and our application of the principles of conservation biology. As a result of our research, we concluded that viability is most influenced by the loss of suitable habitat (i.e., open grasslands) from the encroachment of woody vegetation (i.e., trees and shrubs). We also believe that viability is influenced by what we assume is additive mortality associated with vehicle strikes. We use information from remotely sensed data (e.g., shrub and tree canopy cover) and models (e.g., average annual daily traffic) to describe conditions within our population analysis units now and in the future. While these data are imperfect, they represent the best available information related to known species needs. For example, we know of no Plateau spot-tailed earless lizard occurrence in areas with high tree and/or shrub canopy cover. We also know that Plateau spot-tailed earless lizard have been found dead on roadsides due to being run over by cars. The uncertainty in our current and future conditions assessment could be reduced by studies focusing on understanding more precisely at what thresholds of tree and shrub cover Plateau spot-tailed earless lizard abundance declines, and at what rate that decline occurs as the proportion of tree and shrub cover at a particular scale changes. Similarly, there is uncertainty in how many Plateau spot-tailed earless lizards are hit and killed by cars each year, and how that influences population-level survival rates. Finally, additional inventory work to establish whether the Plateau spot-tailed earless lizard occurs outside of our population analysis units, and if so, where would be a valuable addition to our understanding of the status of this species.

Current Conditions

Recent locality data suggests that the species is well distributed across its current known range, despite the fact that inventory work is time intensive and survey distribution has been constrained by a lack of access to private lands (Duran and Axtell 2011, pp. 17–21; Duran et al. 2012, pp. 305–306; Axtell and de Quieroz 2017, p. 812; LaDuc et al. 2018, pp. 18–39; BIO-West Inc 2020, pp. 6–7; Hibbitts et al. 2021, pp. 496–501, 504–506). The species can be found in large, expansive grasslands, as well as in smaller open patches within areas where woodlands and forests predominate, and it occurs across a wide range of temperature and precipitation regimes. The current resiliency of the Plateau spot-tailed earless lizard is characterized by having four population analysis units (50% of the total area) in the **High Resiliency** category, nine (41% of the area) in the **Moderate Resiliency** category, and three (9% of the area) in the **Low Resiliency** category (Table 6.2; The proportion of area value given in this context is rounded to the nearest whole number.). Given the current conditions of the population analysis units for the Plateau spot-tailed earless lizard, the majority of populations have the ability to withstand stochastic events. The species currently has some redundancy within three of the six ecoregions in which it occurs and across its range (Table 6.5). The Plateau spot-tailed earless lizard has presumably maintained representation similar to its historical in that it is distributed throughout most of its known historical range, and 91% of the area in population analysis units is in either the **High** or **Moderate Resiliency** category (Table 6.7).

Scenario 1

In Scenario 1, we project future declines in the *Overall Resiliency* of the Plateau spot-tailed earless lizard in four population analysis units at timestep 2050 based on forecasting changes in road mortality and woody vegetation encroachment (Table 6.2). In this future scenario, the overall resiliency of the Plateau spot-tailed earless lizard is characterized by having three population analysis units (38% of the area) in the **High Resiliency** category, seven population analysis units (38% of the area) in the **Moderate Resiliency** category, and six population analysis units (23% of the area) in the **Low Resiliency** category. In total, 10 of 16 population analysis units are categorized as **High** or **Moderate Resiliency** at timestep 2050; the majority thus have the ability to withstand stochastic events. In this scenario, as with the current conditions, the species has redundancy within three of the six ecoregions in which it occurs, and across its range (Table 6.5). The Plateau spot-tailed earless lizard is projected to experience minimal changes in representation in this future scenario because it will continue to be distributed throughout most of its known historical range, and 77% of the area in population analysis units is in either the **High** or **Moderate Resiliency** category (Table 6.7,).

Scenario 2

In Scenario 2, we project declines in the *Overall Resiliency* of the Plateau spot-tailed earless lizard in seven population analysis units at timestep 2050 based on forecasting larger changes in road mortality and woody vegetation encroachment (Table 6.3). In this future scenario, the overall resiliency of the Plateau spot-tailed earless lizard is characterized by having three population analysis units (38% of the area) in the **High Resiliency** category, four population analysis units (31% of the area) in the **Moderate Resiliency** category, and nine population analysis units (31% of the area) in the **Low Resiliency** category. In total, the number of population analysis units categorized as **High** or **Moderate Resiliency** is 7 of 16 at timestep 2050; thus, fewer than half are assumed to be able to withstand stochastic events. In this scenario, the species has some redundancy within one of the six ecoregions in which it occurs but maintains redundancy at the scale of the entire species' range (Table 6.6). The Plateau spot-tailed earless lizard is projected to maintain some representation in this future scenario because it will continue to be distributed throughout most of its known historical range, and 69% of the area in population analysis units is in either the **High** or **Moderate Resiliency** category (Table 6.8, Figure 6.2)

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Appendix A. Cause and Effects Tables

Template for Cause and Effects Evaluation

ESA Factor(s): ?	Analysis	Confidence / Uncertainty	Supporting Information
Source(s)	*What is the ultimate source of the actions causing the stressor? I.e., Urban Development, Oil and Gas Development, Agriculture*	See next page for confidences to apply at each step.	Literature Citations, with page numbers for each step. Use superscript to delineate which statement goes with which citation. These can be repeated per theme, but not within a theme.
- Activity(ies)	*What is actually happening on the ground as a result of the action? Be specific here.*		
Stressor(s)	*What are the changes in environmental conditions on the ground that may be affecting the species? For example, removal of nesting habitat, increased temperature, loss of flow*		
- Affected Resource(s)	*What are the resources that are needed by the species that are being affected by this stressor? Or is it a direct effect on individuals?*		
- Exposure of Stressor(s)	*Overlap in time and space. When and where does the stressor overlap with the resource need of the species (life history and habitat needs)? This is not the place to describe where geographically it is occurring, but where in terms of habitat.*		
- Immediacy of Stressor(s)	*What's the timing and frequency of the stressors? Are the stressors happening in the past, present, and/or future?*		
Changes in Resource(s)	*Specifically, how has(is) the resource changed(ing)?*		
Response to Stressors: - Individuals	*What are the effects on individuals of the species to the stressor? (May be by life stage)*		
- Population & Species Responses	*[Following analysis will determine how do individual effects translate to population and species-level responses, and what is the magnitude of this stressor in terms of species viability?]*		
Effects of Stressors: - Populations [Resiliency]	*What are the effects on population characteristics (lower reproductive rates, reduced population growth rate, changes in distribution, etc.)?*		
- Geographic Scope	*What is the geographic extent of the stressor relative to the range of the species/populations? In other words, this stressor affects what proportion of the rangewide populations?*		
- Magnitude	*How large of an effect do you expect it to have on the populations?*		
Summary	*What is the bottom line- is this stressor important to carry forward in your analysis, or is it only having local effects, or no effects?*		

Confidences

This table of Confidence Terminologies explains what we mean when we characterize our confidence levels in the cause and effects tables on the following pages.

Confidence Terminology	Explanation
Highly Confident	We are more than **90% sure** that this relationship or assumption accurately reflects the reality in the wild as supported by documented accounts or research and/or strongly consistent with accepted conservation biology principles.
Moderately Confident	We are **70 to 90% sure** that this relationship or assumption accurately reflects the reality in the wild as supported by some available information and/or consistent with accepted conservation biology principles.
Somewhat Confident	We are **50 to 70% sure** that this relationship or assumption accurately reflects the reality in the wild as supported by some available information and/or consistent with accepted conservation biology principles.
Low Confidence	We are less than **50% sure** that this relationship or assumption accurately reflects the reality in the wild, as there is little or no supporting available information and/or uncertainty consistency with accepted conservation biology principles. Indicates areas of high uncertainty.

Cause and Effects Tables for the Plateau Spot-Tailed Earless Lizard

Theme: Land Cover Change

Land Cover Change ESA Factor(s): A	Analysis	Confidence/ Uncertainty	Supporting Information
Source(s)	Urban, rural, and industrial development Inhibition and/or removal of natural disturbance processes Overutilization of grassland resources by nonnative livestock	Highly Confident	
- Activity(ies)	Construction of buildings Construction of paved surfaces such as roads and parking lots Planting of turf grass Spraying of insecticides Suppression of natural wildfires Suppression of human-ignited wildfires Extirpation of bison Extirpation of prairie dogs Growth of tree and shrub seedlings into mature plants Succession of vegetative communities from grasslands to shrublands to savanna to woodland to forest Preferential browsing of grasses and herbaceous plants over shrub and/or tree seedlings	Highly confident	
Stressor(s)	Conversion of suitable habitat to unsuitable habitat — Conversion of natural land cover to impervious land cover — Conversion of native grassland communities to nonnative grasses — Conversion of open vegetation types to closed vegetation types — Conversion of grassland-dominated lands to shrub and/or forest-dominated land	Highly confident	
- Affected Resource(s)	The terrestrial habitat in which Plateau spot-tailed earless lizard carry out most of their resource functions, including breeding, feeding, sheltering, dispersal, thermoregulation, and survival is directly affected by these stressors. Specifically, open, low density and low canopy cover grassland and herbaceous plant communities that are interspersed with patches of bare soil.	Highly confident	
- Exposure of Stressor(s)	All life stages and habitats are exposed to and affected by these stressors.	Highly confident	
- Immediacy of Stressor(s)	The stressors began over 150 years ago in some parts of the species' range, are present currently, and are anticipated to continue into the foreseeable future.	Highly confident	
Changes in Resource(s)	The loss and/or degradation of suitable habitat can take many specific forms. 1. A reduction in the size and number of patches of land from which most or all above-ground vegetation was removed by bison movements, prairie dogs, or fires.	Highly confident	

Land Cover Change ESA Factor(s): A	**Analysis**	**Confidence/ Uncertainty**	**Supporting Information**
	2. Reduced ratios of grass:herb:shrub: tree communities, such that native grasses and herbaceous plants are less common on the landscape, while shrubs and trees become both larger and denser. This can be caused by the loss of disturbance processes that would set back the growth of trees and shrubs (e.g., wildfire, bison movements) as well as by overutilization by livestock. Livestock preferentially eat grass and herbs, decreasing their ability to compete with less palatable shrubs and trees. 3. Reduced connectivity between patches of suitable habitat. 4. Invasive, nonnative grasses can outcompete native grasses, especially in areas with a history of cultivation. Because the invasive grasses tend to form dense monoculture stands, this leads to a reduction in the number and density of patches of bare ground. Separately, a reduction in insect abundance may occur as a result of development due to increases in impervious cover, changes to vegetation, and use of pesticides.		
Response to Stressors: **- Individuals**	Reduction in overall health and fitness due to reduction in prey quality and availability. Reduction in survival due to loss or degradation of suitable habitat for sheltering and thermoregulation	Somewhat confident	Extirpation of spot-tailed earless lizards from localities that are now urban areas (e.g., Austin, TX).
- Population & Species Responses			
Effects Of Stressors: **- Populations [Resiliency]**	— Reduced abundance due to less supporting habitat and decreased survival — Extirpation or displacement due to elimination or deterioration of suitable habitat — Loss of connectivity that lowers genetic exchange and reduces effective population size	Somewhat confident	
- Geographic Scope	Rangewide: the conversion of suitable habitat into unsuitable habitat affects every population unit. Populations have increased vulnerability where soils and climate promote faster shrubland and forest development.	Highly confident	
- Magnitude	The magnitude of this threat varies from small to severe depending on the spatial scale of interest as well as across the range. Without human intervention, the natural ecological communities vary in their tendency towards closed, dense vegetation.	Moderately Confident	
Summary	Recommend carrying this stressor forward as its impacts vary over the range and examining it in the resiliency framework should yield insights into species viability.	Highly confident	

Theme: Direct Mortality

Direct Mortality ESA Factor(S): E	Analysis	Confidence/ Uncertainty	Supporting Information
Source(s)	Urban, rural, and industrial development Operation of motor vehicles	Highly confident	
- Activity(ies)	Predation by invasive or overabundant predators, such as raccoons, foxes, coyotes, or skunks Predation by pet dogs or cats Driving on roads	Highly confident	
Stressor(s)	Not applicable - direct mortality	Highly confident	
- Affected Resource(s)	Direct effect on individuals	Highly confident	
- Exposure of Stressor(s)	All life stages and habitats are exposed to and affected by these stressors.	Highly confident	
- Immediacy of Stressor(s)	The short-term timing and frequency of direct mortality to Plateau spot-tailed earless lizard from these sources and activities is not known. — The predation of the Plateau spot-tailed earless lizard by pets has been reported in the past and will likely continue into the future. We do not have insights into trends. — The extent of past, present, and likely future predation of the Plateau spot-tailed earless lizard by invasive or overabundant predators is unknown. However, we presume that this may be increasing where urban growth is increasing. — Running over the Plateau spot-tailed earless lizard by operators of motor vehicles has been reported in the past, continues to be observed in the present, and will likely continue into the future. We do not have insights into trends.	Moderately confident	See sources in Activities row
Changes in Resource(s)	Individuals either die from wounds or suffer decreased fitness until/if they are able to recover.	Highly confident	
Response to Stressors: - Individuals	Individuals either die from wounds or suffer decreased fitness until/if they are able to recover.	Highly confident	
- Population & Species Responses			

Direct Mortality ESA Factor(S): E	**Analysis**	**Confidence/ Uncertainty**	**Supporting Information**
Effects Of Stressors: **- Populations [Resiliency]**	We identified the following potential population-level effects: — The destruction of Plateau spot-tailed earless lizard nests and the loss of juveniles or adults by predators has negative effects on recruitment, population growth, and species survival. — Population abundance is decreased. — Population resiliency is decreased because population abundance and fecundity decrease.	Highly confident	
- Geographic Scope	There is evidence that Plateau spot-tailed earless lizards are predated by animals associated with humans and run over by motor vehicles. We assume that populations of Plateau spot-tailed earless lizards that are near human settlements or near areas with substantial motor vehicle traffic will be more impacted by these sources and activities than populations that do not intersect with these factors.	Moderately confident	
- Magnitude	It is difficult to calculate the effect because we do not know how many individuals are being removed from the population due to these effects, or whether/how different life stages are impacted.	Low confidence	
Summary	Recommend carrying forward direct mortality from vehicle strikes.	Highly confident	

Appendix B. Data Analysis

Occurrence

Our *Occurrence* metric is based on the set of observations of the Plateau spot-tailed earless lizard from 2008 to 2022, based on the recommendation of the producers of the data and the fact that the GPS data from 2008 or later have high levels of locational accuracy. The majority of available Plateau spot-tailed earless lizard data, and the only data available across the entire range of the species, consists of presence-only occurrence data. We obtained these data from a wide range of source material, including museum records, citizen science databases, grant and contract reports, journal articles, and personal communications reporting observations of the species (Duran et al. 2010; GBIF.org 2021; Hibbitts 2021, pers. comm.; iNaturalist 2021; Texas Comptroller 2021; Texas Parks and Wildlife Department 2021b; 2021a; Moore 2022, pers. comm.; Rains 2022b, pers. comm.). These data were collected both systematically (i.e., as part of a formal research study) and opportunistically.

In ArcGIS Pro, we used the Select by Location tool to identify all current Plateau spot-tailed earless lizard localities within each population analysis unit. We tallied the number of observations with and without a date. One dataset (Texas Comptroller 2021) included only latitude and longitude, but no dates or other location information, but we were told that all points in that dataset have a date between 2008 and 2022 (LaDuc 2021, p. 1, pers. comm.). We reviewed each point in our dataset and identified likely duplicates based on available information about precise location and date of collection. We then tallied our best estimate of the number of unique observations. We also recorded the years with an observation within each population analysis unit, and counted, for each unit, the number of years with an observation.

Next, using the rules identified for assigning each population analysis unit into High, Moderate, or Low resiliency for this metric, we binned the results from Table B.1, as shown in Table B.2. The basis for assigning population analysis units into resiliency categories for the *Occurrence* metric are as follows:

High Resiliency: Observations are from at least five years during the 2008–2022 timeframe. Estimated number of unique observations is 20 or more. Expert surveyors characterize the unit as one in which Plateau spot-tailed earless lizards are reliably encountered when searching appropriate habitat under good conditions. It is uncommon to fail to locate any Plateau spot-tailed earless lizards if searching within the unit with reasonable survey effort.

Moderate Resiliency: Observations are from two to four years during the 2008–2022 timeframe. Estimated number of unique observations is five to 19. Expert surveyors characterize unit as one in which Plateau spot-tailed earless lizards are found in appropriate habitat under good conditions, but not reliably. It may take many hours of survey effort to locate and catch a Plateau spot-tailed earless lizard.

Low Resiliency: Observations are from one year during the 2008–2022 timeframe. Estimated number of unique observations is fewer than five. Expert surveyors characterize unit as one in which Plateau spot-tailed earless lizards are not usually found, even in apparently appropriate habitat and good conditions.

Table B.1. Raw data used to compute the Occurrence metric. Data shared with us by the Texas Comptroller associated with the work published in LaDuc et al. (2018) lacked date collected, so we compared the location of each of these points to localities obtained elsewhere. We added together the number of observations with dates and our best estimate of the number of undated observations that were unique (not represented in the dataset with dates) to obtain a best estimate of the number of observations within each unit. Separately, we identified which years from the period 2008–2022 had observations in each unit and tallied that total number. The table shows our work.

Population Analysis Unit	**Count of observations with known year**	**Count of observations with unknown year**	**Best estimate of unique undated observations**	**Best estimate of number of observations**	**Years with an observation**	**Count of years with an observation**
Unit 1	25	6	3	28	2009, 2013, 2015, 2016, 2017	5
Unit 2	4	4	1	5	2015	1
Unit 3-A	37	6	4	41	2008, 2009, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2022	10
Unit 3-B	30	40	33	63	2009, 2014, 2015, 2016, 2017, 2019	6
Unit 3-C	14	2	2	16	2009, 2014, 2015, 2016	4
Unit 3-D	101	88	49	150	2009, 2015, 2016, 2017, 2020, 2021	6
Unit 3-E	2	2	0	2	2015	1
Unit 3-F	3	0	0	3	2016, 2017	2
Unit 3-G	2	0	0	2	2016, 2022	2
Unit 3-H	3	0	0	3	2016	1
Unit 4	1	0	0	1	2016	1
Unit 5	2	0	0	2	2020, 2021	2
Unit 6	10	0	0	10	2014, 2017, 2018	3
Unit 7	2	0	0	2	2008, 2010	2
Unit 8	9	2	0	9	2015	1
Unit 9	2	0	0	2	2015, 2016	2

Table B.2. This table shows how we converted the raw data from Table B.1 into a binned category. The binned categories are used to map the numerical values onto a resiliency category, based on the rule described in the text.

Population Analysis Unit	Number of observations, 2008–2022	Resiliency based on observations	Number of years with an observation, 2008–2022	Resiliency based on years	Conflict between observations and years results	Final resiliency category
Unit 1	20+	High	5+	High	no	High
Unit 2	5–19	Moderate	1	Low	yes	Moderate
Unit 3-A	20+	High	5+	High	no	High
Unit 3-B	20+	High	5+	High	no	High
Unit 3-C	5–19	Moderate	2–4	Moderate	no	Moderate
Unit 3-D	20+	High	5+	High	no	High
Unit 3-E	1–4	Low	1	Low	no	Low
Unit 3-F	1–4	Low	2–4	Moderate	yes	Moderate
Unit 3-G	1–4	Low	2–4	Moderate	yes	Moderate
Unit 3-H	1–4	Low	1	Low	no	Low
Unit 4	1–4	Low	1	Low	no	Low
Unit 5	1–4	Low	2–4	Moderate	yes	Moderate
Unit 6	5–19	Moderate	2–4	Moderate	no	Moderate
Unit 7	1–4	Low	2–4	Moderate	yes	Moderate
Unit 8	5–19	Moderate	1	Low	yes	Moderate
Unit 9	1–4	Low	2–4	Moderate	yes	Low

Seven population analysis units had a conflict in the resiliency value that should be assigned based on the rules above.

- Unit 2 and Unit 8 would both be Moderate Resiliency based on the number of observations, but Low Resiliency based on the number of years with observations. We selected Moderate Resiliency for both units with the guidance of species experts, who reported that although they visited these units in only one year, they easily found Plateau spot-tailed earless lizards during their search. Because the purpose of that research was inventory, they did not return to the location, feeling confident that the Plateau spot-tailed earless lizard was persisting in that area.
- Unit 3-F and Unit 3-G would both be Low Resiliency based on the number of observations, but Moderate Resiliency based on the number of years with observations. We chose to assign these units to Moderate Resiliency for the metric overall because the observations were distributed in space as well as time.
- Unit 5 would be Moderate Resiliency based on the number of observations, but Low Resiliency based on the number of years with observations. We chose to assign this unit to Moderate Resiliency for the metric overall because the notes associated with some of the observations indicated that multiple lizards were found at one locality and included multiple hatchlings.
- Unit 7 would be Low Resiliency based on the number of observations, but Moderate Resiliency based on the number of years with observations. We chose to assign this unit to Moderate Resiliency for the metric overall because this unit was not part of the major inventory effort from 2015–2017 (LaDuc et al. 2018, pp. 25–30) and so we believe that the reason for the low number of observations in this unit compared to the other is more reflective of survey effort than of low Plateau spot-tailed earless lizard numbers.
- Unit 9 would be Low Resiliency based on the number of observations, but Moderate Resiliency based on the number of years with observations. We chose to assign this unit to Low Resiliency for the metric overall because species experts were aware of numerous surveys completed by both them and other herpetologists without success. All observations for this unit are opportunistic.

Traffic Intensity

We used ArcGIS Pro software (ESRI 2021) and R statistical software (R Core Team 2022) to calculate the traffic intensity index for each population analysis unit.

Road length and daily traffic values were extracted from the TxDOT Roadway Inventory datasets (TxDOT 2018; 2019; 2020a). We used U.S. Census Bureau TIGER/Line shapefiles to delineate urban areas (U.S. Census Bureau 2022b). Locations of active oil and gas wells were obtained from the S&P Global Enerdeq Browser (IHS 2022a). Locations of wind turbines were obtained from a U.S. Geological Survey dataset (U.S. Geological Survey 2022a).

The first steps take place in ArcGIS Pro. We loaded the TxDOT data from each year 2013–2020. We modified the population analysis unit polygon data layer by using the Erase tool to eliminate areas within the U.S. Census Urban Areas layer from our population analysis units. We did this because we do not think that the Plateau spot-tailed earless lizard can survive in these areas and because including data for roads, vegetation, etc. in the city can skew the data such that it does not present a clear picture of conditions within the portions of the population analysis unit where the Plateau spot-tailed earless lizard has the potential to occur. We then clipped each year's data to our polygon layer of the population analysis units "less urban." We used the Spatial Join tool on the clipped data in order to create an attribute table that included all of the roadway data and the appropriate population analysis unit name for each line segment. We added a field called "Length_km" to this new layer and used the Calculate Geometry tool to calculate the length of each road segment in kilometers using the Albers Equal Area Conic projection. Finally, we export the attribute table to a csv file. To obtain information on the active wells and windmills in each unit, we employed a similar process. For the wells, first we loaded our data into ArcGIS Pro. We used the Select by Attributes tool to select wells where PRD_STATUS = A (production status = active). We created a temporary layer from the selected features, then clipped that layer to the polygon layer of the population analysis units "less urban." This removes all wells outside of a population analysis unit. We then used the Spatial Join tool, which produces an attribute table with all of the well data and the name of the population analysis unit for each individual well. Finally, we export the attribute table to a csv file. For the windmills, we loaded our data into ArcGIS Pro. Next, we used the Spatial Join tool to produce an attribute table with all of the windmill data and the name of the population analysis unit for each individual windmill. Finally, we export the attribute table to a csv file.

The csv data files produced in ArcGIS Pro are then loaded into R for further data processing and analysis. For the roadway data layers, we next remove columns other than those for the annual average daily traffic, segment length, and the population analysis units. For each segment, we calculate the annual average daily traffic per kilometer by dividing the average annual daily traffic by the segment length for each row (individual road segment) in the dataset. We then calculate the sum, for each combination of population analysis unit and year, of the total length of roads within the unit in kilometers, and the total traffic per kilometer. Table B.3 shows the results at this stage for the year 2020. For the well data, we load the datasets into R and then sum the total number of wells within each unit. This dataset does not have information about the year a well became active, so we do not have a year column for it. Table B.4 shows the count of active wells for all units (as of 2022, when the dataset was acquired). For the wind turbines, we do have information about what year the wind turbines became active, and so we count the number of windmills per unit, per year. Table B.5 shows the count of active wind turbines in each unit that has wind turbines for the year 2020.

Table B.3. For each population analysis unit in 2020, the sum of the length of all roads within the unit and the sum of the average daily traffic values per kilometer for each road segment in the unit.

Population Analysis Unit	Year	Sum Road Length (km)	Sum Average Daily Traffic (km)
Unit 1	2020	530	8826756
Unit 2	2020	273	50997276
Unit 3-A	2020	437	38162126
Unit 3-B	2020	422	7970863
Unit 3-C	2020	515	21198334
Unit 3-D	2020	2337	200369685
Unit 3-E	2020	180	332192
Unit 3-F	2020	151	367456
Unit 3-G	2020	172	5825288
Unit 3-H	2020	27.6	7264
Unit 4	2020	176	488975
Unit 5	2020	55.4	372290
Unit 6	2020	370	59884609
Unit 7	2020	74.7	19632
Unit 8	2020	245	2531660
Unit 9	2020	208	137908686

Table B.4. The count of active oil and gas wells in each unit as of early 2022.

Population Analysis Unit	Count of Active Wells
Unit 1	3960
Unit 2	152
Unit 3-A	2542
Unit 3-B	726
Unit 3-C	322
Unit 3-D	273
Unit 3-E	1
Unit 3-F	31
Unit 3-G	45
Unit 3-H	59
Unit 4	23
Unit 5	665
Unit 6	0
Unit 7	0
Unit 8	87
Unit 9	0

Table B.5. The count of active wind turbines in each unit in the year 2020.

Population Analysis Unit	Year	Count of Active Windmills
Unit 1	2020	185
Unit 2	2020	231
Unit 3-A	2020	17
Unit 3-B	2020	39
Unit 3-C	2020	109
Unit 3-D	2020	170
Unit 3-E	2020	41
Unit 3-F	2020	0
Unit 3-G	2020	0
Unit 3-H	2020	0
Unit 4	2020	57
Unit 5	2020	0
Unit 6	2020	0
Unit 7	2020	0
Unit 8	2020	0
Unit 9	2020	0

The traffic intensity index is calculated for each unit and year separately. Table B.6 shows example output for Unit 1. For each year of data, we compute an initial traffic intensity index by calculating the sum-total kilometers of roads in a unit, multiplying that by the average annual daily traffic per kilometer in that unit, and then dividing by the area of the unit in square kilometers. We then modify the initial index value using our well and windmill data. We calculated a "wells and windmills adjustment" by summing the total number of oil and gas wells or wind turbines in a given population analysis unit and dividing this value by the square root of the area of the unit in square kilometers (effectively quantifying the number of well and windmills per kilometer, in order to maintain compatibility with the original metric's units). The wells and windmills adjustment is then added to the initial index value and the result is the final traffic intensity index used for the metric of the same name. For example, the process for Unit 1 in 2020 is as follows (values shown are rounded to the nearest integer; actual values used in the calculations within R were not rounded):

1. Initial Traffic Intensity Index $= \frac{530 * 8826756}{1823} = 2567838$

2. Wells and Windmills Adjustment $= \frac{185 + 3960}{\sqrt{1823}} = 97$

3. Final Traffic Intensity Index $= 2567838 + 97 = 2567935$

Table B.6. Data calculations for Unit 1 for the Traffic Intensity Index.

Year	Sum Road Length (km)	Sum Average Daily Traffic (km)	Initial Traffic Intensity Index	Wells and Windmills Adjustment	Final Traffic Intensity Index
2013	529	1,477,202	428,948	93	429,041
2014	529	1,712,566	497,293	93	497,386
2015	529	1,253,775	364,070	95	364,165
2016	529	1,175,682	341,393	95	341,488
2017	534	10,007,843	2,931,017	96	2,931,113
2018	530	9,413,294	2,738,471	96	2,738,567
2019	530	15,634,391	4,548,283	96	4,548,379
2020	530	8,826,756	2,567,838	97	2,567,935

For the current resiliency, we took the average of the final traffic intensity index for the years, 2018, 2019, and 2020. In the case of Unit 1, this results in a value of 3,284,961, which corresponds to a determination of High Resiliency for the metric. Values above 10,000,000 are assigned to the Moderate Resiliency category for this metric. Results for this calculation and the corresponding resiliency value are shown in Table B.7.

Table B.7. Final average traffic intensity index values for the time period 2018–2020 and their corresponding resiliency category. These values are used in the current resiliency analysis, as described in Chapter 5.

Population Analysis Unit	Average Final Traffic Intensity Index, 2018–2020	Resiliency Category
Unit 1	3,284,961	High
Unit 2	13,967,128	Moderate
Unit 3-A	8,024,782	High
Unit 3-B	2,185,228	High
Unit 3-C	5,408,600	High
Unit 3-D	160,873,340	Moderate
Unit 3-E	142,827	High
Unit 3-F	54,640	High
Unit 3-G	1,549,967	High
Unit 3-H	631	High
Unit 4	213,058	High
Unit 5	87,043	High
Unit 6	29,962,079	Moderate
Unit 7	4,309	High
Unit 8	567,373	High
Unit 9	49,579,304	Moderate

We were unable to locate suitable datasets containing projections of public roads and their traffic levels. Therefore, we developed our own projections in order to use the Traffic Intensity metric again in the future resiliency analysis. We did this using a simple linear model (regression analysis) to extrapolate from the trends apparent from 2013–2020 at our future timestep of 2050. The generic equation for a linear model is $y = \alpha + \beta x$, where α is the y-intercept, x is the year, y is the final traffic intensity metric, and β is the slope, or rate of change over x. We use the *lm()* function to solve this equation for each unit, inputting the years and the final traffic intensity values for each year (Table B.8). We extract the βs for each population analysis unit and use the *predict()* function to project mean values and an 80% prediction interval at year 2050. We used an 80% prediction interval because a 95% prediction interval resulted in nonsensical (below 0) values for the lower boundary. The upper and lower values for the prediction interval are used to parameterize two future scenarios (Table 6.1). Table B.8 shows the final traffic intensity values used for the current and future resiliency analyses, and Table B.9 shows these values transformed into resiliency categories for the metric overall.

Table B.8. Traffic intensity index values for current and future resiliency analyses, as well as the β value from the linear regression in R used as input to the predict function.

Population Analysis Unit	Current Conditions: Average Final Traffic Intensity Index, 2018–2020	β value from linear regression	Future Scenario 1: Lower boundary of the 80% prediction interval	Future Scenario 2: Upper boundary of the 80% prediction interval
Unit 1	3,284,960	535,001	12,097,488	27,352,072
Unit 2	13,967,126	2,406,940	57,423,183	119,358,059
Unit 3-A	8,024,779	1,231,404	33,295,951	58,736,119
Unit 3-B	2,185,228	148,310	4,805,240	8,751,660
Unit 3-C	5,408,600	826,671	20,862,826	41,354,034
Unit 3-D	160,873,338	27,151,446	616,121,302	1,371,849,568
Unit 3-E	142,827	24,999	668,064	1,146,278
Unit 3-F	54,640	8,677	236,999	413,992
Unit 3-G	1,549,967	284,205	7,297,181	13,215,027
Unit 3-H	631	104	1,409	6,213
Unit 4	213,056	37,396	678,684	2,090,156
Unit 5	87,043	13,435	137,813	842,514
Unit 6	29,962,079	5,372,016	137,961,169	250,945,552
Unit 7	4,309	668	3,647	46,894
Unit 8	567,373	97,678	2,538,866	4,605,409
Unit 9	49,579,304	8,117,336	235,417,499	362,693,866

Table B.9. Resiliency categories for the Traffic Intensity metric, based on applying the rule described in the text to the numerical results shown in the Table B.8 above.

Population Analysis Unit	Current Conditions: Average Final Traffic Intensity Index, 2018–2020	Future Scenario 1: Lower boundary of the 80% prediction interval	Future Scenario 2: Upper boundary of the 80% prediction interval
Unit 1	High	Moderate	Moderate
Unit 2	Moderate	Moderate	Moderate
Unit 3-A	High	Moderate	Moderate
Unit 3-B	High	High	High
Unit 3-C	High	Moderate	Moderate
Unit 3-D	Moderate	Moderate	Moderate
Unit 3-E	High	High	High
Unit 3-F	High	High	High
Unit 3-G	High	High	Moderate
Unit 3-H	High	High	High
Unit 4	High	High	High
Unit 5	High	High	High
Unit 6	Moderate	Moderate	Moderate
Unit 7	High	High	High
Unit 8	High	High	High
Unit 9	Moderate	Moderate	Moderate

Suitable Habitat

We developed a spatially explicit habitat suitability model for the Plateau spot-tailed earless lizard that covers its entire current range (U.S. Fish and Wildlife Service 2022a, entire). The model includes two abiotic soils variables (depth to bedrock and percent sand at 30 cm) and two land cover variables (percent tree canopy cover and percent shrub cover). The soils variables are constant over time, whereas the land cover variables are available for each year from 1986–2021 (University of Montana 2022); the model draws from 2020 data for these, and so represents habitat suitability as a snapshot in time. The model output is an average of the results from an ensemble of five algorithms (boosted regression trees, generalized additive models, generalized linear models, MAXENT, and random forests) and consists of a raster with 30-m pixels. The models were run on a larger extent than the set of population analysis units in order to eliminate edge effects. In our case, we used the Minimum Bounding Geometry tool to create a polygon that included the full extent of every population analysis unit, and then buffered it by 10 km. This extent became the extent over which the models were run.

Because the habitat suitability model was in raster format and we wanted to map the results onto our population analysis units, we converted our population analysis unit polygons into a raster file. We did this in ArcGIS Pro using the Polygon to Raster tool, snapping to the SDM raster outputs. We then reclassified the value of the new raster so that the values matched the index of units (i.e., Unit 1 = 1, Unit 2 = 2, Unit 3-A = 3, Unit 3-B = 4, etc.). We exported the attribute table from the reclassified raster to a csv file. Also in ArcGIS Pro, we used the Combine tool to merge the reclassified population analysis unit raster and the habitat suitability model raster. We then exported the attribute table from the new raster to a csv file. We simplified this output into a binary raster where each raster pixel was classified as either meeting or not meeting the minimum habitat suitability needs of the species. The threshold value for this reclassification is the lowest habitat suitability value associated with an occurrence point (omission rate = 0, sensitivity = 1) (Pearson 2010, p. 77). We used the Extract Multi Values to Points tool on the habitat suitability raster layer and the point layer of current Plateau spot-tailed earless lizard localities to determine the lowest habitat suitability value associated with a locality. This value was 120. We then calculated the proportion of each unit that met minimum habitat suitability for the Plateau spot-tailed earless lizard.

In R, we loaded the csv files from our raster attribute tables. We calculated the area in each population analysis unit (excluding urban areas) by multiplying the count of raster pixels in each unit by 0.0009, which converts one $30m^2$ pixel into km^2. We calculated the area in each combination of population analysis unit and habitat suitability value using the same equation. Because we were interested in the area of each population analysis unit meeting a minimum value for habitat suitability, we next filtered the dataset to remove all rows in the data with values less than 120. Next, we summed the total area of suitable habitat for each population analysis unit and calculated the proportion of the unit that met the minimum suitable habitat threshold. The basis for assigning population analysis units into resiliency categories for the *Suitable Habitat* metric are as follows:

High Resiliency: At least 60% of the population analysis unit has a habitat suitability value above the minimum threshold.

Moderate Resiliency: Between 40% and 60% of the population analysis unit has a habitat suitability value above the minimum threshold.

Low Resiliency: Less than 40% of the population analysis unit has a habitat suitability value above the minimum threshold.

The results used in the current resiliency analysis are shown in Table B.10.

Table B.10. This table shows the area of each population analysis unit, the area represented by habitat suitability raster values greater than or equal to 120, the proportion of the population analysis unit (calculated by dividing the area meeting the standard by the area of the unit), and the corresponding resiliency category associated with that proportion.

Population Analysis Unit	Area (km^2) of Unit	Area (km^2) Meeting Minimal Habitat Standard	Proportion of Unit Meeting Minimal Habitat Standard	Resiliency Category
Unit 1	1,823	1,779	98%	High
Unit 2	1,152	919	80%	High
Unit 3-A	2,321	2,248	97%	High
Unit 3-B	1,686	1,646	98%	High
Unit 3-C	2,221	1,938	88%	High
Unit 3-D	3,985	3,607	92%	High
Unit 3-E	424	357	84%	High
Unit 3-F	947	777	82%	High
Unit 3-G	712	634	89%	High
Unit 3-H	478	417	87%	High
Unit 4	447	322	72%	High
Unit 5	489	388	80%	High
Unit 6	852	517	61%	High
Unit 7	458	137	30%	Low
Unit 8	1,113	817	73%	High
Unit 9	494	224	45%	Moderate

Because the habitat suitability model was created for a point in time (2020), and the available information did not allow us to project future habitat suitability using the same methods, we altered our approach to habitat suitability for the future conditions analysis. First, we obtained the vegetation cover data that were used as predictor variables for the habitat suitability model (University of Montana et al. 2022). We created a shapefile of our population analysis units without urban areas and uploaded it to the Rangeland Analysis Platform. We then downloaded an excel file for each population analysis unit, which summarized the vegetation cover percentages and annual temperature and precipitation average by year. Table B.11 shows a subset of the data for Unit 1 to illustrate what the data are like after download. We loaded the data for each population analysis unit into R and then filtered the table to retain only the Tree and Shrub canopy cover percentages. We then summed the percent cover of Trees and Shrubs together to derive a total woody canopy cover proportion. The results for the year 2020 are shown in Table B.12.

Table B.11. Subset of processed data downloaded from the Rangelands Analysis Project web interface. AFG is Annual Forbs and Grasses; PFG is Perennial Forbs and Grasses; SHR is Shrubs; TRE is Trees; LTR is Litter; BGR is Bare Ground; Annual Temp and Annual Precip represent averages for the year.

Year	AFG	PFG	SHR	TRE	LTR	BGR	Annual Temp	Annual Precip
1986	11.42	40.19	4.92	1.82	9.38	19.28	63.97	29.05
1987	11.59	44.65	10.73	2.24	5.97	10.75	61.48	19.74
1988	4.51	53.15	7.09	1.51	9.29	10.06	62.21	17.57
1989	3.55	29.04	4.65	1.64	12.08	27.44	63.06	12.74
1990	0.57	8.38	1.43	0.35	2.43	21.02	63.45	20.52

Table B.12. Percent of each population analysis unit with woody cover (total of the percent tree canopy cover and the percent shrub canopy cover) and without woody cover (100 – the value in the Percent Woody Cover column) in the year 2020.

Population Analysis Unit	Percent Woody Cover	Percent Without Woody Cover
Unit 1	12.88	87.12
Unit 2	25.97	74.03
Unit 3-A	21.69	78.31
Unit 3-B	20.62	79.38
Unit 3-C	26.93	73.07
Unit 3-D	18.71	81.29
Unit 3-E	22.15	77.85
Unit 3-F	36.57	63.43
Unit 3-G	32.95	67.05
Unit 3-H	32.94	67.06
Unit 4	25.44	74.56
Unit 5	32.89	67.11
Unit 6	44.56	55.44
Unit 7	47.85	52.15
Unit 8	37.89	62.11
Unit 9	37.5	62.5

Next, we sought a correlation between the proportion of the unit meeting minimum habitat suitability (the value used for the current resiliency analysis) and the proportion of the unit without tree or shrub canopy cover. We examined the values side-by-side (Table B.13) and plotted them against each other (Figure B.1). Based on a qualitative review of Table B.13 and Figure B.1, we determined that an average area without woody cover greater than 65% was correlated with High Resiliency based on the habitat suitability model values, and an average area without woody cover less than 55% was correlated with Low Resiliency based on the habitat suitability model values.

Table B.13. Percent of each population analysis unit meeting the minimal habitat suitability standard and the percent of each population analysis unit without woody cover in the year 2020. Note that the table has been sorted from most to least percentage of the unit meeting the minimal habitat suitability standard.

Population Analysis Unit	Percent of Unit Meeting Minimal Habitat Standard	Current Resiliency Category for Suitable Habitat Metric	Percent Without Woody Cover in 2020
Unit 1	97.60	High	87.12
Unit 3-D	92.16	High	81.29
Unit 3-B	97.63	High	79.38
Unit 3-A	96.88	High	78.31
Unit 3-E	84.18	High	77.85
Unit 4	71.99	High	74.56
Unit 2	79.73	High	74.03
Unit 3-C	88.29	High	73.07
Unit 5	79.50	High	67.11
Unit 3-H	87.25	High	67.06
Unit 3-G	89.07	High	67.05
Unit 3-F	82.08	High	63.43
Unit 9	45.30	Moderate	62.5
Unit 8	73.35	High	62.11
Unit 6	61.10	High	55.44
Unit 7	29.80	Low	52.15

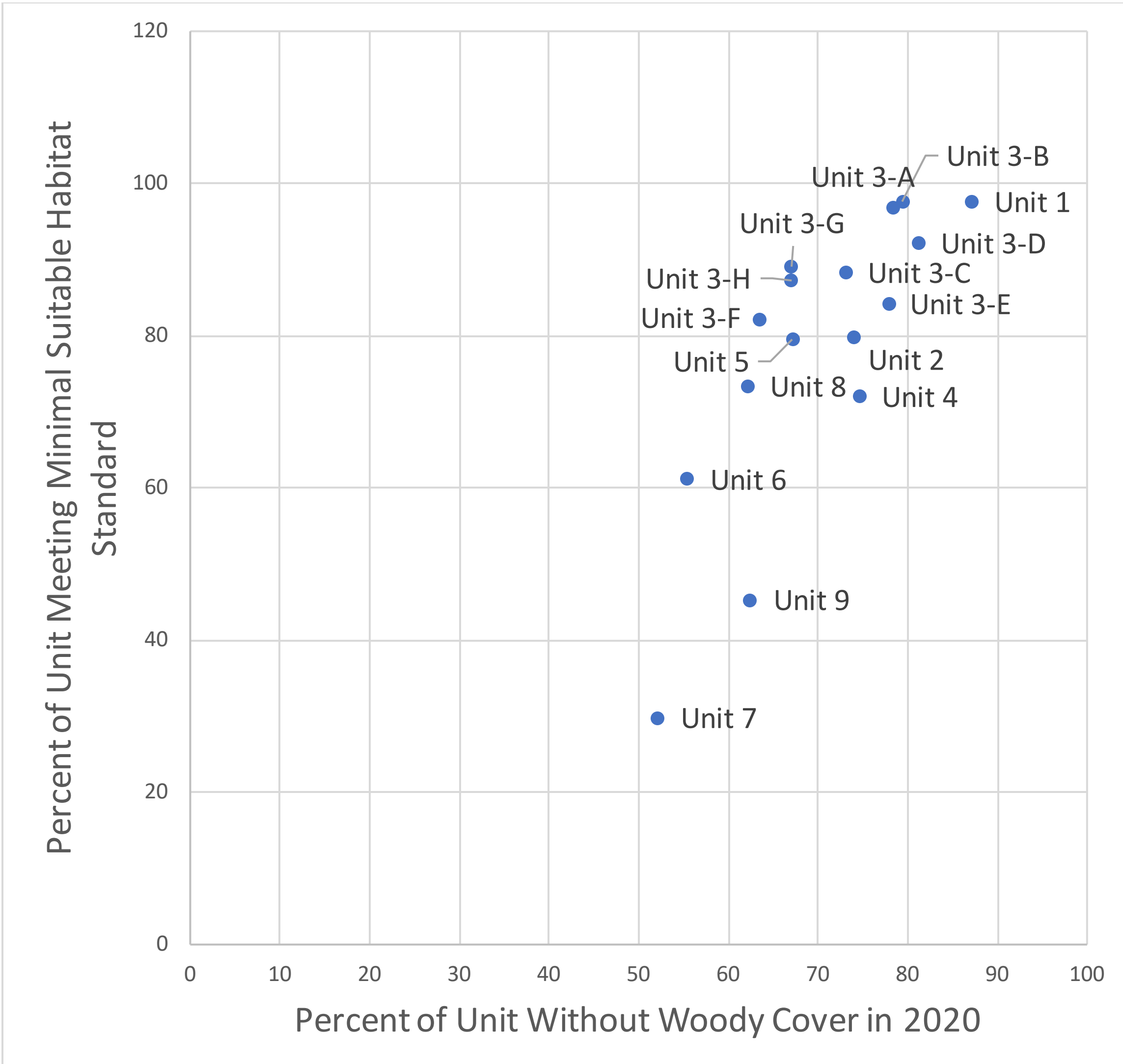

Figure B.1. Scatterplot of population analysis units. The y-axis denotes the percent of a population analysis unit that meets the minimal suitable habitat standard (according to the habitat suitability model), and the x-axis denotes the percent of a population analysis unit that lacked woody cover (tree and/or shrub canopy cover) in 2020 (according to the Rangelands Analysis Project dataset).

Next, we developed our own projections for the percent of each unit without woody cover for the future timestep of 2050. We followed a similar process as for the Traffic Intensity metric. We used a simple linear model (regression analysis) to extrapolate from the trends apparent from 1986–2021 to our future timestep of 2050. The generic equation for a linear model is $y = \alpha + \beta x$, where α is the y-intercept, x is the year, y is the final traffic intensity metric, and β is the slope, or rate of change over x. We used the *lm()* function to solve this equation for each unit, inputting the years and the overall percent of each unit with woody (tree or shrub) cover. We extracted the βs for each population analysis unit (Table B.14) and used the *predict()* function to project mean values and an 95% prediction interval at year 2050. We subtracted the percent area with woody cover from 100 to obtain a percent area without woody cover. We use the lower boundary of this interval for Scenario 1, and the mean value of future projection for Scenario 2. We use the mean value instead of the upper boundary because we suspect that the linear model likely overpredicts future woody plant cover over the long term; that is, that woody plant cover has some upper edaphic limit in terms of its total percent cover. Table B.15 shows the final percent area without woody cover values used for the current and future resiliency analyses, and Table B.16 shows these values transformed into resiliency categories for the metric overall.

Table B.14. Beta values output from the linear regression function in R. The beta value represents the percent increase in woody cover each year for each population analysis unit.

Population Analysis Unit	β value from linear regression (%)
Unit 1	0.27
Unit 3-D	0.43
Unit 3-B	0.40
Unit 3-A	0.31
Unit 3-E	0.41
Unit 4	0.22
Unit 2	0.38
Unit 3-C	0.42
Unit 5	0.45
Unit 3-H	0.30
Unit 3-G	0.33
Unit 3-F	0.35
Unit 9	0.47
Unit 8	0.66
Unit 6	0.37
Unit 7	0.17

Table B.15. Percent of unit values for population analysis units associated with the Suitable Habitat metric.

Population Analysis Unit	Current Conditions: Percent of unit meeting minimal habitat standard	Percent of unit without woody cover in 2020	Future Scenario 1: Projected lower 95% prediction interval future area without woody cover	Future Scenario 2: Projected mean future area without woody cover
Unit 1	97.60	87.12	81.4	74.7
Unit 2	79.73	81.29	68.3	58.9
Unit 3-A	96.88	79.38	70.8	61.6
Unit 3-B	97.63	78.31	73.9	65.3
Unit 3-C	88.29	77.85	68.6	58.0
Unit 3-D	92.16	74.56	76.8	71.2
Unit 3-E	84.18	74.03	67.3	61.4
Unit 3-F	82.08	73.07	61.2	50.8
Unit 3-G	89.07	67.11	60.4	51.0
Unit 3-H	87.25	67.06	66.3	56.6
Unit 4	71.99	67.05	70.3	62.6
Unit 5	79.50	63.43	66.7	54.8
Unit 6	61.10	62.5	52.5	38.8
Unit 7	29.80	62.11	43.3	31.8
Unit 8	73.35	55.44	61.5	50.7
Unit 9	45.30	52.15	64.9	58.1

Table B.16. Resiliency category for each population analysis unit for the current and future resiliency analyses.

Population Analysis Unit	Current Resiliency Category	Future Scenario 1 Resiliency Category	Future Scenario 2 Resiliency Category
Unit 1	High	High	High
Unit 2	High	High	Moderate
Unit 3-A	High	High	Moderate
Unit 3-B	High	High	High
Unit 3-C	High	High	Moderate
Unit 3-D	High	High	High
Unit 3-E	High	High	Moderate
Unit 3-F	High	Moderate	Low
Unit 3-G	High	Moderate	Low
Unit 3-H	High	High	Moderate
Unit 4	High	High	Moderate
Unit 5	High	High	Low
Unit 6	High	Low	Low
Unit 7	Low	Low	Low
Unit 8	High	Moderate	Low
Unit 9	Moderate	Moderate	Moderate

Biophysical Setting

We used ArcGIS Pro GIS software (ESRI 2021) and R statistical software (R Core Team 2022) to develop the Biophysical Setting resiliency metric.

The Biophysical Settings (BPS) spatial dataset was downloaded as 30-m pixel raster data from the Landfire project website (Landfire 2016). We loaded this layer into ArcGIS Pro. We then used the Combine tool to merge the reclassified population analysis unit raster (the methodology for creating this layer is described in the above section on Habitat Suitability) and the BPS raster. We exported the attribute table from the new raster layer to a csv file. We also exported the attribute table from the unaltered BPS raster to a csv file.

We then loaded the csv files into R for further data processing and analysis. We calculated the area of each BPS type in each population analysis unit by multiplying the count of raster pixels by 0.0009, which converts one 30m^2 pixel into km^2. We then merged the two datasets using the BPS model as a key value. We reviewed the 45 BPS models found in the Plateau spot-tailed earless lizard population analysis (Landfire 2016). Each BPS model is associated with a vegetation group that represents a coarser assemblage of many BPS types (Landfire 2022). After our review, we determined that the vegetation groups adequately distinguished between BPS that would be more or less likely to support the Plateau spot-tailed earless lizard under natural conditions. We then summed the total area in km^2 for each vegetation group in each population analysis unit (Table B.17).

Table B.17. Area in square kilometers for each vegetation group in each population analysis unit. Vegetation groups are a coarser grouping of the Biophysical Setting models created by the Landfire project.

Population Analysis Unit	Barren-Rock/ Sand/Clay	Conifer	Grassland	Open Water	Riparian	Shrubland	Sparse	Hardwood
Unit 1	0.21	59.64	1,681.33	1.37	29.10	51.02	0.12	0
Unit 2	0.02	316.61	697.19	0.05	75.43	2.55	0	60.24
Unit 3-A	0.12	870.74	1,356.40	0.64	48.78	8.45	0	34.87
Unit 3-B	0.11	219.54	1,057.85	0.24	7.89	0.01	0	399.92
Unit 3-C	0.70	317.23	951.97	13.09	140.83	0.55	0	770.32
Unit 3-D	0.41	79.48	3,065.00	6.12	159.30	39.02	0	565.02
Unit 3-E	0.01	15.34	341.79	0.55	8.75	10.65	0	46.91
Unit 3-F	0.01	142.63	234.84	0.13	23.45	0.05	0	545.92
Unit 3-G	0.11	70.10	205.09	0.42	13.50	0.06	0	422.24
Unit 3-H	0	18.91	220.25	0.00	6.03	0.02	0	232.48
Unit 4	0.01	20.56	254.62	0.42	3.86	9.75	0	157.69
Unit 5	0.00	53.99	217.09	0.03	2.66	0.01	0	214.80
Unit 6	0.11	146.11	105.75	2.01	41.30	0.18	0	550.64
Unit 7	0.09	52.27	214.34	1.39	27.10	0.37	0	162.91
Unit 8	0.02	88.97	192.79	0.13	14.91	0.21	0	816.44
Unit 9	0.09	27.09	5.39	2.33	9.31	0.11	0	450.07

Next, we filtered the dataset to remove rows associated with those vegetation groups less likely to support the Plateau spot-tailed earless lizard over time. The vegetation groups determined to be more resilient in terms of remaining open grasslands are “Barren-Rock/Sand/Clay,” “Grassland,” and “Sparse.” The groups that we believe are less likely to naturally remain in an open, grassy condition suitable for the Plateau spot-tailed earless lizard are “Conifer,” “Hardwood,” “Open Water,” “Riparian,” and “Shrubland.” After filtering, we combined the remaining vegetation groups and summed their total area. We divided this value by the area in each population analysis unit to derive a proportion of each population analysis unit comprised of more resilient BPS types (Table B.18). We binned the results into the resiliency categories according to the rules for the metric:

High Resiliency: At least 60% of the population analysis unit is comprised of Landfire BPS types considered more resilient to maintaining open conditions appropriate for the Plateau spot-tailed earless lizard.

Moderate Resiliency: Between 40% and 60% of the population analysis unit is comprised of Landfire BPS types considered more resilient to maintaining open conditions appropriate for the Plateau spot-tailed earless lizard.

Low Resiliency: Less than 40% of the population analysis unit is comprised of Landfire BPS types considered more resilient to maintaining open conditions appropriate for the Plateau spot-tailed earless lizard.

Table B.18. The area in each unit and the proportion of each unit associated with more resilient vegetation groups. The vegetation groups are a coarser version of the BPS types from the Landfire project (Landfire 2022). They include "Barren," "Grassland," and "Sparse." The resiliency category shown in based on the implementation of the rules described in the text.

Population Analysis Unit	Area of more resilient vegetation groups (km^2)	Proportion of unit comprised of more resilient vegetation groups	Resiliency category
Unit 1	1681.7	92%	High
Unit 2	697.2	61%	High
Unit 3-A	1356.5	58%	Moderate
Unit 3-B	1058.0	63%	High
Unit 3-C	952.7	43%	Moderate
Unit 3-D	3065.4	77%	High
Unit 3-E	341.8	81%	High
Unit 3-F	234.9	25%	Low
Unit 3-G	205.2	29%	Low
Unit 3-H	220.2	46%	Moderate
Unit 4	254.6	57%	Moderate
Unit 5	217.1	44%	Moderate
Unit 6	105.9	12%	Low
Unit 7	214.4	47%	Moderate
Unit 8	192.8	17%	Low
Unit 9	5.5	1%	Low

Cropland

We used R statistical software (R Core Team 2022) to calculate the total area in cropland for each unit. We downloaded USDA CropScape data for the years 2019, 2020, and 2021 (USDA 2019; 2020; 2021). We calculated the total area occupied by crops for each year within each population analysis unit, then calculated the average area in cropland for each population analysis unit across these three years. The results are shown in Table B.19. To populate Table 3.1, we calculated the average area in each specific crop type for each population analysis unit from 2019–2021 and reported the crops with an average area greater than 10 km^2 (3.86 mi^2). The specific values for these crops are shown in Table B.20.

Table B.19. Percent of each population analysis area devote to cropland. The percentage reflects the 3-year average for 2019–2021.

Population Analysis Unit	Percent Area in Crops
Unit 1	32.1%
Unit 2	1.9%
Unit 3 Subunit A	0.2%
Unit 3 Subunit B	4.8%
Unit 3 Subunit C	3.5%
Unit 3 Subunit D	34.6%
Unit 3 Subunit E	26.9%
Unit 3 Subunit F	0.2%
Unit 3 Subunit G	0.1%
Unit 3 Subunit H	0.2%
Unit 4	16.8%
Unit 5	0.2%
Unit 6	0.8%
Unit 7	0.4%
Unit 8	0.0%
Unit 9	0.4%

Table B.20. The average area in km^2 for each population analysis unit and crop for which the average was at least 10 km^2 (3.86 mi^2) over the period 2019–2021.

Population Analysis Unit	**Crop**	**Average Area (km^2) for 2019–2021**
Unit 1	Cotton	527
Unit 1	Winter Wheat	46
Unit 2	Winter Wheat	15
Unit 3 Subunit B	Cotton	45
Unit 3 Subunit B	Winter Wheat	17
Unit 3 Subunit C	Cotton	32
Unit 3 Subunit C	Winter Wheat	33
Unit 3 Subunit D	Corn	27
Unit 3 Subunit D	Cotton	696
Unit 3 Subunit D	Other Hay/Non Alfalfa	23
Unit 3 Subunit D	Sorghum	168
Unit 3 Subunit D	Winter Wheat	423
Unit 3 Subunit E	Cotton	30
Unit 3 Subunit E	Sorghum	19
Unit 3 Subunit E	Winter Wheat	55
Unit 4	Cotton	10
Unit 4	Winter Wheat	43