Species Status Assessment Report for Cactus Ferruginous Pygmy-owl *(Glaucidium brasilianum cactorum)*

Adult Male Cactus Ferruginous Pygmy-Owl, Pima County, AZ
Photo Credit: FWS

December 2022
Version 1.2

U.S. Fish and Wildlife Service, Region 2
Albuquerque, NM

This document was prepared by Scott Richardson, with assistance from Rachel Laura and the Cactus Ferruginous Pygmy-owl Species Status Assessment Core Team including:

Aaron Flesch – University of Arizona and Independent Ecologist
Tara Harris – Phoenix Zoo
Keith Hughes – Bureau of Land Management
Shawn Lowery – Arizona Game and Fish Department
Dr. Bill Mannan – University of Arizona (retired)
Danny Martin – National Park Service – Organ Pipe Cactus National Monument
Clifford Shackelford – Texas Parks and Wildlife Department
Julia Sittig – Altar Valley Conservation Alliance
Mary Kay Skoruppa – USFWS – Corpus Christi ES Office
Eric Verwys – Tohono O'odham Nation

Special thanks to Jim Dick and Mike Dick in the USFWS Region 2 Regional Office, as well as Rekha Warrier, Pradeep Koulgi, and Jason Laura, who provided invaluable technical assistance and analysis in developing the models used in this Species Status Assessment.

Additionally, valuable input into our analysis was provided by peer and partner reviewers and other members of the SSA team. We appreciate their input and comments, which resulted in a more robust status assessment and final report.

Suggested reference:
United States Fish and Wildlife Service. 2022. Species status assessment report for *Glaucidium brasilianum cactorum* (cactus ferruginous pygmy-owl), Version 1.2. United States Fish and Wildlife Service, Tucson, Arizona. 183 pp. + 6 appendices.

EXECUTIVE SUMMARY

This species status assessment reports the results of a comprehensive status review for the cactus ferruginous pygmy-owl (*Glaucidium brasilianum cactorum*) and provides a thorough account of the subspecies' overall viability and extinction risk. The cactus ferruginous pygmy-owl (also "pygmy-owl" in this document) is a small cavity nesting owl in the family Strigidae, which occurs from southern Arizona south through Michoacán, Mexico and from southern Texas south through Nuevo Leon and Tamaulipas, Mexico.

To evaluate the biological status of the pygmy-owl, both currently and into the future, we assessed a range of conditions to allow us to consider the subspecies' resiliency, redundancy, and representation (together, the 3Rs) across its range. The pygmy-owl needs multiple resilient populations and population groups (multiple breeding pairs of pygmy-owls within relatively discreet geographic areas) distributed widely across its range, to maintain its persistence into the future and to avoid extinction. Many factors influence the resiliency of a population in response to stochastic events. The primary factors that we identified with regard to the pygmy-owl are abundance of pygmy-owls, occupied population groups with potential for interchange of individuals, evidence of reproduction, and adequate vegetation intactness, soil moisture, and vegetation greenness. As we consider the future viability of the subspecies, more population groups with high resiliency distributed across both populations of the pygmy-owl would be associated with higher overall subspecies viability.

For our projections of current and future population conditions in this species status assessment, populations in high (healthy) condition are expected to have high resiliency over the next 30-years (i.e., abundance is increasing, the majority of available habitat is occupied, and populations are successfully reproducing, habitats are intact with adequate prey availability, and vegetation cover is adequate and healthy). Populations in high condition are expected to persist into the future (>85 % chance of persistence beyond 30 years), and have the ability to withstand stochastic events that may occur. Populations in moderate condition have less resiliency than those in high condition, but the majority (>60 – 85%) of these populations are expected to persist beyond 30 years. Populations in moderate condition have lower rates of abundance and occupancy than those in high condition and the overall condition of habitat is reduced. Populations in low (unhealthy) condition have low resiliency and are not necessarily able to withstand stochastic events. As a result, they are less likely to persist beyond 30 years (<60%).

The pygmy-owl is known historically from five analysis units (defined in this species status assessment) within two populations. There are three analysis units in the western population (Arizona, Northern Sonora, and Western Mexico) and two analysis units in the eastern population (Texas and Northeastern Mexico). While pygmy-owls have not been extirpated from any analysis unit, population groups have been extirpated within the Arizona and the Texas analysis units. We have assessed the current and future levels of resiliency, redundancy, and representation for the pygmy-owl for each analysis unit and population. This was done by first rating the resiliency condition for each analysis unit and then considering the representation and redundancy for each analysis unit, both currently and in the future. Ratings are a qualitative assessment of the relative condition of occupied analysis units based on the knowledge and

expertise of FWS staff, as well as available literature, reports, and papers, and in consultation with experts in owl and raptor ecology and factors affecting the viability of pygmy-owls.

Beyond demographic factors (abundance, survival, and productivity), our analysis of the past, current, and future influences on what the pygmy-owl needs for long-term viability revealed that there are two influences that pose the largest risk to future viability of the subspecies: habitat loss/fragmentation and vegetation quality which influences prey availability and cover for predator avoidance and thermoregulation. The influences of climate change affect both of these stressors, exacerbating effects to the quality and extent of pygmy-owl habitat, including cover, habitat connectivity, nest cavity availability, and prey availability. Demographic factors, as well as these habitat factors and ongoing conservation efforts, are carried forward in our assessment of the future conditions of the pygmy-owl populations and the viability of the subspecies overall.

If populations lose resiliency due the risks they face, they are more vulnerable to extirpation, with resulting losses in representation and redundancy. Because there is some uncertainty regarding: 1) how climate will change in the future, which in turn will have an effect on the severity of future periods of drought and warming; 2) the extent and location of land use activities that lead to pygmy-owl habitat loss and fragmentation in the future; and 3) whether and where conservation actions which improve demographic and habitat factors will be implemented and be effective in improving the viability of pygmy-owl populations, we have projected what the pygmy-owl may have in terms of resiliency, redundancy, and representation under four plausible future scenarios (Scenario 1: Continuation; Scenario 2: Increased Effects; Scenario 3: Reduced Effects, and Scenario 4: Conservation Planning (included as Appendix 4)). These future scenarios project the viability of the pygmy-owl over the next 30 years. We chose 30 years because this is within the range of available population growth and climate change model projections and this incorporates multiple generations of pygmy-owls and the observed natural fluctuations in pygmy-owls numbers.

Scenario 1, or the Continuation scenario, evaluates the condition of pygmy-owl if there is no increase in risks to the populations from what exists today. Scenario 2, or the Increased Effects scenario, evaluates the response of the subspecies to changes in threats and stressors, including increased levels of climate change affecting prey availability and vegetation and cover, reduction in demographic support (rescue effect), reduced vegetation intactness, and reduced vegetative greenness (health). Scenario 3, or the Reduced Effects scenario, considers the response of pygmy-owls to future changes in threats and stressors that are reduced from current levels, as well as conservation actions that are effective. Finally, Scenario 4, or the Conservation Planning scenario (Appendix 4), explores possible conservation strategies that if implemented, could improve current conditions.

Resiliency of pygmy-owl populations depends on future availability of intact vegetation of adequate quality to provide for the subspecies' needs such as nesting cavities, available prey, and interchange of individuals among population groups. We expect all five analysis units that comprise the eastern and western pygmy-owl populations to experience changes to these aspects of their habitat in different ways under the different scenarios. We projected the expected future resiliency, representation, and redundancy of the pygmy-owl based on the events that would occur under each scenario (Table ES-1).

In 30 years, under Scenario 1 – Continuation, we would expect viability of the pygmy-owl to be characterized by lower levels of resiliency, representation, and redundancy than it has currently. No analysis units would be in high condition, two would remain in moderate condition (>60% – 85% probability of persistence in 30 years), and three would remain in low condition (0% - 60% probability of persistence in 30 years), primarily due to low vegetation intactness.

In 30 years, under Scenario 2 – Increased Effects, we would expect viability of pygmy-owl populations to be characterized by lower levels of resiliency, representation, and redundancy than it has currently. No analysis units would be in high condition and four out of five analysis units are projected to be in low condition. Therefore, all but the western Mexico analysis unit would have a 40 - 100% chance of extirpation within 30 years.

In 30 years, under Scenario 3 – Reduced Effects, we would expect viability of the pygmy-owl to be characterized by lower levels of resiliency, representation, and redundancy than it has currently, with the exception of the Arizona and Texas analysis units which would potentially have improved demographic factors due to the effectiveness of conservation actions. However, no analysis units would be in high condition, two would remain in moderate condition (>60% – 85% probability of persistence in 30 years), and three would remain in low condition (0% - 60% probability of persistence in 30 years), primarily due to low vegetation intactness.

A Species Status Assessment summary for the pygmy-owl is provided in Table ES-2.

Table ES-1. Pygmy-owl population and analysis unit conditions in 30 years under each scenario.

	Population Condition			
Population/Analysis Unit	**Current Condition**	**Scenario 1- Continuation**	**Scenario 2- Increased Effects**	**Scenario 3 – Reduced Effects**
Western/Arizona	**Low**	**Low**	**Low**	**Low**
Western/Northern Sonora	**Moderate**	**Low**	**Low**	**Low**
Western/Western Mexico	**High**	**Moderate**	**Moderate**	**Moderate**
Eastern/Texas	**Moderate**	**Low**	**Low**	**Moderate**
Eastern/Northeastern Mexico	**Moderate**	**Moderate**	**Low**	**Moderate**

Table ES-2. Species Status Assessment summary for the cactus ferruginous pygmy-owl.

3Rs	Needs	Current Condition	Future Condition (Viability)
Resiliency (Large populations able to withstand stochastic events)	• Nesting cavities • Adequate prey year-round • Vegetation cover for protection and hunting • Adequate cover for thermoregulation • Intact vegetation to facilitate dispersal and provide demographic support (rescue effect) • Population groups of adequate size to provide floaters in the population	• All five analysis units making up the two pygmy-owl populations are occupied. • One analysis unit has low abundance; two analysis units have low vegetation intactness; and two analysis units have low vegetation greenness. • Population Status: ○ 1 high resiliency ○ 3 moderate resiliency ○ 1 low resiliency	Projections based on future scenarios in 30 years: • **Continuation**: Threats continue on current trajectory. All analysis units remain extant. Resiliency ratings drop in 4 of the 5 analysis units: • None in high resiliency • 2 in moderate resiliency • 3 in low resiliency • See Table ES-1 for other scenarios.
Representation (Genetic and ecological diversity to maintain adaptive potential)	• Maintenance of genetic diversity within both populations. • Maintenance of population groups and analysis units within areas of unique ecological diversity.	• Genetic and ecological representation occur within both populations and all analysis units. • Extant population groups are currently experiencing isolation by distance and geographic isolation, likely resulting in genetic differentiation among them; it is likely that population groups were historically more abundant and interconnected.	Projections based on future scenarios in 30 years: • **Continuation:** Representation is maintained in both populations and all analysis units, but the degree of representation is reduced in three of the five analysis units due to reduced abundance or low levels of vegetation intactness and vegetation greenness. • See Table ES-1 for other scenarios.
Redundancy (Number and distribution of populations to withstand catastrophic events)	• Multiple population groups within each analysis unit of both populations in each area of genetic and ecological representation	• Population groups within two of the five analysis units have likely been extirpated, reducing redundancy in both the eastern and western populations of the pygmy-owl.	Projections based on future scenarios in 30 years: • **Continuation**: It is likely that redundancy will remain reduced in three of the five analysis units resulting in reduced redundancy in both populations of pygmy-owls. • See Table ES-1 for other scenarios.

Table of Contents

CHAPTER 1. INTRODUCTION

The Species Status Assessment (SSA) framework (FWS 2016, entire) is an analytical approach to assess, with the best available information, the needs, current status, and future status of a species of conservation concern. The SSA Framework uses the conservation biology principles of resiliency, redundancy, and representation (collectively known as the “3Rs”) as a lens to evaluate the current and future condition of a species. We used the SSA framework to conduct an in-depth review of the biology and the various factors (both negative and positive) that influence the cactus ferruginous pygmy-owl (also “pygmy-owl” in this document; *Glaucidium brasilianum cactorum*), evaluate its current biological status, and project the potential future status of resources and conditions as a means of assessing the pygmy-owl’s viability. The result is an SSA Report that characterizes the pygmy-owl’s ability to sustain populations in the wild over time (viability) based on the best scientific understanding of current and future abundance and distribution within this subspecies’ ecological settings. The intent is for the SSA Report to be easily updated as new information becomes available and to support all functions of the U.S. Fish and Wildlife Service (FWS, we) Endangered Species Program from Candidate Assessment to Listing to Consultations to Recovery.

This SSA report is not a decisional document; rather, it provides the biological and scientific foundation for our decisions concerning the pygmy-owl under the Endangered Species Act of 1973, as amended (Act; 16 U.S.C. 1531 *et seq.*). As such, the SSA Report will be a living document upon which other documents, such as listing rules, critical habitat, recovery plans, and 5-year reviews, would be based if the species warrants listing under the Act.

The cactus ferruginous pygmy-owl, a subspecies of the ferruginous pygmy-owl (*G. brasilianum*), is a small, cryptic owl that is often difficult to observe. Its natural history and conservation needs are not well understood and despite ongoing research in Texas, Arizona, and northern Sonora, the available information remains limited. In addition, factors influencing demographics (e.g., habitat configuration, causes of mortality and reproductive failure, and prey availability) may vary geographically, increasing the need for information from all parts of the range.

At the northern edge of its geographic range, the ferruginous pygmy-owl reaches central Arizona and extreme southern Texas (Fig. 1.1). Since 1937, the form found from central Arizona south to Michoacán in western Mexico (Johnsgard 1988) has been recognized as the subspecies *cactorum* (van Rossem 1937, Friedmann *et al. 1*950, Blake 1953, Sprunt 1955, Phillips *et al. 1*964, Monson and Phillips 1981, Millsap and Johnson 1988, Binford 1989). Whether the ferruginous pygmy-owl found between southern Texas and Tamaulipas and Nuevo Leon in northeastern Mexico (Johnsgard 1988) is also *cactorum* has not been definitively resolved. Peters (1940) refers to the ferruginous pygmy-owl of Texas as *ridgwayi* and to the ferruginous pygmy-owl of Arizona as *cactorum*. Relatively recent genetic work by Proudfoot *et al.*(2006a, entire and 2006b, entire), as well as other authorities for owl taxonomy, classify the subspecies *cactorum* under *Glaucidium ridgwayi* with its distribution only in Arizona and western Mexico (Navarro-Sigüenza and Peterson 2004, p. 5; König *et al. 1*999, pp. 372-373; Heidrich *et al. 1*995, p. 25). Regarding this difference in taxonomic classification, for this SSA Report we will follow FWS policy and, where the taxonomic classification of an organism has not been resolved, defer to the classification followed by the recognized species group authority in taxonomy (in this case, the American Ornithological Society (AOS), previously known as the American Ornithological

Union (AOU)). Therefore, for this SSA Report, we will evaluate the pygmy-owl as *Glaucidium brasilianum cactorum* (AOU 1957, p. 282) (see Section 2.1 below for additional discussion of the taxonomic classification of the pygmy-owl).

Figure 1.1 The geographic range of the cactus ferruginous pygmy-owl and the five analysis units as described and analyzed in this SSA report.

Two populations of *cactorum* are generally recognized (e.g., Burton 1973, Johnsgard 1988, but see comments above). In the west, the cactus ferruginous pygmy-owl occurs north to central Arizona. The historical boundaries of its distribution in Arizona are New River in the north, the confluence of the Gila and San Francisco rivers to the east, and the desert of southern Yuma County to the west (Fisher 1893, Phillips *et al. 1*964, Monson and Phillips 1981, Hunter 1988). This western population also extends south to Michoacan along the Pacific slope of the Mexican Plateau, where it is common in lowlands and foothills (Peterson and Chalif 1973, p. 85). The eastern population of *cactorum* occurs from extreme southern Texas south to Tamaulipas and Nuevo Leon in northeastern Mexico (Johnsgard 1988, pp. 159 – 160). In Texas, it occurs in the live oak (*Quercus virginiana*)/honey mesquite (*Prosopis glandulosa*) forest of the historical Wild Horse Desert, primarily in Brooks and Kenedy counties (Mays 1996). Historically, it was also often reported along the Rio Grande in Starr and Hidalgo counties (Oberholser 1974, Texas Ornithol. Soc. 1984, Tewes 1993, p. 8). The eastern and western populations of the pygmy-owl are separated over most of their geographic distribution by a series of biogeographic barriers: the United States' Chihuahuan desert basins and associated mountain ranges and Mexico's Sierra Madre Occidental and Oriental and Mexican Plateaus. These barriers may prevent contact between the two populations. There is no record of the cactus ferruginous pygmy-owl in any location in the United States between Arizona and south Texas (Bailey 1928; Phillips *et al. 1*964; Oberholser 1974; Williams 1997).

The pygmy-owl was listed as an endangered species in 1997 (62 FR 10730). Following a long history of litigation, the FWS removed the pygmy-owl from the list of threatened and endangered species in 2006 (71 FR 19425). Shortly after delisting, the Center for Biological Diversity and Defenders of Wildlife submitted a new petition to the FWS to once again list the pygmy-owl as threatened or endangered. The new petition was primarily based on new information on the genetics and taxonomy of the pygmy-owl, and sought protection in both the United States and Mexico. The FWS issued a 90-day finding on the petition, finding that the petition was valid and presented substantial information that listing of the pygmy-owl may be warranted (73 FR 31418). The FWS issued a final 12-month finding in October 2011 (76 FR 61856) stating that listing for the pygmy-owl (with the currently accepted taxonomy for the subspecies) was not warranted throughout all or a significant portion of its range, including the petitioned and other potential DPS configurations. In August, 2014, a complaint was filed challenging the FWS' "Significant Portion of the Range" policy through the 2011 pygmy-owl 12-month finding (Case 4:12-cv-00627-CKJ). This case took a number of years to work through the courts, but a final ruling was made in March of 2017 that vacated and remanded the 12-month finding back to the FWS for revision (Case 4:14-cv-02506-RM). This SSA will inform our revision of the 2011 12-month finding.

For the purposes of this SSA, we are analyzing factors that influence the viability of populations. As discussed in more detail below (Chapter 2), we have divided the pygmy-owl into two populations configured within the current taxonomic classification. There is a western population that includes southern Arizona and western Mexico south from Sonora to Michoacán, and an eastern population that includes Texas and the northeastern states of Tamaulipas and Nuevo Leon in Mexico. These populations are defined by published genetic boundaries, as well as distance separating them and geographic barriers such as the Sierra Madres.

In this assessment, we generally define viability as the ability of the cactus ferruginous pygmy-owl to sustain populations in natural systems over time. Using the SSA framework (Figure 1.2), we consider what the subspecies needs to maintain viability by characterizing the status of the subspecies in terms of its resiliency, redundancy, and representation (Wolf *et al. 2*015, entire).

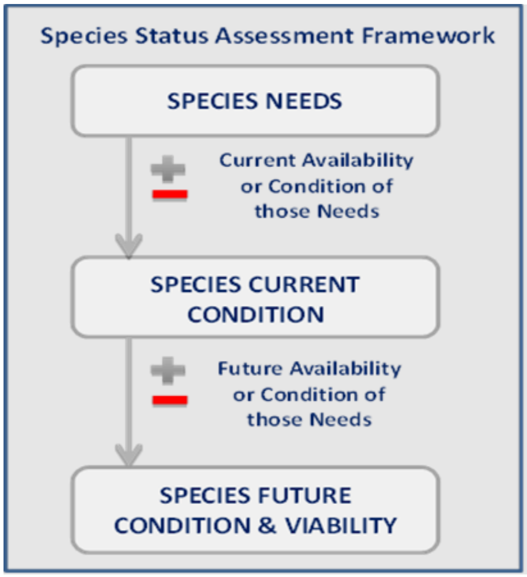


Figure 1.2 Species Status Assessment framework

Resiliency describes the ability of populations to withstand *stochastic* events (arising from random factors). We can measure resiliency based on metrics of population health; for example, relative or absolute density/abundance, or comparing reproductive (e.g., fecundity) versus death rates. Highly resilient populations are better able to withstand disturbances such as random fluctuations in reproductive rates (demographic stochasticity), variations in rainfall or prey abundance (environmental stochasticity), or the impacts of anthropogenic activities.

Representation describes the ability of a species to adapt to changing environmental conditions. Representation can be measured by the breadth of genetic or environmental diversity within and among populations and gauges the probability that a species is capable of adapting to environmental changes. The more representation, or diversity, a species has, the more it is capable of adapting to changes (natural or human caused) in its environment. In the absence of species-specific genetic and ecological diversity information, we evaluate representation based on the extent and variability of habitat characteristics across the species' geographical range.

Redundancy describes the ability of a species to withstand catastrophic events. Measured by the number of populations, their resiliency, and their distribution (and connectivity), redundancy gauges the probability that the species has a margin of safety to withstand or can bounce back from catastrophic events (such as a rare destructive natural event or episode involving many populations; for example, wildfire or flooding).

To evaluate the biological status of the pygmy-owl into the future, we assessed a range of possible future conditions to allow us to consider the species' resiliency, redundancy, and representation. This SSA Report provides a thorough assessment of biology and natural history and assesses demographic risks, stressors, and limiting factors in the context of determining the viability and risks of extinction for the species going forward.

The format for this SSA Report includes: 1) this introduction (Chapter 1); 2) the life history and biology of the pygmy-owl (Chapter 2); 3) the individual needs of pygmy-owls (Chapter 3); 4) population needs including the historical and current distribution of the pygmy-owl (Chapter 4); 5) subspecies needs and a framework for determining the distribution of resilient populations across its range for subspecies viability (Chapter 5); 6) current condition of the pygmy-owl (Chapter 6); 7) the likely causes of the current and future status of the pygmy-owl and stressors that affect the subspecies' viability (Chapter 7); and 8) a description of subspecies' future viability in terms of resiliency, redundancy, and representation (Chapter 8). This document is a compilation of the best available scientific and commercial information (information from non-governmental entities such as consulting firms, contractors, and individuals associated with professional organizations) and a description of past, present, and likely future risk factors to the cactus ferruginous pygmy-owl.

CHAPTER 2. LIFE HISTORY AND BIOLOGY

In this chapter we provide basic biological information about the cactus ferruginous pygmy-owl, including its taxonomic history, genetics, morphological description, and known life history traits.

2.1. Taxonomy

The cactus ferruginous pygmy-owl is a small, cavity-nesting owl in the order Strigiformes and the family Strigidae (ITIS 2020, Enriquez *et al. 2*017, p. 11; Proudfoot *et al. 2*020, p.3). Some studies incorporating vocalizations, ecology, and molecular genetics by König (1991) and Heidrich *et al.* (1995) suggest that the ferruginous pygmy-owl is most closely related to Austral and Peruvian pygmy-owls, which were formerly considered subspecies, in part, of the ferruginous pygmy-owl. Nonetheless, currently there are as many as fifteen subspecies of ferruginous pygmy-owl recognized over the entire range, with the cactus ferruginous pygmy-owl being the northernmost subspecies (Proudfoot *et al.* 2020). The subspecies *cactorum* is the subject of this SSA and was originally described in the United States as being common in the lower Rio Grande Valley in southern Texas (Oberholser 1974, p. 452) and along the Salt and Gila Rivers in central Arizona (Fisher 1893, p. 199; Breninger 1898, p. 128; Gilman 1909, p. 148).

Questions remain regarding the species status of several taxa in the *brasilianum* group. Proudfoot *et al.* (2006a and 2006b, entire) proposed splitting *Glaucidium brasilianum* into two species based on mitochondrial DNA analysis and phylogeography. The researchers observed that populations in Arizona, Texas, and Mexico are genetically distinct from populations in South America: they share no mitochondrial haplotypes, and have evidently no gene flow with South American populations (Proudfoot *et al. 2*006a, entire; Proudfoot *et al. 2*006b, entire). Similarly, Heidrich *et al.* (1995, p. 25) and König *et al.* (2009) separate all North American taxa (south to northwestern Colombia) as *Glaucidium ridgwayi* (Ridgway's pygmy-owl), "on the basis of DNA evidence and vocalizations".

When FWS listed the pygmy-owl as endangered in 1997 (62 FR 10730; March 10, 1997), and in all subsequent regulatory and legal actions, we used the currently accepted taxonomic classification, *Glaucidium brasilianum cactorum*, and distribution of this subspecies as published by the American Ornithological Union (AOU), now American Ornithological Society (AOS), the recognized authority on avian taxonomy. Groups classified within species, such as subspecies, are important in the discussion of biodiversity because they represent the evolutionary potential within a species. Recognizing this, a number of existing lists of threatened, endangered, or special status species include subspecific groups (Haig *et al. 2*006, p. 1585). However, the AOS does not currently recognize subspecies in their published lists. The current AOS taxonomic classification of the *cactorum* subspecies is from the 1957 AOU Checklist (AOU 1957).

We considered *G. b. cactorum* to occur from lowland central Arizona south through western Mexico to the Mexican states of Colima and Michoacán, and from southern Texas south through the Mexican states of Tamaulipas and Nuevo Leon, consistent with most of the contemporary literature (Johnsgard 1988, p. 159; Millsap and Johnson 1988, p. 137; Johnson *et al. 2*003, pp. 389 – 390; Proudfoot *et al. 2*020, p. 3), and the last American Ornithologist Union (AOU) list that addressed avian classification to the subspecies level (AOU 1957). In 2009, the Committee on Classification and Nomenclature on North and Middle American birds (the Checklist Committee) of the AOU, now AOS, considered a proposal to separate *Glaucidium ridgwayi* as a distinct species, but rejected that proposal, citing the need to wait for additional work (AOU 2009). The issue has not been considered again by the AOS since 2009 and we are not aware of any new sampling or genetic information that would settle the issue of the taxonomic classification of the pygmy-owl.

The most recent genetic analysis related to the cactus ferruginous pygmy-owl was completed by the Arizona Game and Fish Department in 2021. This additional genetic information continues to show that there is genetic connectivity between the pygmy-owls in the Sonoran Desert (Arizona and northern Sonora) and the rest of the pygmy-owl population to the south (western Mexico) and that genetic differentiation amongst pygmy-owls sampled is as a result of isolation by distance, rather that geographic isolation (Cobbold et al. 2022b, entire). Thus, we do not yet have enough information to say whether pygmy-owls at the far ends of their distribution (Texas and Arizona) represent different subspecies, but the work by Cobbold et al. (2022b, entire) suggests there is likely to some degree of genetic similarity that can contribute to redundancy between the eastern and western populations of the pygmy-owl where they are closest to each other (Transvolcanic Belt region of Mexico).

Following delisting of the pygmy-owl in 2006, the FWS was petitioned to relist the pygmy-owl (CBD and DOW 2007). The petitioners requested a revised taxonomic consideration for the pygmy-owl based on Proudfoot *et al.* (2006a, p. 9; 2006b, p. 946) and König *et al.* (1999, pp. 160, 370–373), classifying the northern portion of *Glaucidium brasilianum*'s range as an entirely separate species, *G. ridgwayi*, and recognizing two subspecies of *G. ridgwayi*—*G. r. cactorum* in western Mexico and Arizona and *G. r. ridgwayi* in eastern Mexico and Texas. Other recent studies proposing or supporting the change to *G. ridgwayi* for the northern portion of *G. brasilianum's* range have been published in the past 20 years (Navarro-Sigüenza and Peterson 2004, p. 5; Wink *et al. 2*008, pp. 42 – 63; Enríquez *et al. 2*017, p. 15).

From a historical perspective, taxonomic nomenclature for the pygmy-owl has changed over time. Originally called *Glaucidium ferrugineum* in 1872 by Coues (Coues 1872, p. 370), the pygmy-owl has also been known as *G. ferrugineus* (Aiken 1937, p. 29) and *G. phalo(a)enoides* (Fisher 1893, p. 199; Gilman 1909, p. 115, Swarth 1914, p. 31; Kimball 1921, p. 57). Since the 1920's, the pygmy-owl has been classified as *G. brasilianum* (van Rossem 1937, p. 27; Bent 1938, p. 435; Peters 1940, p. 130; Brandt 1951, p. 653; Sutton 1951, p. 168). We will focus our discussion at the subspecies level since the scope of our analysis is at the subspecies level of classification.

A number of subspecies of *G. brasilianum* have been described or suggested (Proudfoot and Johnson 2000, p. 4; Friedmann *et al. 1*950, pp. 145-147), including various descriptions of a *cactorum* subspecies. With regard to existing literature, van Rossem (1937, pp. 27–28) gave the earliest description of the *cactorum* subspecies. This was a newly described subspecies of ferruginous pygmy-owl and was described from a "giant cactus grove between Empalme and Guaymas…Sonora, Mexico" (van Rossem 1937, p. 27). Van Rossem restricted this new subspecies to northwestern Mexico and Arizona. Van Rossem also included a more southern and eastern subspecies, *ridgwayi*, that was described as occurring in southern Mexico and central America, but also Texas (van Rossem 1937, pp. 27-28). He specifically excluded the Texas population from *cactorum*, about which he wrote "they approximate very closely the measurements and tail characters of *cactorum* … in color they are best referred to *ridgwayi*" (van Rossem 1937, pp. 27–28; italics added). The 1944 AOU checklist accepted this classification and described its distribution as southern Arizona to Nayarit, in western Mexico (AOU 1944, p. 50). However, in a later publication van Rossem (1945, p. 111) indicated that *cactorum* extended only to the Sonora and Sinaloa border in Mexico, perhaps excluding Nayarit, because his 1937 publication indicates that the specimen from Nayarit was not typical (van Rossem 1937, p. 28). Karalus and Eckert (1974, p. 223) give a southern distribution for *cactorum* of western and northwestern Sonora. Proudfoot, *et al.* (2006a, p. 9; 2006b, p. 7) indicate the state of Sinaloa is the southern extent of the range, while König *et al.* (1999, p. 373) extend the distribution of *cactorum* into Nayarit and Jalisco in western Mexico. Freethy (1992, p. 121) simply states that western Mexico is the southern limit of *cactorum*. Clements (2007, p. 171) recognizes the *cactorum* subspecies, but gives no distribution.

The chronology described in the previous paragraph, which excludes the currently accepted distribution of *Glaucidium brasilianum cactorum* per the AOS, indicates there is inconsistency regarding the southern extent of the subspecies. With the exception of van Rossem (1937, pp. 27-28), who uses morphological characteristics to describe the subspecies, most of the above descriptions of the *cactorum* subspecies do not indicate why they have ascribed the subspecies to the ranges indicated in these publications. König *et al.* (1999, p. 373) simply uses the morphological characters of van Rossem (1937, pp. 27-28). König *et al.*(1999, entire) and Proudfoot *et al.*(2006a; 2006b, entire) do classify *cactorum* based on genetic data, but draw different conclusions with regard to the southern boundary of the subspecies' distribution. The incremental southward extension of the various *cactorum* ranges may provide some support for the idea of a clinal pattern of differentiation in which genetic and morphological differences occur in an incremental manner, as opposed to more abrupt changes that are more likely to represent a boundary between two distinct subspecies groupings. The uncertainty of the southern boundary would suggest that additional sampling is needed to refine this portion of the range of *cactorum*.

As discussed above, as we evaluated the cactus ferruginous pygmy-owl's current status, we found that, although there is genetic differentiation at the far ends of the pygmy-owl's distribution represented by Arizona and Texas, there continues to be uncertainty with regard to how this pattern is represented in the southern portion of the range. This area represents the boundary between the two proposed subspecies, which raises the question of whether there is adequate data to support a change in species classification and define the eastern and western distributions as separate subspecies as proposed by Proudfoot et al. (2006a, entire; 2006b, entire). The AGFD did completed additional pygmy-owl genetic sampling in the southern portion of the pygmy-owl's range in Mexico in 2022 (Cobbold et al. 2022b, entire). This work did not collect samples far enough south into southern Mexico and Central America to resolve the proposed taxonomic change of Proudfoot et al. (2006a, entire; 2006b, entire), but it did confirm that genetic differentiation does occur across the range of what is currently classified as the subspecies *cactorum*, and that this pattern of differentiation is the result of isolation by distance (Cobbold et al. 2022b, entire). Additionally, this updated analysis and additional genetic sampling did seem to answer the question of whether the Transvolcanic Belt of Mexico at the southern end of the pygmy-owl's range presents a barrier to gene flow across this area. Based on additional sampling conducted specifically in the area of the Transvolcanic Belt, an area hypothesized to be a potential barrier to movement and gene flow, pygmy-owl samples collected north and south of, as well as within, the Transvolcanic Belt clustered in a single genetically related group (Cobbold et al. (2022b, p. 16). This suggests a high degree of gene flow between these population groups. Consequently, their results suggest that the Mexican Transvolcanic Belt does not represent a dispersal barrier to pygmy-owl population groups located on either side of the geological feature within those areas they sampled. Additionally, genetic differentiation followed a pattern of isolation by distance, a model under which the strongest differences in genetic structure are expected to occur at the extremities of a species' or subspecies' range (Cobbold et al. 2022b, p. 15). Between the extremities, there is gradual genetic differentiation, rather than abrupt changes, across the range. Sudden changes would be more likely to represent dispersal barriers, and therefore boundaries between different genetic groupings. Although these datasets show that there are genetic differences across the range of the pygmy-owl, they do not resolve whether there is adequate genetic differentiation along the gradient from Arizona to Texas to warrant the taxonomic changes recommended by Proudfoot et al. (2006a, entire, and 2006b, entire). In particular, sample sizes in the southern portion of the range remain low. Samples in this portion of the range are critical to determining if there are indeed two distinct subspecies of pygmy-owl.

In addition to reviewing historical and current descriptions of the subspecies, in 2008 we requested review and input on the issue of taxonomic classification of the petitioned entity from 10 individuals with biological expertise and background in this issue. Of the 10 we consulted, five provided comments on specific questions we asked regarding the issues of taxonomic classification, genetic differentiation, and genetic diversity based on recent and historical studies and publications related to pygmy-owl taxonomic classification. Information submitted by all five experts indicated that there is insufficient information regarding how to definitively describe this subspecies. Additional work is needed to clarify the distribution of the subspecies, especially in regards to the southern boundary (Voelker 2008, pers. comm.; Cicero 2008, pers. comm.; Robbins 2008, pers. comm.; Oyler-McCance 2008, pers. comm.; Dumbacher 2008, pers. comm.).

Proudfoot and his fellow authors (Proudfoot *et al. 2*006a; 2006b), similar to the authors of many other publications related to pygmy-owl taxonomy, pointed out the need for additional work to clarify the taxonomic classification of pygmy-owls. Therefore, when we consider the recent information provided by Proudfoot *et al.*(2006a, pp.; 2006b, entire) and König *et al.*(1999, entire), in combination with the historical descriptions of distributions for the subspecies *cactorum*, there is evidence of a general nature that reclassification of this subspecies may have merit. However, after reviewing the best available information, we find that uncertainty and inconsistency exists with regard to the delineation of the range of these subspecies.

The peer reviewers who provided information to the FWS regarding this issue represent respected experts with considerable knowledge of the current science regarding avian taxonomy and classification. They point out that a combination of factors, including morphological, vocal, and genetic, need to be considered in greater depth, with additional sampling and analysis of existing samples, to determine if the petitioned taxonomic classification should be accepted, and we are in agreement with these comments. Given the uncertainty and lack of clarification found in the best available scientific and commercial information, we rely on the "biological expertise of the Department and the scientific community concerning the relevant taxonomic group" (50 CFR 424.11(a)) and the "standard taxonomic distinctions (50 CFR 424.11(a)).

In summary, we find that, although there is genetic differentiation found at the far ends of the pygmy-owl's distribution represented by Arizona and Texas, there continues to be uncertainty in the southern portion of the range where the boundary between the two subspecies is likely to exist which raises the question of whether there is adequate data to support a change in species classification and define the eastern and western distributions as separate subspecies. While future work and studies may clarify and resolve these issues, we follow current FWS policy and procedures and we will continue to use the currently accepted distribution of *G. brasilianum cactorum* as described in the 1957 AOU checklist and various other publications (Johnsgard 1988, p. 159; Millsap and Johnson 1988, p. 137; Oberholser 1974, p. 452; Friedmann *et al. 1*950, p. 145). Figure 1.1 in the previous chapter shows the distribution of the pygmy-owl based on the taxonomic classification used in this SSA.

A detailed summary of the taxonomy of the pygmy-owl is described by Integrated Taxonomic Information System (ITIS). The ITIS is a partnership of United States, Canadian, and Mexican agencies, as well as other organizations and taxonomic specialists. The partnership provides authoritative taxonomic information on plants, animals, fungi and microbes of North America and the world.

The currently accepted classification (ITIS 2020) is:

Kingdom: Animalia

Subkingdom: Bilateria

Infrakingdom: Deuterostomia

Phylum: Chordata

Subphylum: Vertebrata

Infraphylum: Gnathostomata

Superclass: Tetrapoda

Class: Aves, birds

Order: Strigiformes (owls)

Family: Strigidae (typical owls)

Subfamily: Surniinae

Genus: Glaucidium F. Boie. (pygmy-owls)

Species: *Glaucidium brasilianum* J.F. Gmelin. (ferruginous pygmy-owls)

Subspecies: *Glaucidium brasilianum cactorum* van Rossem.

2.2. Genetic Composition and Diversity

In this section we review available information on the genetic composition and diversity in cactus ferruginous pygmy-owls in North America. Pygmy-owls in North America (Mexico, Texas, and Arizona) are phylogenetically distinct from those in Central and South America and, as discussed above, potentially warrant designation as a separate species (Proudfoot *et al. 2*006a, p. 9; Proudfoot *et al. 2*006b, entire). Furthermore, based on mitochondrial DNA (mitochondrial cytochrome *b* gene) and 11 microsatellite loci, there is evidence that pygmy-owls in Arizona, Sonora, and Sinaloa are genetically distinct from those in Texas and eastern and southern Mexico (Proudfoot *et al. 2*006a, entire; Proudfoot *et al. 2*006b, entire). These differences potentially are a product of a relatively recent northward expansion of the range of pygmy-owls with the Sierra Madre Occidental and the Sierra Madre Oriental serving as barriers to gene flow between eastern and western Mexico (Proudfoot *et al. 2*006a, p. 9). Initially, there was also some evidence of restricted gene flow between owls in Arizona and Sonora, and those in Sinaloa (Proudfoot *et al. 2*006b, p. 953), but additional sampling indicated that these populations are not distinct (Proudfoot 2021, pers. comm.).

Pygmy-owls in Arizona and Sonora show evidence of a recent genetic bottleneck (probably because of low numbers), but have maintained a significant level of genetic variability; heterozygosity of owls in Arizona was similar to levels estimated for owls in Mexico and Texas (Proudfoot *et al. 2*006b, p. 953). Overall, pygmy-owls in the United States and Mexico have average to high levels of genetic diversity, when compared to other non-migratory species of birds, and most variation is within populations (Proudfoot *et al. 2*006b, pp. 952–953). The lack of variation among pygmy-owl populations suggests considerable gene flow between populations in the United States and Mexico. But, if these populations are isolated from one another, the lack of among-population variation could be explained if the isolation was recent (Proudfoot *et al. 2*006b, p. 952), or if the populations in the United States were from a common source (Williams *et al. 2*002).

In general, patterns of gene flow for the pygmy-owl indicate genetic variation resulted from isolation-by-distance. Under this scenario, individuals are spatially distributed across their range with limited dispersal among geographic regions. Thus, allele frequencies vary gradually throughout the range, which accounts for the low levels of among-group variation and the mixed membership in multiple groups revealed from cluster analysis (Proudfoot 2006a, p. 7; Proudfoot 2006 b, p. 953). There is evidence of distinct groupings of individuals from Texas and the region of Oaxaca, Tabasco, and Veracruz. Data also suggest rather limited exchange between peripheral populations and the core populations in south-central Mexico. Results from Proudfoot *et al.* (2006b, p. 953) may indicate a significant expansion of the Texas population group (multiple breeding pairs of pygmy-owls within relatively discreet geographic areas) since it split from the source population group in Mexico. The Texas population groups are separate from the Mexico population groups as evidenced by range fragmentation with restricted gene flow and isolation-by-distance between the Texas population groups and the population groups in south-central and southeast Mexico. Additional evidence for restricted gene flow between Texas and population groups to the south in Mexico is provided from the disproportionate number of private alleles, with Texas having more than twice as many as the combined population groups of south-central and southeast Mexico. Evidence from pygmy-owl allele frequencies in the

Arizona-Sonora, Sinaloa, and Texas appear to genetically differentiate them from the rest of Mexico (Proudfoot *et al. 2*006b, p. 953).

Genetic differences between owls in Arizona-Sonora-Sinaloa, and south western Mexico (western population) and those in Texas and eastern Mexico (eastern population), combined with some differences in threats to pygmy-owls and their status in these regions, dictate that they be considered separately in assessing their status and in the development of management plans (Proudfoot *et al. 2*006a, pp. 9-10; Proudfoot *et al. 2*006b, pp. 953– 954). Differences in management and protection across the international border with Mexico make it reasonable that pygmy-owl population groups in both Arizona and Texas also be considered separately when assessing their status and in the development of conservation or management plans. It is also important to point out that, particularly in the northern portion of the geographic range, pygmy-owls function similar to metapopulations and are dependent upon exchange of individuals to provide genetic diversity and to "rescue" population groups that may decline or are extirpated due to various causes discussed later in this document.

2.3. Morphology

The cactus ferruginous pygmy-owl is a small bird (see Figure 2.1), approximately 17 centimeters (cm) (6.75 inches (in)) long. Generally, male pygmy-owls average 58 grams (g) to 66 g (2.0 to 2.3 ounces (oz)) and females average 70 g to 75 g (2.4 to 2.6 oz) (AGFD 2008b, pers. comm.; Proudfoot and Johnson 2000, p. 16; Johnsgard 1988, p. 159).

Figure 2.1 Nestling pygmy-owl on finger showing size of this owl (photo credit: Glenn Proudfoot)

The pygmy-owl is reddish brown overall, with a cream-colored belly streaked with reddish brown. Color may vary, with some individuals being more grayish brown (Proudfoot and Johnson 2000, pp. 15–16). The crown is lightly streaked, and a pair of dark brown or black spots outlined in white occurs on the nape, suggesting "eyes," leading to the name "Cuatro Ojos" (four eyes), as it is sometimes called in Mexico (Oberholser 1974, p. 451) (Figure 2.2). The species lacks obvious ear tufts (Santillan, *et al. 2*008, p. 154), and the eyes are yellow. The tail is relatively long for an owl and is reddish brown in color, with darker brown bars. Males have pale bands between the dark bars on the tail, while females have darker reddish bands between the dark bars (Figure 2.3). Pygmy-owls have relatively large feet and talons (Figure 2.4).

Figure 2.2 Adult male pygmy-owl showing "eyes" on the back of the head (photo credit: Glenn Proudfoot)

Figure 2.3 Adult male (left) and adult female (right) pygmy-owls showing sexual dimorphism related to feather/tail coloration (photo credit: Glenn Proudfoot)

Figure 2.4 Hatch-year pygmy-owl showing large feet and talons (photo credit: Dennis Abbate)

Overall, juveniles are similar to adults but are distinguished for the first few weeks by their shorter tails and by well-contrasted white, tear-drop-like feather ends that form a broken line running from shoulder to rump when the birds are perched. Other characteristics of fledglings include lighter, less distinct eye patches on the nape, the lack of buff on their crowns, and more white on their underparts (Cartron *et al. 2*000, p. 7). Fledglings in Arizona also exhibit a more chocolate brown color, lacking any real rufous coloration except on their tails (Abbate *et al. 1*996).

2.4. Life History

Daily Activity

Regardless of the season, the pygmy-owl is primarily diurnal (active during daylight) with crepuscular (active at dawn and dusk) tendencies. Pygmy-owls are typically inactive during the middle of the day and the middle of the night, although on nights with a full or nearly-full moon, they will remain active at night while the moon is visible similar to some other owls (Flesch and Steidl 2007, p. 36; Takats and Holroyd 1997, p. 427). Schaldach (1963, p. 40) indicated that pygmy-owls respond vocally on moonlit nights, although they will rarely fly or otherwise change their positions at night. However, Proudfoot *et al.* (2020, unpaginated) and our observations indicate that pygmy-owls can be active during the night as observed in nest box video recordings and during netting activities. Daily weather conditions and breeding season chronology can also influence daily activities. However, studies of daily time budgets are limited and Proudfoot *et al.*(2020) suggest that further analysis is needed to determine exactly what correlations exist with regard to night activity and moon phase, as well as to clarify activity tendencies (i.e., diurnal, nocturnal, crepuscular).

Because of its small size, long tail, and atypical diurnal and crepuscular behavior, the pygmy-owl may easily be mistaken for a passerine. When agitated, it perches with its tail cocked upward or jerks its tail up and down and from side to side (Proudfoot *et al. 2*020, unpaginated).

Home Range and Territories

Data on pygmy-owl home range and territory size are limited. However, a number of studies have presented such data, although sample sizes and methods used are not consistent and we acknowledge that sample size and estimator approach can greatly influence estimates. The following reports the best available information with regard to pygmy-owl home range and territory sizes.

Proudfoot (1996) indicated that pygmy-owls may show seasonal variation in areal use (i.e., size of areas used while monitored) and habitat association. In Texas, information obtained from 10 radio-tagged adult males tracked from incubation to dispersal of young (i.e., 3 Apr-12 Aug) and from three males tracked after dispersal (i.e., 16 Sep-26 Nov 1994) showed a 3.4-fold increase in mean areal use between nesting and post-nesting males. In addition, areas used during nesting contained considerably more understory than areas used after nesting. These variations in areal and habitat use may be attributed to seasonal alterations in prey abundance and to parental care; as summer changes to fall, declining numbers of prey may require a larger foraging area. Increased understory also likely improves access to escape and concealment cover for fledglings.

In Texas, areal use by nine radio-tagged adult males, monitored from approximately one week before incubation to approximately one week after, ranged from 1.3 to 23.1 hectares (ha) (3.2 to 57.1 acres (ac); 15–42 coordinates); one unmated adult male used 110 ha (271.8 ac) during same time period (37 locations). From fledging-dispersal of young, five radio-tagged families (i.e., two adults [one male, one female] and three fledglings/family) used 9.3, 13.7, 16.9, 36.7, and 59.5 ha (22.9, 33.8, 41.7, 90.7, and 147.0 ac; 46, 58, 126, 117, and 125 coordinates recorded). One hatch-year young and two adult males monitored from October to November used 19.6, 72.8, and 116.4 ha (48.4, 179.9, and 287.6 ac), respectively (10–27 locations recorded). In Arizona, pygmy-owls monitored during nesting used from 2-20.2 ha (5-50 ac), and an unpaired male used approximately 87.8 ha (217 ac) (Abbate *et al. 1*999).

In Texas, males defended 350-600 meter (m) (382.7 – 656.1 yards (yds)) radii throughout year, possibly for the life of the pair bond (Proudfoot and Beasom 1996); neighboring territories did not overlap during incubation through dispersal of young; areas used after dispersal did overlap (Proudfoot 1996).. In southwestern Arizona, radii of year-round territories was about 160 m (174.9 yds) (Hensely 1954), but territory shape ranged from circular to nearly triangular. All territories were centered on large desert washes. Unmated males may establish territories with floating core areas of 100-150 m (109.3-164.0 yds) radii (Tibbitts 2000, pers. comm.). Flesch (2003, p. 153) also found the territories contained one or more linear strands of xeroriparian woodland vegetation. His study in the Altar Valley of southern Arizona documented that the average area used by nesting pygmy-owls was 21.9 ha and ranged from 9.9 ha to 4.3 ha (calculated using MCP). In Arizona and Texas, territory boundaries may be established at first breeding (Proudfoot *et al. 2*020, unpaginated).

Flesch and Steidl (2007, p. 25) found that the nesting territory size of male pygmy-owls that successfully nested averaged 27.4 ha (95% MC) and 37.1 ha (100% MCP) in northern Sonora. They also documented that the average greatest distance a male pygmy-owl would move from its active nest site was 712 meters and ranged from 375 meters to 1,156 meters.

Closest nests in Texas were 741 m (810.3 yds) apart (n = 44). In Arizona in 1998, distance between nests (n = 3) averaged 4.38 kilometers (km) (2.7 miles (mi)) and distance between territory centers of unpaired pygmy-owls (n = 6) averaged 3.3 km (2.0 mi) (Abbate *et al. 1*999, p. 20). We are aware of additional, more recent, unpublished data held by AGFD and FWS for nest sites in Arizona and these data from subsequent years in Arizona, if analyzed, would likely decrease these average distances between nests and territories, but that analysis has not been completed. However, recent pygmy-owl survey work associated with the Pima County Multispecies Conservation Plan documented pygmy-owl nests 570 m, 595 m, 615 m, and 735 m apart (Flesch 2018a, p. 10).

In northern Sonora, spacing between neighboring pygmy-owl nests averaged just over 1000 m., with a range of 308 – 2126 m., but such spacing decreased for nests in areas of northern Sonora that were further east and south. Interestingly, the density of saguaros had no effect on nest spacing, but spacing between nests decreased as vegetation volume increased (Flesch and Steidl 2010, p. 1028).

Migration

Pygmy-owls are considered nonmigratory throughout their range. There are winter (November to January) pygmy-owl locations from throughout their historical range in Arizona (University of Arizona 1995, pp. 1–2; Snyder 2005, pers. comm.; Abbate *et al. 1*999, pp. 14–17; 2000, pp. 12–13) and also in Texas (Proudfoot 1996, p. 19; Mays 1996, p. 14). These winter records suggest that, while the area used by pygmy-owls may change seasonally, pygmy-owls are found within their home ranges throughout the year and that they do not migrate seasonally. Although pygmy-owls in Arizona do not appear to migrate, dispersing juveniles can make significant movements (e.g., from 2-50 km; Abbate *et al. 1*999; AGFD 2000, unpubl. data). Such movements are particularly important in areas of the pygmy-owl's range that function similar to metapopulations.

Prey

Pygmy-owls are known as fierce hunters capable of killing prey twice their own size (Terres 1991, Sick 1993). Early accounts describe the cactus ferruginous pygmy-owl attacking young chickens and adult birds the size of robins (Breninger 1898, Bent 1938, Johnsgard 1988). In Arizona, this owl was observed killing mourning doves (*Zenaida macroura*) and large desert spiny lizards (*Sceloporus magister*) (Abbate *et al. 1*999, pp. 35 – 40). In Texas, it feeds on large prey such as eastern meadowlarks (*Sturnella magna*) and hispid cotton rats (*Sigmodon hispidus*) (Proudfoot and Beasom 1997).

Hunting behavior generally consists of sudden perch-to-prey strikes; however, pygmy-owls also hunt by inspecting tree and saguaro cavities for other nesting birds, and possibly bats. Aerial capture of winged prey (e.g., birds and bats) is unknown. Flight is considerably noisier than most other owls, which is generally considered "silent". Ears are symmetrical, hence, vision must play a pivotal role in acquiring food (Proudfoot *et al. 2*020, unpaginated).The pygmy-owl is largely a generalist predator. Oberholser (1974, p. 451) indicated that the pygmy-owl's diet included lizards, large insects, rodents, and birds (some as large as or larger than the owl itself). In Texas, insects, reptiles, birds, small mammals, and amphibians, to a lesser extent, are eaten by pygmy-owls (Proudfoot and Johnson 2000, p. 6). In Arizona, reptiles, birds, small mammals, and insects have all been recorded in the diet of the pygmy-owl (Abbate *et al. 1*999, pp. 35–40). Seasonal and annual variations in diet occur throughout its range (Proudfoot and Johnson 2000, p. 6; Abbate *et al. 1*999, pp. 35–40). The pygmy-owl is an opportunistic predator: it takes advantage of seasonal opportunities such as the emergence of insects or the presence of nestlings in nearby nests (Abbate *et al. 1*996). After a meal, the owl may cache prey remains in a tree, cavity, or ball of mistletoe (*Phoradendron* sp.) (Sprunt 1955, Abbate *et al. 1*996, Proudfoot 1996). See Proudfoot and Beasom (1997) and Abbate *et al.* (1999) for a more detailed description of the documented prey items of the pygmy-owl.

Mobbing

The pygmy-owl is referred to as the "terror of small birdlife" (Sprunt 1955). Thus, it is not surprising that this owl is commonly mobbed (harassed) by a wide variety of other bird species (Gilman 1909, Sutton 1951, Sprunt 1955), presumably in response to being a regular predator on those species (Proudfoot and Johnson 2000, p. 10; Abbate *et al. 1*999, pp. 25–26; Hunter 1988, p. 1). The mobbing behavior of birds can often aid in locating a well-hidden pygmy-owl, as multiple individuals and species will often participate in the mobbing and identify the perch of the pygmy-owl. The dark eye-spots on the back of the pygmy-owl's head appear to result in avian mobbers making fewer close passes to the back of the pygmy-owl, potentially protecting the pygmy-owl from attacks from the back by mobbers (Deppe, *et al. 2*003, pp. 769-770).

Predation

Due to their small size and occurrence in similar habitats as many of their predators, pygmy-owls are preyed upon by a variety of species. Documented and likely predators in Texas and Arizona include raccoons (*Procyon lotor*), great horned owls (*Bubo virginianus*), Cooper's hawks (*Accipiter cooperii*), Harris' hawks (*Parabuteo unicinctus*), Western screech owls (*Megascops kennicottii*), bull snakes (*Pituophis catenifer sayi*), and domestic cats (*Felis domesticus*) (Abbate *et al. 1*999, p. 27; Proudfoot and Johnson 2000, p. 10). Pygmy-owls may be particularly vulnerable to predation and other threats during and shortly after fledging (Abbate *et al. 1*999, p. 50).

In Texas, evidence at nest sites (i.e., lack of egg shell remains and nest site disturbance) suggest snakes are a main nest predator of pygmy-owls in this region (Proudfoot 1996, p. 72). Using chemoreception, snakes cue in on the odors of fecal matter, and possibly prey remains, that emanate from the nest (Savidge 1987). In Tamaulipas, Mexico (where pygmy-owls occur), Enkerlin-Hoeflich *et al.* (1993) recorded indigo snake (*Drymarchon corais*, a species also prevalent in Texas) predation on cavity nesting green-cheeked Amazon parrots (*Amazona viridigenalis*). This information, along with Proudfoot's personal observation of indigo snakes climbing trees in his Texas study area and his observations that a bullsnake (P. c. *sayi*) in Texas regurgitated six nestling pygmy-owls shortly after it was pulled from a nest box, led Proudfoot to conclude that snakes are a primary nest predator of pygmy-owls in Texas (Proudfoot 1996, p. 72; Proudfoot pers. comm., 2003). Such predation of pygmy-owls has not been observed in Arizona, but possible predators in Arizona include climbing snakes such as the coachwhip (*Masticophis flagellum*) and gopher snake (*Pituophis catenifer*) which have been observed climbing saguaros and have the ability to raid nests and take fledglings. Boal *et al.* (1997) documented the depredation of an elf owl nest by a gopher snake in Arizona, indicating nest predation of small, cavity-nesting owls does occur. Coachwhip snakes, a common tree-climbing predator, were observed depredating fledgling pygmy-owls in Sonora, Mexico (Flesch and Steidl 2010, p. 1036). Predation may be a factor driving pygmy-owls to select nest cavities that are higher above ground in saguaro cacti.

Western screech owls are a particular concern as they occur in most areas where pygmy-owls reside (often using saguaro cavities for nests) and have been implicated by anecdotal observations as potential predators throughout southern Arizona. In Texas, observations of nesting Eastern screech owls (*Megascopes asio*) in the same set of three nest boxes where pygmy-owls were found dead have also been documented on several occasions (Proudfoot pers. comm. 2003).

Breeding

Pygmy-owls are thought to be monogamous, can breed in their first year, and typically mate for life. Both sexes appear to breed annually. Pair bonds between females and males can begin to form as early as the fall after they fledge, if mates are available. Males begin to make territorial calls the following early spring (i.e., February), about 2-3 months before egg-laying. A short window of calling activity by pygmy-owls does occur in the fall as well. This may be a physiological response to similar day-length periods as spring, or it may be related to dispersal and is the result of established males warning of dispersing males or dispersing hatch-year males trying to establish territories in vacant habitat. Pygmy-owls have been found to be responsive to survey calls in October in Arizona (Flesch 2018a, pp. 8 – 9).

Nest sites are cavities in trees and columnar cacti (e.g., saguaros) that are excavated by woodpeckers, or form naturally from decay after tree branches break off. Territories normally contain several potential nest and roost cavities from which responding females select a nest. Hence, cavities per acre may be a fundamental criterion for habitat selection. Historically, pygmy-owls in Arizona used cavities in cottonwood, mesquite, and ash trees, and saguaro cacti for nest sites (Millsap and Johnson 1988, pp. 137–138). Current information from Arizona indicates nests are usually located in cavities in saguaro cacti, accounting for all but two of the known nests documented from 1996 to 2020 (n > 50) (Abbate *et al. 1*996, p. 15; 1999, p. 41; 2000, p. 13; AGFD 2003, pers. comm.). Pygmy-owl nests in Texas were primarily in mesquite and live oak trees (Proudfoot 1996, pp. 36–38), and nests in Sonora, Mexico, were nearly always in columnar cacti (Flesch and Steidl 2002, p. 6). Flesch and Steidl (2010, pp. 1025 – 1028) described several different factors influencing pygmy-owl nest site selection, indicating that pygmy-owls used taller saguaros with more arms and more cavities for nest sites; selected nest cavities will small to moderate cavity openings; and selected cavities of larger volume as indicated by stem swelling around the nest cavity. Recent data collected by Phoenix Zoo collected at nest sites in southern Arizona showed that the vertical diameter of nest cavities ranged from 5.1 – 8.9 cm and horizontal diameter ranged from 5.1 – 8.3 cm (Phoenix Zoo, unpublished data). Pygmy-owls will also use nest boxes for nesting (Proudfoot 1996, p. 67). More specific information on suitable nest cavity selection by pygmy-owls is found below in Section 3.1.

Nest selection occurs following courtship, with eggs typically being laid from late March into June. Average clutch size as reported by Johnsgard (1988, p. 162) for the United States and Mexico was 3.3 (range 2 to 5, n = 43). In Texas, Proudfoot and Johnson (2000, p. 11) report an average clutch size of 4.9 (range 3 to 7, n = 58). First eggs hatch generally around mid-May, and fledging occurs from late-May through June. Eggs are white, oval to spherical in shape, and average 28.5 mm in length. The female incubates the eggs for 28 days, and hatching is asynchronous, one hatching every 20-26 hours. The female largely stays in the cavity with the hatchlings for the first week after hatching, while the male provides food. After the first week, both parents provide food. Nestlings fledge between 21 and 30 days after hatching, and depend on their parents for food for up to eight weeks. Data indicate that adults maintain their pair bond following the dispersal of the juveniles (Proudfoot 1996, unpubl. data).

One unique issue related to pygmy-owls' breeding behavior in Arizona is the documented occurrence of incestuous pairings. Color band marking to discriminate individual pygmy-owls confirmed a successful pairing of siblings in 1998. These siblings were hatched the previous breeding season (Abbate *et al. 1*999, p. 53). Incest in raptors is considered rare and its occurrence has been documented in only about 20 cases representing nine species (Carlson et.al. 1998; Stewart *et al. 2*007, p. 227). Four of the seven species are owls and include: barn owls (*Tyto alba*), burrowing owl (*Athene cunicularia*), screech owl (*Otus asio*) and spotted owls (*Strix occidentalis*). Similar dispersal direction and relatively short dispersal distances may play a role in the pairing of siblings (Carlson *et al. 1*998; Stewart et al, 2007, p. 227).

An additional incestuous pairing was revealed while monitoring a male juvenile that was radio-marked after fledging in 1998. Abbate *et al.* (2000, p. 21) documented territory establishment in the fall of the same year. Monitoring efforts in the same area during spring of 1999 indicated that this male had paired with a female and nesting activity was in progress. Observation of the color band on the female owl revealed that she was the sibling of the male with which she was paired. This becomes even more significant when we consider these two owls were the offspring of another incestuous pair that were siblings from a 1998 nest. These unusual pairings may be the result of dispersal behavior or extremely low numbers of available mates within a small population. We also suggest habitat loss, fragmentation and dispersal barriers may influence dispersal of young from certain nest sites, keeping dispersing birds in closer proximity than would ordinarily occur (Abbate *et al. 1*999, p. 53).

Dispersal

Fledglings disperse from their natal sites about eight weeks after they fledge. Observations in both Arizona and northern Sonora indicate that initial dispersal movements are often initiated during the full moon phase closest to the eighth week post-fledging (Flesch and Steidl 2007, p. 36). It appears that the dispersal strategy for males differs from females. Males typically disperse shorter distances, setting up a territory in the first available habitat patch they encounter. Females, on the other hand, typically disperse longer distances and disperse until they find an available mate. This can include movements into subsequent breeding seasons. The first dispersal of fledglings in Arizona and Texas was documented as July 24th and August 14th, respectively (Proudfoot and Johnson 2000, p. 10). Dispersal distance ranges from 2.5 to 20.91

km (1.55 to 13.00 mi) in Arizona (Abbate *et al.* 2000, p. 21) and 16 to 31 km (9.6 to 18.6 mi) in Texas (Proudfoot and Johnson 2000, p. 13). One juvenile female pygmy-owl in Arizona dispersed a total of 260 km (161 mi) between August 2003 and April 2004 (AGFD 2008a, pers. comm.). In Sonora, Mexico, Flesch and Steidl (2007, p. 37) documented dispersal distances ranging from 1.1 to 19.2 km (0.7 to 11.5 mi). Fledglings often travel greater than 1 km (0.6 mi) the first day and have moved up to 1.6 km (1 mi) in a night (Abbate *et al.* 2000). Dispersal is a key factor in maintaining pygmy-owl numbers and occupancy, especially in areas of the pygmy-owl's range that function similar to metapopulations.

Similar to normal daily activities by pygmy-owls, dispersing pygmy-owls appear to fly from tree to tree instead of long flights. However, our observations indicate that dispersing pygmy-owls will sometimes use habitat that is of different or lesser quality that they use to establish territories or for nesting. For example, dispersing pygmy-owls in Arizona have used creosote flats generally lacking trees during dispersal, as well as crossing mountain ranges that exceed 4,000 feet elevation. Dispersing owls in Texas have also dispersed through areas that lack tree cover. Direction of dispersal appears to be random (Proudfoot and Johnson 2000). Once a dispersing male pygmy-owl settles in a territory, they rarely make additional movements. Spring surveys have found male juveniles in the same general location as observed the preceding fall (Abbate *et al.* 2000). However, unpaired female dispersers may make additional movements into the subsequent breeding season (AGFD unpubl. data). Dispersing pygmy-owls appear to be hesitant to cross large busy highways and open fields (Abbate *et al.* 2000, pp. 28 – 29; Flesch and Steidl 2007, entire). Ultimately, pygmy-owl occupancy decreases in areas of increased roadway size and agricultural development (Flesch 2017, p. 5).

Longevity

The average lifespan for a cactus ferruginous pygmy-owl is probably 3 – 5 years (Proudfoot 2009, pers. comm.; AGFD 2009b, pers. comm.). However, lifespan has been documented to be 7 to 9 years in the wild (Proudfoot 2009, pers. comm.) and 10 years in captivity (AGFD 2009b, pers. comm.).

2.5. Habitat

Pygmy-owls are found in a variety of vegetation communities, including Sonoran desertscrub and semidesert grasslands in Arizona and northern Sonora, thornscrub and dry deciduous forests in southern Sonora south to Michoacán, and Tamaulipan brushland in northeastern Mexico and live oak forest in Texas. However, available information regarding specific pygmy-owl habitat elements within these vegetation communities is mostly limited to Arizona, Texas, and northern Sonora.

The pygmy-owl is a creature of edges found in semi-open areas of thorny scrub and woodlands in association with giant cacti, scattered patches of woodlands in open landscapes, mostly dry woods, and evergreen secondary growth (König *et al.* 1999, p. 373). It is often found at the edges of riparian and xeroriparian drainages and even habitat edges created by villages, towns, and cities (Proudfoot and Johnson 2000, p. 5; Abbate *et al. 1*999, pp. 14–23). The pygmy-owl is a secondary cavity nester, and nests occur within woodpecker holes and natural cavities in giant cacti, but also in trees and even in a sand bank (Flesch 2003, pp. 130–132; Proudfoot and Johnson 2000, p. 11; Russell and Monson 1998, p. 141; Johnsgard 1988, p. 162). Tewes (1993, p. 22) contends that status and occurrence of the pygmy-owl is related to the availability of nest cavities.

While native and nonnative plant species composition differs among the various locations within the range of the pygmy-owl, there are certain unifying characteristics such as the presence of vegetation in fairly dense thickets or woodlands; the presence of trees, saguaros, organ pipe cactus (*Stenocereus thurberi*), or other columnar cacti large enough to support cavities for nesting; and elevations typically below 1,200 m (4,000 ft) (Swarth 1914, p. 31; Karalus and Eckert 1974, p. 218; Monson and Phillips 1981, pp. 71–72; Johnsgard 1988, Enríquez-Rocha *et al. 1*993, p. 158; Proudfoot 1996, p. 75; Proudfoot and Johnson 2000, p. 5). Large trees provide canopy cover for predatory avoidance, thermoregulation, nesting cavities, and foraging habitat. Mid- and lower story vegetation provides protection from predators and contributes to the diversity of prey available to pygmy-owls (Wilcox *et al. 2*000, pp. 6–9). The physical settings and vegetation compositions of different areas within the large geographic range of the pygmy-owl often have very little in common. However, the frequent association of pygmy-owls with the described unifying characteristics suggests that vegetation structure is likely more important to this owl than the specific vegetation composition (Carton *et al. 2*000, p. 9).

Defining Analysis Units

The overall geographic range of the pygmy-owl is very large, approximately 140,625 square mi (364,217square km), and covers two countries, the United States and Mexico. Because of its large size, the overall range of the pygmy-owl is quite diverse from social, political, climatic, geographic, and vegetative perspectives. In addition, from a genetic standpoint, although the recent genetic work by Proudfoot *et al.* (2006a, entire and 2006b, entire) has not yet resulted in a revision in the taxonomic classification of the pygmy-owl, additional work may well support a revision. Nonetheless, recent genetic work and taxonomic considerations have provided enough information to indicate there is genetic variation across the currently defined range of the pygmy-owl. In the context of this SSA, we believe it makes sense to divide the overall range of the pygmy-owl into smaller analysis units to facilitate our evaluation of the subspecies’ status. This approach is supported by the following input from past peer reviewers of pygmy-owl documents. In her peer review of FWS’ 2011 12-month review of the pygmy-owl, Cicero (2008, pers. comm.) stated, “On the basis of these data [referring to Proudfoot *et al. 2*006a and 2006b], I would argue that Arizona and Texas populations should be managed as separate units”. Similarly, a second peer reviewer indicates that, “within the United States, it is clear that the Arizona group is much different from the Texas group and should not be considered as one group” (Oyler-McCance 2008, pers. comm.).

Less is known about variation in the pygmy-owl population groups in Mexico, but we do know that the courts have upheld FWS' use of the international border to differentiate social, political and management differences between the United States and Mexico (Nat'l Ass'n of Home Builders v. Norton, 340 F.3d 835, 852 (9th Cir. 2003) ("NAHB II"). In this ruling, the Court supported the well-established propositions that (1) international borders can divide protected and unprotected populations; and (2) the United States can protect endangered populations within its borders even if other populations of the same species are more abundant in other countries (Nat'l Ass'n of Home Builders v. Norton, 340 F.3d 842 (9th Cir. 2003) ("NAHB II").

It is clear from the genetic and taxonomic work completed subsequent to the initial listing of the pygmy-owl in 1997 that the eastern and western portions of the pygmy-owl range differ genetically and should be considered to be separate populations (Koenig *et al.* 1999, pp. 372-373; Navarro-Sigüenza and Peterson 2004, p. 5; Proudfoot *et al.* 2006a and 2006b). This is also consistent with the analysis completed in the original listing decision for the pygmy-owl (FWS 1997, p. 10731). Due to differences in genetics, vegetation communities, geography, management, conservation efforts, status, and threats (Brown 1994, entire; 61 FR 4722 [FWS DPS Policy]; Flesch 2003, pp. 40, 100; Proudfoot *et al.* 2006a and 2006b), we further divided the eastern and western populations of pygmy-owl into five analysis units. The Arizona and Texas analysis units are defined by the international border with Mexico and the extent of available data related to the pygmy-owl. In western Mexico, the Northern Sonora analysis unit is differentiated from the Western Mexico analysis unit based primarily on vegetation communities, but also on types of threats, the status of the pygmy-owl, and available pygmy-owl data. The Northeastern Mexico analysis unit is defined by primarily by the international border, differences in management and status of the pygmy-owl, and the availability of pygmy-owl data. Within this SSA, we use these analysis units to discuss pygmy-owl distribution, abundance, stressors, conservation actions, and assess population-level resiliency (see Figure 1.1).

With regard to the pygmy-owl's life history requirements discussed in this section of the SSA, habitat use varies across its range. Therefore, we use the five analysis units to describe this variation in habitat use and requirements. It is important to understand that the extent of suitable vegetation referred to in our descriptions of the analysis units below refer to just that, vegetation communities that likely contain habitat elements needed by pygmy-owls, and do not define areas of pygmy-owl habitat which contains other factors in addition to vegetation community.

2.5.1. Arizona

In Arizona, pygmy-owls rarely occur below 300 m (1,000 ft) or above 1,220 m (4,000 ft) (Proudfoot and Johnson 2000). Historically, pygmy-owls were documented in cottonwood-mesquite forests and mesquite woodlands along the Gila and Salt rivers and major tributaries (Bendire 1892, Gilman 1909, Johnson *et al.* 1987). Others describe the historical pygmy-owl habitat in Arizona as cottonwood and mesquite riparian woodlands (Bendire 1888, Breninger 1898, Phillips *et al.* 1964) and Sonoran desertscrub (Johnson and Haight 1985).

Currently most pygmy-owls are found in the Sonoran desertscrub communities (as described by Brown 1994) in southern Arizona. These communities include xeroriparian vegetation (dense thickets bordering dry desert washes) consisting of palo verde (*Cercidium* spp.), mesquite (*Prosopis* spp.), acacia (spp.), and saguaro (*Carnegiea gigantean*) (Johnson and Height 1985, Millsap and Johnson 1988) (Figure 2.5), often with ironwood (*Olneya tesota*) (Figure 2.6) and/or exotic landscaping supported by irrigation (Abbate *et al. 1*996). Pygmy-owls are also commonly located in semidesert and Sonoran savanna grasslands with xeroriparian washes (e.g., the Altar Valley). Dominant tree species in riparian areas include mesquite, ash (*Fraxinus* spp.), and hackberry (*Celtis* spp.). Uplands in these areas primarily consist of grasslands with dispersed mesquite trees, and very few, isolated saguaro cacti in some areas. The Arizona analysis unit is comprised of 39% Federal lands, 17% State and Local government lands, 23% Tribal lands, and 21% private lands. Figure 2.8 shows the extent of modeled suitable vegetation for pygmy-owls the Arizona analysis unit.

Figure 2.5 Sonoran desertscrub pygmy-owl habitat in Arizona (Photo credit: George Andrejko, AGFD)

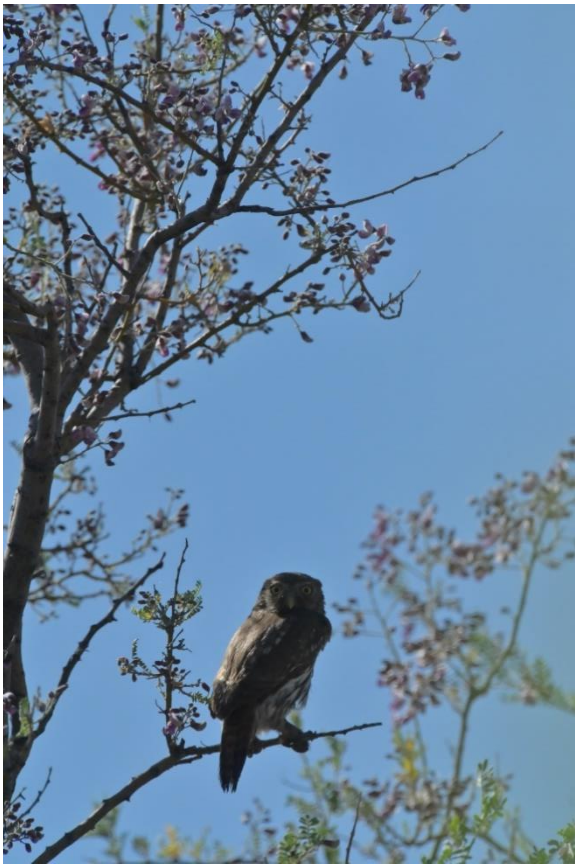


Figure 2.6 Pygmy-owl in a blooming ironwood tree, a key element of pygmy-owl habitat in the Sonoran desert (Photo credit: George Andrejko, AGFD).

2.5.2 Northern Sonora

In Sonora, the pygmy-owl was originally common in the lower Sonoran and Tropical Zones, primarily in giant cactus associations (van Rossem 1945, p. 111). The subspecies is resident throughout most of the desertscrub, tropical thornscrub, and dry subtropical forests of Sonora, being most common in the latter association (Russell and Monson 1998, p. 141). Flesch (2003) reported that pygmy-owls occurred in the greatest numbers and highest frequencies within the Arizona Upland subdivision of Sonoran desertscrub (Figure 2.7). Densities were greatest in the Plains of Sonora and lowest in Sinaloan Thornscrub. Density of owls was relatively high in the central Gulf of California coast, but frequency of occurrence was low. Similar to Arizona, Semidesert Grasslands were second only to Arizona Upland for frequency of occurrence of pygmy-owls. Figure 2.9 shows the extent of modeled suitable vegetation for pygmy-owls found in the Northern Sonora analysis unit.

Figure 2.7. Sonoran desertscrub pygmy-owl habitat in northern Sonora (Photo courtesy of Aaron Flesch).

Approximately 98% of the lands in Mexico are under private ownership. The remaining approximately two percent are a combination of Federal, State, municipal, communal, and indigenous lands, with the latter three being managed similar to private lands (Mesta 2020, p.1). Protected Areas (national parks, biospheres, national monuments, sanctuaries, etc.) make up approximately 9.5% of Mexico's landmass, with only about 25% of these protected areas being publically owned (Mesta 2020, pers. comm.). Protected areas occur in all three of the pygmy-owl analysis units in Mexico, but they make up, at most, just under seven percent of any analysis unit (see Figure 2.15). In Mexico there are federal, state, or municipal protected Natural Areas. These areas can work well as conservation strategies for the pygmy-owl. There is now a new option for protected areas called Voluntary Conservation Areas (Áreas Destinadas Voluntariamente a la Conservación; ADVA) which are areas for conservation and can be a good conservation strategy (https://www.gob.mx/conanp/articulos/areas-destinadas-voluntariamente-a-la-conservacionparticipacion-social-por-el-ambiente-193042) (Enríquez 2021, p. 2).

2.5.3 Texas

In Texas, the pygmy-owl was historically found in *Prosopis* spp., *Ebenopsis ebano* (ebony), and *Arundinaria gigantea* (cane) along the Rio Grande River, and a more general distribution in riparian trees, brush, palm, and mesquite thickets (Oberholser 1974, p. 451). Vegetation associations used by pygmy-owls are also described as coastal-plain oak associations, mesquite bosques, and Tamaulipan thornscrub in south Texas (Tewes 1993; Wauer *et al. 1*993; Mays 1996). It is now found primarily in undisturbed live oak-mesquite forests and mesquite brush, ebony, and riparian areas of the historical Wild Horse Desert north of Brownsville, Texas (Proudfoot and Johnson 2000, p. 5) (Figures 2109, 2.11, 2.12). This important live oak habitat is susceptible to die off during droughts (Crosswhite 1980, p. 171). A unique aspect of the Texas analysis unit is that it is comprised of 98% private lands and only 2% Federal lands. Within the United States, this configuration of land ownership necessitates a different approach to conservation than in the Arizona analysis unit, the majority of which is Federal lands. Figure 2.11 shows the extent of modeled suitable vegetation for pygmy-owls in the Texas analysis unit.

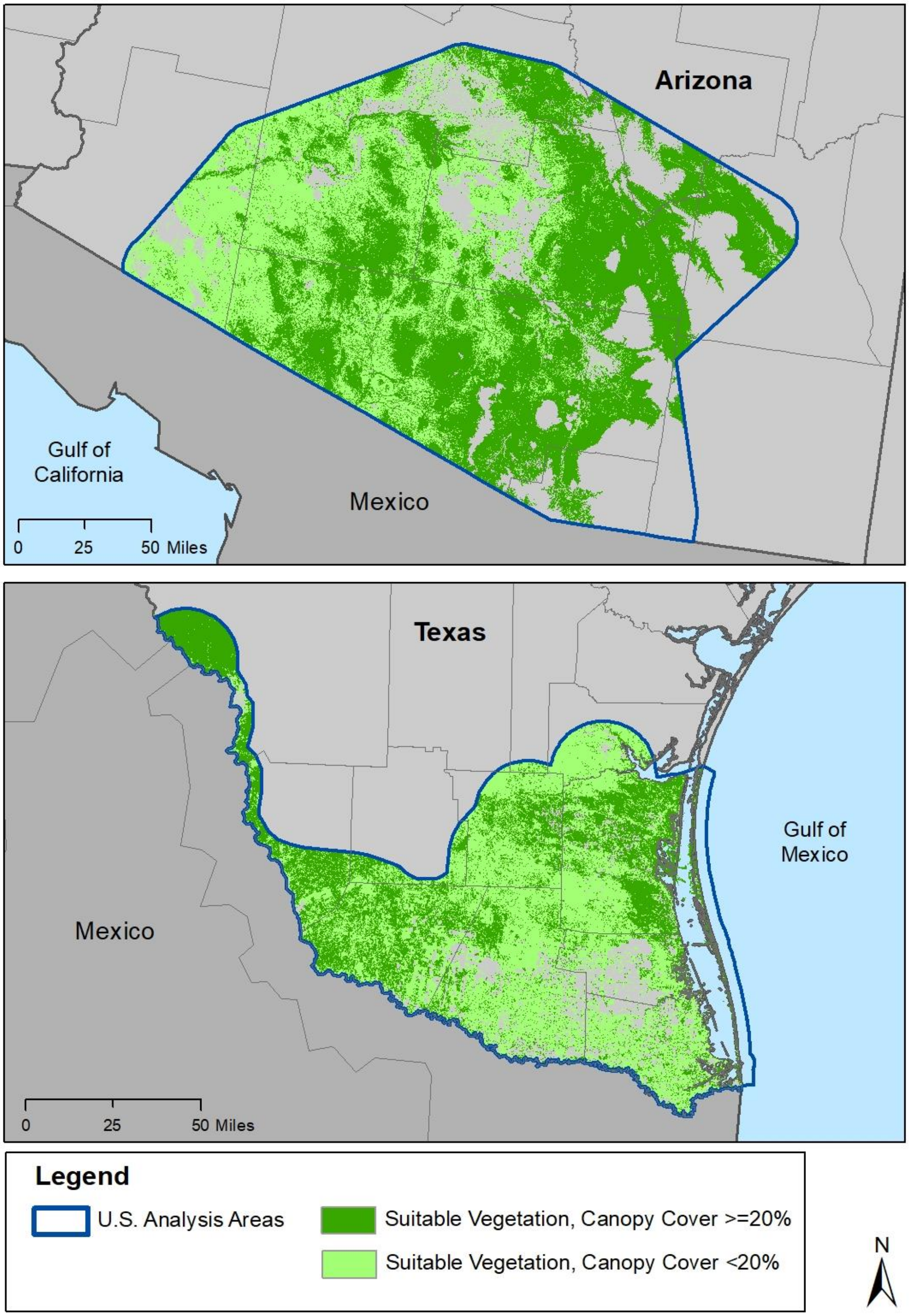


Figure 2.8 Estimated areas of suitable vegetation cover within the Arizona and Texas analysis units.

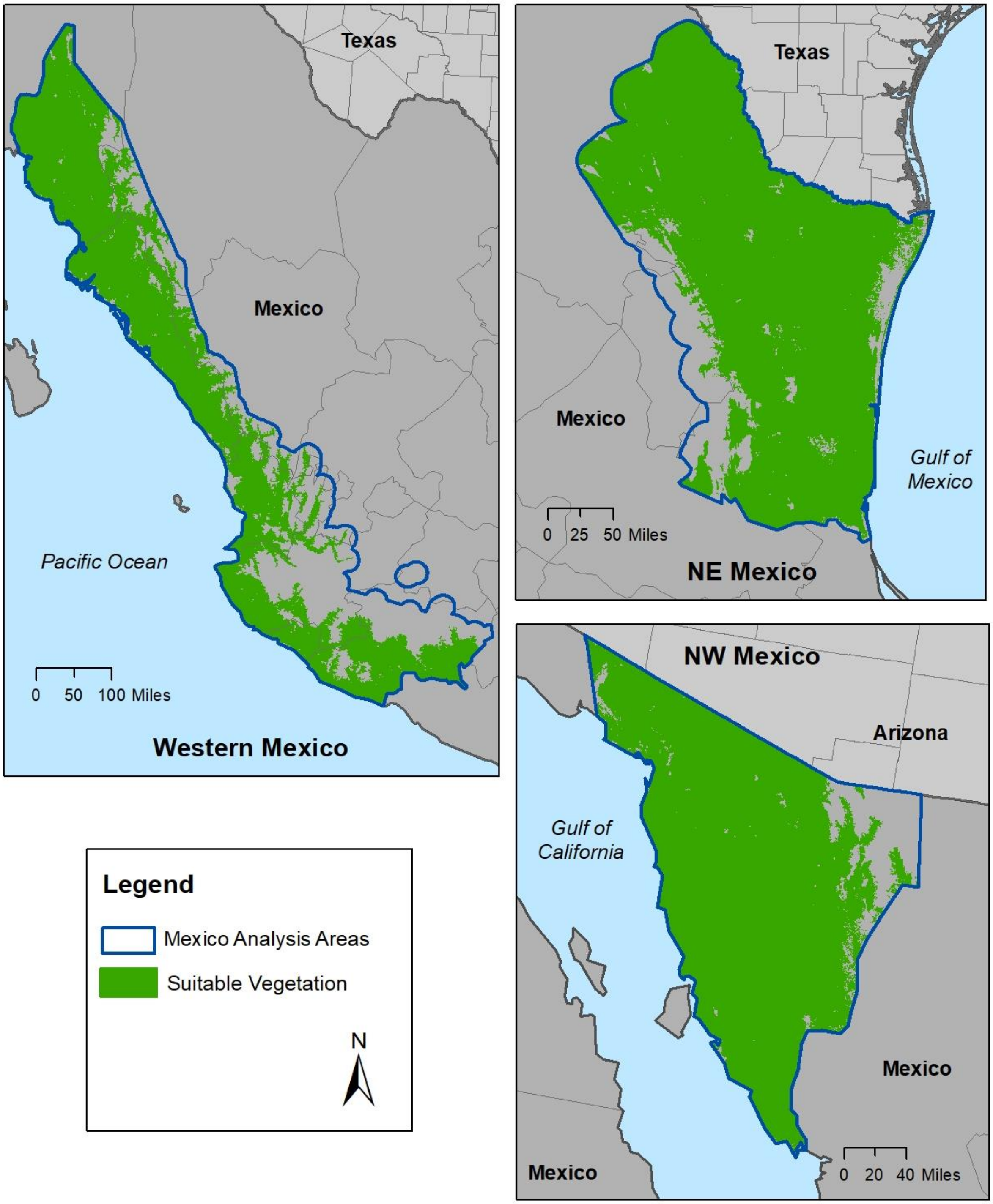


Figure 2.9 Estimated areas of suitable vegetation cover within the Mexico analysis units.

Figure 2.10 Disturbed pygmy-owl thornscrub habitat in Texas. (Photo credit: Glenn Proudfoot)

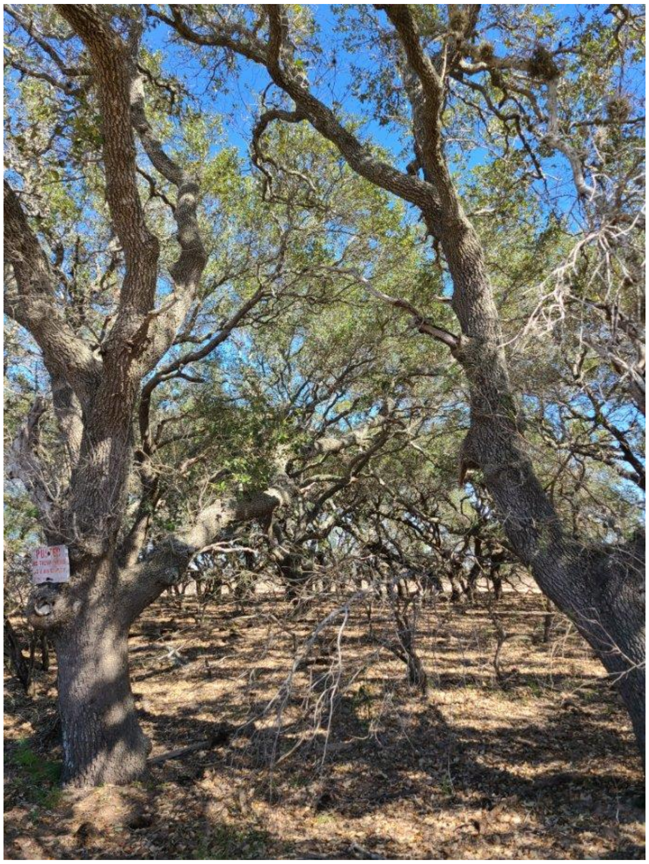


Figure 2.11 Live oak pygmy-owl habitat in Texas (Photo Courtesy of FWS)

Figure 2.12. Oak motte pygmy-owl habitat in Texas (Photo courtesy of Bill Carr)

2.5.4 Western Mexico

In western Mexico, the pygmy-owl occurs in a wide variety of vegetation associations from sea level to 1,219 m (4,000 ft) (Friedmann *et al.* 1950). The pygmy-owl is absent from tropical deciduous forests and higher vegetation zones in west Mexico, where it is replaced by the Colima pygmy-owl (*Glaucidium palmarum*) and the northern pygmy-owl (*G. gnoma*) (Schaldach 1963, p. 40; Buchanan 1964, pp. 104–105; Howell and Robbins 1995, pp. 19–20). Dry, subtropical forests provide important pygmy-owl habitat elements, as evidenced by pygmy-owls being more common in this vegetation community type than in other community types in Mexico. The dry, subtropical forests comprise the majority of the pygmy-owl's southern range in Mexico. The presence of large trees and columnar cacti for nesting, and diversity of cover and prey types, contribute to the value of dry subtropical forests as pygmy-owl habitat (Figure 2.13). Figure 2.9 shows the extent of modeled suitable vegetation for pygmy-owls in the Western Mexico analysis unit.

Figure 2.13. Thornscrub habitat in Western Mexico (Photo credit: AGFD)

Approximately 98% of the lands in Mexico are under private ownership. The remaining approximately two percent are a combination of Federal, State, municipal, communal, and indigenous lands, with the latter three being managed similar to private lands (Mesta 2020, pers. comm.). Protected Areas (national parks, biospheres, national monuments, sanctuaries, etc.) make up approximately 9.5% of Mexico's landmass, with only about 25% of these protected areas being publically owned (Mesta 2020, pers. comm.). Protected areas occur in all three of the pygmy-owl analysis units in Mexico, but they make up, at most, just under seven percent of any analysis unit (see Figure 2.15). In Mexico there are federal, state, or municipal protected Natural Areas. These areas can work well as conservation strategies for the pygmy-owl. There is now a new option for protected areas called Voluntary Conservation Areas (Áreas Destinadas Voluntariamente a la Conservación; ADVA) which are areas for conservation and can be a good conservation strategy (https://www.gob.mx/conanp/articulos/areas-destinadas-voluntariamente-a-la-conservacionparticipacion-social-por-el-ambiente-193042) (Enríquez 2021, p. 2).

2.5.5 Northeastern Mexico

In northeastern Mexico, the pygmy-owl is typically found below 305 m (1,000 ft) (Friedmann *et al. 1*950). The pygmy-owl most commonly occupies riparian forest in east Mexico (Sutton 1951), but is found in lowland thickets, thornscrub associations, riparian woodlands, and second-growth forests in northeastern Mexico. (van Rossem 1945, Enríquez-Rocha *et al. 1*993, Tewes 1993; Figure 2.14). Specific vegetation communities in northeastern Mexico that provide habitat for the pygmy-owls include Tamaulipan thornscrub, Tamaulipan deciduous forest, riverbottom woodlands, and thornforests. (Enrique-Rocha *et al. 1*993, FWS 1997) or lowland thickets, thornscrub associations, riparian woodlands and second-growth forests in northeastern Mexico (van Rossem 1945, Enríquez-Rocha *et al. 1*993, Tewes 1993). Figure 2.98 shows the modeled suitable vegetation for pygmy-owls in the Northeastern Mexico analysis unit.

Figure 2.14. Tamaulipan Ramadero habitat in northeastern Mexico (Photo credit: Chris Best)

Approximately 98% of the lands in Mexico are under private ownership. The remaining approximately two percent are a combination of Federal, State, municipal, communal, and indigenous lands, with the latter three being managed similar to private lands (Mesta 2020, pers. comm.). Protected Areas (national parks, biospheres, national monuments, sanctuaries, etc.) make up approximately 9.5% of Mexico's landmass, with only about 25% of these protected areas being publically owned (Mesta 2020, pers. comm.). Protected areas occur in all three of the pygmy-owl analysis units in Mexico, but they make up, at most, just under seven percent of any analysis unit (see Figure 2.15). In Mexico there are federal, state, or municipal protected Natural Areas. These areas can work well as conservation strategies for the pygmy-owl. There is now a new option for protected areas called Voluntary Conservation Areas (Áreas Destinadas Voluntariamente a la Conservación; ADVA) which are areas for conservation and can be a good conservation strategy (https://www.gob.mx/conanp/articulos/areas-destinadas-voluntariamente-a-la-conservacionparticipacion-social-por-el-ambiente-193042) (Enríquez 2021, p. 2).

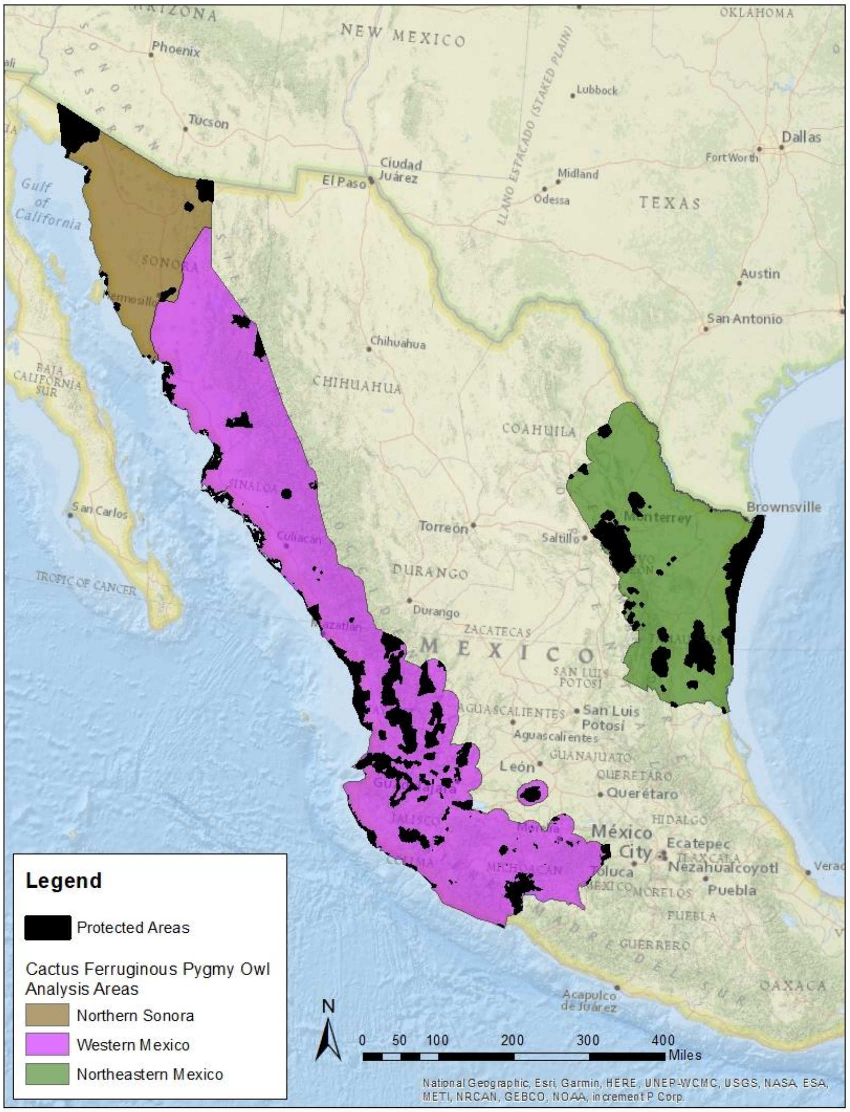


Figure 2.15 Protected areas in Mexico by analysis unit.

CHAPTER 3. INDIVIDUAL NEEDS

We assessed the best available information to identify the physical and biological needs to support individual fitness at all life stages for the pygmy-owl. For the purpose of this SSA, the needs that were considered most significant include cavity availability, vegetation structural diversity, woodland tree canopy, overall cover, prey availability, adequate habitat patch size, and habitat connectivity. Table 3.1 shows specific individual needs in relation to life stage and associated life history behaviors.

Table 3.1 Individual needs for all life history stages and the associated behaviors of the cactus ferruginous pygmy-owl; under Behaviors, B = breeding, F = feeding, S = shelter, and D = dispersal.

Individual Needs		
Stage	Needs	Behavior
Adult (Year-round)	Available nest cavities	B, S
	Vegetation structural diversity	F, S
	Woodland tree canopy	F, S
	Seasonal prey availability	F, B
	Habitat arrangement and patch size	F, B, S
	Available mates	B
Nestling (April – May)	Adequate nest cavity	S
	Adequate prey resources	F
	Low parasite load	S
Fledgling (June – August)	Adequate cover	S
	Habitat arrangement and patch size	F, S
	Prey availability	F
Disperser (September – October)	Adequate patches of available habitat	F, S, D
	Habitat connectivity	D
	Adequate cover	S
	Available mates	D, B

3.1 Cavity Availability

Characteristics of nest cavities often influence habitat selection and reproductive performance of cavity-nesting birds (Nilsson 1984, Sonerud 1985). Pygmy-owls are primarily secondary cavity nesters and in Arizona, almost exclusively use saguaro cavities excavated by Gila woodpeckers (*Melanerpes uropygialis*) and gilded flickers (*Colaptes chrysoides*) (see Figure 3.2). Because pygmy-owls do not excavate their own nest cavities, the status and density of woodpeckers within pygmy-owl habitats is important to the availability of pygmy-owl nest cavities. Only two nests in Arizona have been in tree cavities since monitoring began in 1998 (n > 50); one in a native velvet ash tree and one in a landscaped eucalyptus tree (*Eucalyptus polyanthemos*). It is not known if these tree cavities occurred naturally or were the result of woodpecker activity. The essential elements that support nesting include saguaro cacti with cavities (tree cavities to a lesser extent) containing adequate depth and volume to provide space for incubation and nestling development, as well as protection from predators. Saguaro cavities also mitigate temperatures extremes (both high and low temperatures) throughout incubation and nestling development. In other words, because saguaro cavities maintain a more constant temperature, saguaro cavities stay warmer during cool/cold nights and cooler during warm/hot days creating more favorable nesting conditions. Research has been conducted on the ability of saguaro cavities to buffer temperatures and humidity in pygmy-owl nest cavities (Walker *et al.* 2020; Lowery *et al.* 2003; see Figure 3.1).

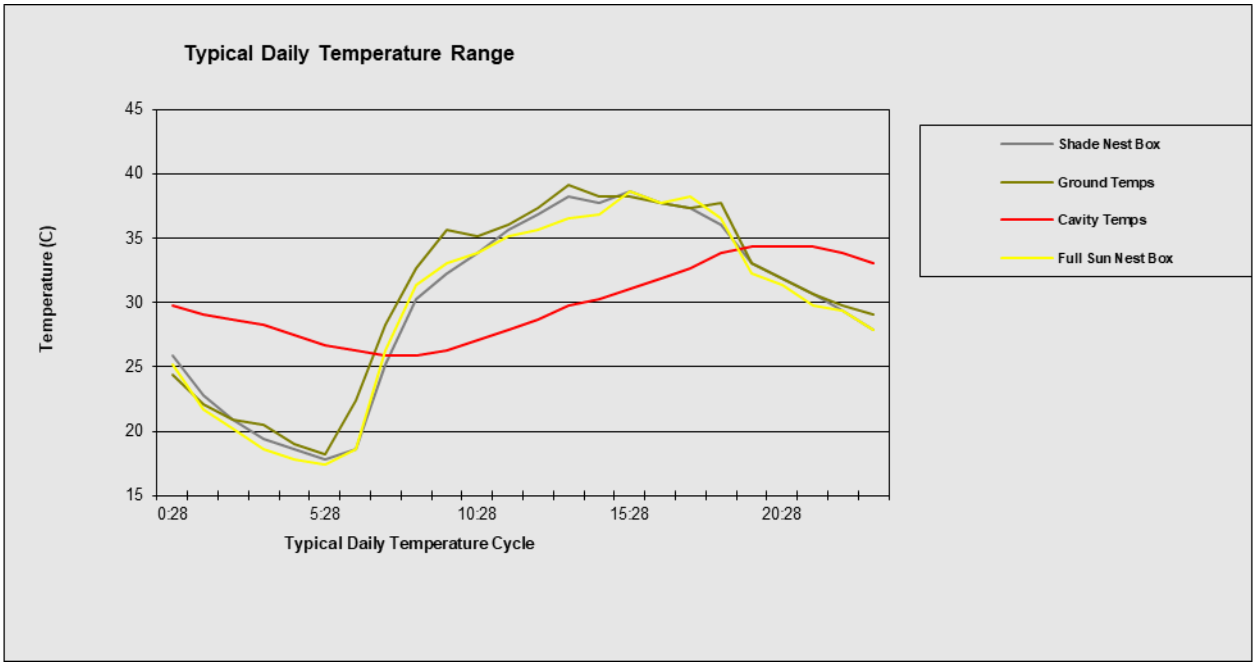


Figure 3.1. AGFD nest cavity temperature curves illustrate that saguaro, and potentially other columnar cactus cavities, mitigate high and low temperatures. Thermal resistance of saguaro cavities buffers the temperature during a 24-hour period; cavities are warmer during the morning and cooler during the hottest part of the day.

Cavity availability is a key pygmy-owl habitat factor. However, cavity use outside of the nesting season is limited. Most pygmy-owl roost sites are found in woody vegetation that provides protection from predators and assists thermoregulation (Abbate *et al.* 1996; Proudfoot 1996). However, anecdotal observations indicate pygmy-owls will occasionally use cavities throughout the year to avoid adverse weather conditions and to cache prey items (AGFD 2000, unpublished data). While pygmy-owl breeding activity areas usually contain multiple saguaros, some territories contain a solitary nest saguaro with the nearest alternate more than 400 m distant. Thus, suitability of an area for pygmy-owl nesting can result from the presence of even a single saguaro or tree that contains available nest cavities as long as other necessary habitat elements are present (Flesch and Steidl 2010, pp. 1025 – 1028). However, the greater the availability of appropriate nest substrates, the greater the likelihood that an area will support and maintain pygmy-owl occupancy. In areas lacking a high density of potential cavities, there is considerable competition for available cavities because areas occupied by pygmy-owls also support other cavity-nesting species such as elf owls *(Micrathene whitneyi)*, screech owls, woodpeckers, flycatchers (*Myiarchus spp.)*, purple martins (*Progne subis)*, and Bewick's wrens (*Thryomanes bewickii)*. Bees will also create hives in cavities in saguaros and trees (FWS 2007, entire). Therefore, the greater availability of cavities, the less effect competition will have pygmy-owls finding available nest cavities.

Due to the diversity of vegetation communities across the geographic range of the pygmy-owl, cavity availability can be influenced differently by different factors depending on natural and human-influenced conditions occurring locally on the landscape. For example, invasive plant species in the Sonoran desert of Arizona and Sonora affect the availability of columnar cacti supporting pygmy-owl nests through competition for resources and through fire and changes in the natural fire regime (Esque and Schwalbe 2002, p. 165). Columnar cacti and other Sonoran desert species are not fire adapted and are lost as invasive species create fire-driven conditions on the landscape. These effects may not be as impacting in the live oak mottes of Texas because live oak can survive low to moderate intensity fire and can re-sprout following fire. In portions of the tropical and dry deciduous forests of western Mexico, deforestation can influence cavity availability in ways not experienced in other parts of the pygmy-owl's geographic range (Trejo and Dirzo 2000, p. 133). It is important to consider the range and diversity of factors affecting pygmy-owl nest cavity availability in all of the pygmy-owl analysis units.

In northern Sonora, Mexico, important characteristics of pygmy-owl nest cavities included cavity height, entrance area, volume, and orientation (Flesch and Steidl 2010, pp. 1034–1036). Height of nest cavities influenced cavity selection, nest survival, and productivity of pygmy-owls, potentially due to lower predation risk higher above ground (Nilsson 1984, Li and Martin 1991). Coachwhip snakes (*Masticophis flagellum*), for example, a common tree-climbing predator that was observed depredating fledgling pygmy-owls may not search cavities in saguaros or that are that high above ground (Flesch and Steidl 2010, p. 1036). Although predation is often thought to drive selection of cavities that are higher above ground, thermoregulatory factors may also be important in desert environments because temperatures within saguaro cavities decrease with increasing height (Soule 1964).

Flesch and Steidl (2010) showed that cavities that were high above the ground and that had small- to moderate-sized entrances were especially important to nest site selection and reproduction of pygmy-owls. Cavity availability in their study indicated that, in Sonora, availability of cavities generally increased from north to south and was greatest at middle latitudes where saguaro cacti were more abundant. Use was consistent of cavities meeting these particular requirements, regardless of geographic location, suggesting that only a limited range of cavity conditions were suitable for owls.

Specific factors driving nest cavity selection for pygmy-owls appear related to cavity selection that will provide the optimal environment for incubation and nestling survival. The conditions driving cavity selection by pygmy-owls are likely similar to that described for other cavity nesting birds. For example, in desert environments, birds select nest orientations that moderate temperatures within nests (Ricklefs and Hainsworth 1969). In the study by Flesch and Steidl (2010) in Sonora, as temperatures increased toward the western portion of their study area, use of west-facing nest cavities decreased and use of north-facing cavities increased. Because summer temperatures are lower in north- vs. west-facing saguaro cavities (Soule 1964), these changes in nest orientation likely offer thermoregulatory advantages to owls and could explain lower rates of nest failure in cavities with cooler microclimates (Flesch and Steidl 2010). Gila woodpeckers (*Melanerpes uropygialis*; Inouye *et al. 1*981, Korol and Hutto 1984) and elf owls (*Micrathene whitneyi*; Hardy and Morrison 2001), two common cavity nesters in the region, also select north-facing nest cavities in the hotter western portion of the study area, whereas nest orientations are more variable in the east (Goad and Mannan 1987, Kerpez and Smith 1990).

Flesch and Steidl (2010) reported on a number of criteria related to pygmy-owl cavity selection in Sonora, Mexico. Here, nest cavities differed from available cavities by entrance area, volume, orientation, and height. Owls selected cavities within a much narrower range of entrance areas than available, and selection was strongest for cavities with small- to moderate-sized entrances and lower outside this range. Cavities of a more suitable size for nesting pygmy-owls may be indicated by external swelling of the saguaro stem caused by the formation of a cavity in that stem. Anecdotal observations in Arizona indicate that cavities associated with stem swelling are often used as nest cavities by pygmy-owls. Flesch and Steidl (2010) measured and quantified this variable for cavity selection. They found that owls selected nest cavities with more external stem swelling than available. Odds of a cavity with a moderate-sized stem bulge being selected were 88 times that for cavities with no bulge after accounting for other factors. Only 21% of available cavities had moderate or high levels of stem swelling, yet 49% of nests were within these types of cavities. Cavity orientation may also be a factor in nest cavity selection by pygmy-owls. In Sonora, orientation of both nest and available cavities were nonrandom. Flesch and Steidl (2010, p. 1028) found that owls were less likely to select west-facing cavities compared to north-facing cavities, especially in the hotter, drier environments found further west and north in Sonora. Similarly, probability of use of north-facing cavities increased somewhat from east to west along the same geographic gradient, despite no variation in availability. Overall, 72% of west-facing nests were in the cooler eastern portion of the study area, whereas 67% of north-facing nests were in the hotter western portion (Flesch and Steidl 2010).

Figure 3.2 Adult pygmy-owl delivering prey item to nest cavity in a saguaro cactus in Arizona. (Photo credit: Paul Bannick)

In Texas, results obtained from box plot and transect studies conducted by Proudfoot (1996, pp. 67 – 68) suggest cavities suitable for pygmy-owl use occur at a rate of 0.2 or 0.4/ha respectively. Results from transects indicate an estimated 11,600 cavities of suitable size for pygmy-owls throughout the Texas study area. The study area was approximately 30,000 ha. However, assuming cavities are equally distributed, and based on information obtained from radio-tagged pygmy-owls (i.e., habitat types used by pygmy-owls during the nesting season only occur on about 10% of Proudfoot's study area), there were only 1,160 suitable cavities available to pygmy-owls (Proudfoot 1996, pp. 67–68). Territorial behavior of pygmy-owls would further limit access to cavities. However, information obtained by Proudfoot from inspecting natural and excavated cavities (i.e., no avian occupants recorded during inspection) and nest boxes (i.e., only 48 nest boxes were used by five avian species during the study) suggests a substantial number of suitable nest cavities occurred on the study area (Proudfoot 1996, pp.67–68). Cavities in Texas were primarily found in live oaks and all active pygmy-owl nest cavities were on the underside of upward and outward sloping limbs. (Proudfoot 1996, p. 36). Nest cavities documented were located at heights that ranged from eight feet to 16 feet above ground level (Proudfoot 1996, p. 38).

3.2 Woodland Tree Canopy Cover

Because the pygmy-owl is an obligate cavity nester, it requires trees or cacti large enough to contain a cavity, as well as cavity excavators like woodpeckers. Historical records suggest that in riparian areas, mesquite, a hardwood less readily excavated by Gila woodpeckers and northern flickers, was less frequently used than softwood trees (Hunter 1988). Such areas of woodland tree cover also provide cover from predators and a diversity of conditions that support a variety of prey species. Riparian flood-plains support most of the low-elevation woodland vegetation in many of the areas within the range of the pygmy-owl. These areas attract a disproportionate abundance of wildlife (Carothers and Johnson 1975; Hubbard 1977; Pase and Layser 1977). Migrating passerines, for instance, exhibit a strong preference for riparian corridors over the adjacent uplands (Stevens *et al. 1*977). In the Altar Valley of southern Arizona, Flesch (1999) described occupied pygmy-owl sites as being associated with well-developed wooded vegetation along one or more washes. Woodland patches were more structurally developed and of larger size than unoccupied sites.

Woodland tree canopy cover is probably the most significant habitat factor contributing to environmental suitability for pygmy-owls (Flesch *et al.* (2015, pp. 22-26). Woody vegetation cover not only provides supporting microclimates for nest cavities in columnar cacti, but also provide alternative nest substrates in cavities in large trees. Additionally, the majority of pygmy-owl roost sites occur in woody vegetation because cavity use is only occasional once nestlings have fledged. Areas supporting high woodland tree canopy cover are characterized by large trees that provide needed protection from predators, as well as cover that provides relief from temperature extremes (Flesch *et al.* (2015, pp. 22-26). This habitat type is often found along rivers and washes and around ponds and stock tanks. Generally, these are riparian areas that support large trees and high vegetation diversity (Flesch 1999). Such areas provide trees sufficient in size to support cavity excavation by woodpeckers.

An early habitat selection study in Arizona indicated that nest sites tend to have a higher degree of canopy cover than random sites (Wilcox *et al. 2*000). In addition, habitat descriptions of areas with the highest concentrations of pygmy-owls are most commonly characterized by semi-open or open woodlands, often in proximity to forests or patches of forests. Where they are found in forested areas, they are typically observed along edges or in openings, rather than deep in the forest itself (Binford 1989, Sick 1993), although this may be a bias of increased visibility. Total vegetation density may not be as important as the presence of patches of dense vegetation with a developed canopy layer interspersed with open areas.

In northern Sonora, Flesch *et al.* (2015, pp. 22-26) found that the amount of woody vegetation cover within pygmy-owl territories positively affected productivity in those territories. This positive effect on productivity is likely related to reduced predation, increased foraging opportunities, and buffering of extreme weather conditions. Woodland habitats occupied by pygmy-owls in northern Sonora include riparian woodlands in Sonoran desert-scrub and tree-invaded grasslands, similar to where pygmy-owls are found in Arizona.

3.3 Vegetation Structural Diversity

While taller tree canopy cover is probably the primary habitat need for pygmy-owls, it is also important that habitat contain vegetation structural diversity. Such diversity includes areas of open or bare ground, ground cover that is low-growing (but not so dense as to affect prey availability), a shrub layer, and a tree canopy layer. Analyses of 18 perch sites and 3 nests sites in Arizona suggest that pygmy-owls use areas with relatively high levels of structural diversity in the suburban/rural interface in northwest Tucson (Wilcox *et al. 1*999). In the Altar Valley, Flesch (1999) described occupied sites as being associated with well-developed wooded vegetation along one or more washes. This vegetation structural diversity provides cover for predator avoidance and thermoregulation, as well as providing a diversity of resources to increase prey availability. Structural diversity provides for a variety of hunting perches and nest guard trees. Pygmy-owls select areas of habitat with high vegetation structural diversity and the associated benefits. For example, in Texas, information obtained from tracking 37 radio-tagged individuals during nesting showed preference for areas dominated by trees >26 cm diameter at breast height (dbh) with moderate (50–75%) to dense (76–100%) understory (Proudfoot 1996, p.49). Habitat descriptions in the tropics and in Texas suggest the importance of thickets and woodlands with a dense understory that often consists of spiny shrubs. This pattern is consistent with Proudfoot (1996, p. 18-19) which examined habitat use versus availability and found that pygmy-owls nested disproportionately in areas with moderate to dense understory. A dense understory may benefit the pygmy-owl by providing a shelter from climatic stresses and potential predators, especially in the case of juveniles (Abbate *et al. 1*996; Proudfoot 1996). Greater habitat complexity may also result in more foraging opportunities for pygmy-owls. Habitat analysis in Arizona indicated that higher vegetation diversity is found more often at pygmy-owl nest sites than at random sites (Wilcox *et al. 2*000).

3.4 Appropriate Spatial Arrangement and Size of Habitat Patch

Adequate size and spatial arrangement of habitat elements within a pygmy-owl's home range are necessary for a pygmy-owl to be able to meet all of its life history requirements. Habitat patches must be of sufficient size to provide the diversity of cover and prey needed to sustain the pygmy-owl on a seasonal and annual basis. For example, a pygmy-owl's home range must be large enough to contain suitable and available cavities for nesting, cover to address seasonal weather extremes and predator avoidance, provide sufficient prey availability across seasons, and to support a mate and offspring. Flesch *et al.* (2015, pp. 22-26) found that vegetation structure (woody vegetation cover) and extent (larger, unfragmented patches) within pygmy-owl territories reduced vulnerability to predation, promoted foraging opportunities, and mitigated harsh environmental conditions. Additionally, pygmy-owl reproductive output within territory patches declined with increasing conspecific density around the territory and, as distance between pygmy-owl territories is reduced, territory size, and resources contract, increasing competition for resources and increase the energetic costs of territory defense (Flesch *et al. 2*015, pp. 26-27). Pygmy-owl territories of sufficient size that provide higher quality habitat can help offset such effects. The area used by pygmy-owls expands during the winter months when prey availability and diversity are reduced. Drought can reduce prey availability and cover necessitating shifts in annual use areas. Competition for nest cavities can cause nest sites to move from year to year. Therefore, adequate size and spatial arrangement of pygmy-owl habitat patches and the presence of appropriate habitat factors within those patches over time is necessary for pygmy-owls to survive, reproduce, and fledge offspring.

Although pygmy-owls occupy the same general area year-round (Phillips *et al. 1*964, Oberholser 1974), the size of area used and the composition of vegetation may vary among seasons (Proudfoot 1996). Tracking of ten radio-tagged adult males from incubation through dispersal of young (i.e., April 3-August 12) and three males post-dispersal (i.e., September 16-November 26, 1994) showed a 3.4-fold increase in average size of area used between nesting and post-nesting males (Proudfoot 1996). Also, nesting habitat contained considerably more understory vegetation than areas used post-nesting (Proudfoot 1996). These alterations in areal expanse and habitat use may be related to seasonal variations in prey abundance and parental care (Proudfoot 1996; Proudfoot and Beasom 1997). Thus, a pygmy-owl's home range must be of adequate size and have the appropriate spatial arrangement of resources to support the family group of owls throughout the year. In Texas, the area used by nine radio-tagged adult males monitored from before to after incubation ranged from 1.3-23 ha (3.2–57 ac). An unmated adult male monitored during the same period used 110 ha (271.6 ac). From fledging through dispersal, five radio-tagged families (i.e., two adults [one male and one female] and three fledglings/family) used from 9.3-59.4 ha (22.9–146.9 ac). From October through November, two radio-tagged males and one yearling used 112.5, 72.8, 19.6 ha (278.4, 179.8, and 48.4 ac), respectively (Proudfoot 1996). In Arizona, pygmy-owls monitored during nesting used from 2–20.2 ha (5–50 ac), and an unpaired male used approximately 87.8 ha (217 ac) (Abbate *et al. 1*999). Additional research on pygmy-owl home ranges, particularly any differences in home range size based on vegetation types or breeding status, is necessary before the size of areas used by pygmy-owls can be well understood.

3.5 Interconnected Habitat

Connectivity (the opposite of fragmentation) has become one of the most accepted principles of conservation planning (Noss 1994, p. 7). Habitats that are functionally connected to enable natural movements of pygmy-owls are less subject to extinction pressures when compared to habitats disturbed and fragmented by human activities. Interconnected habitat is necessary on two scales: (1) within a home range, and (2) across the landscape. At the home range scale, interconnected habitat is important because it enables adult pygmy-owls to hunt across the area for available prey to support the adult nesting pair of owls, as well as their offspring. Such interconnected habitat provides for movements of the family unit while the adults are teaching the offspring predator avoidance and hunting skills and adequate cover and space for the offspring to learn flight proficiency. Landscape disturbance can disrupt dispersal movements in ways that reduce colonization success, functional connectivity, and local rates of patch occupancy (Flesch *et al. 2*010; Flesch 2017, pp. 3 – 4). The very low number of pygmy-owls found in riparian vegetation in recent years may reflect loss of habitat connectivity rather than lack of suitability (Carton *et al. 2*000). Interconnected pygmy-owl habitat across the landscape enables demographic support (rescue effect) of pygmy-owl population groups through dispersal and other movements. Dispersing pygmy-owls utilize interconnected habitats to increase the numbers of owls within adjacent population groups and increase available mates within those population groups. These movements also maintain or increase genetic diversity. Habitat fragmentation causes a number of issues at the landscape level, including edge effects that reduce the area of secure interior patches of habitat, increased proliferation of weeding and non-native species, increased human activity impacts, and disruption of natural processes related to hydrology, habitat succession, and others (Noss 1994, p. 7).

3.6 Prey Availability

While pygmy-owls are considered generalists in their prey consumption, certain prey items may only be available seasonally. Habitat for pygmy-owls must support resources for seasonally available prey items such that prey is consistently available during all seasons of the year. For example, lizards and insects are typically only available during the warm seasons of the year but, while they are available, they can make up the majority of a pygmy-owl's diet. Additionally, other prey items are only available under certain conditions (e.g. cicada hatch). Birds as prey items are typically available year-round, but are of greatest importance in the diet of pygmy-owls in the winter when other prey items are not as available. See Proudfoot and Beasom (1997) and Abbate *et al.* (1999) for a more detailed description of the documented prey items of the pygmy-owl.

3.7 Available Mates

Because pygmy-owl population groups are patchily distributed across the landscape and because pygmy-owl abundance varies across its distribution, sufficient mates may not exist to support the formation of adequate numbers of breeding pairs and unpaired individuals do not contribute to breeding. Dispersing pygmy-owls must be able to locate available mates and established breeding pairs of pygmy-owls must be able to find replacement mates available if one member of a breeding pair perishes. This availability of mates is often supplied by "floaters" (unpaired individuals of breeding age) in the population. Pygmy-owl population groups must be of sufficient size to provide adequate numbers of floaters to provide mates for dispersing pygmy-owls or single members of a previous breeding pair. In addition, adjacent pygmy-owl population groups must be stable to increasing in order for it to be advantageous for floaters to leave a source group to rescue population groups that have insufficient productivity to maintain the viability of the population group. Thus, to maintain pygmy-owl population viability, population groups within each pygmy-owl analysis unit must have a high resiliency.

In territorial birds, floaters are dispersing, nonbreeding individuals that can enter the reproductive population when a breeding territory becomes available (Penteriani *et al. 2*008). Young birds often become floaters during their movements between natal sites and first breeding sites (i.e., natal dispersal) (Greenwood 1980). Floaters are common in some populations, as evidenced by the rapid replacement of breeding individuals when they die or are experimentally removed (Newton 1992; Hogstad 1999; Bruinzeel and van de Pol 2004). The behavior of floaters, although difficult to study, is potentially important because floaters may influence the dynamics, distribution, and stability of the breeding populations in which they occur (e.g., Penteriani *et al. 2*005; Penteriani *et al. 2*006; Penteriani *et al. 2*008; Penteriani and Delgado 2009).

Constrained movement of floaters could confer at least two advantages. First, knowledge of sources of food, cover, and water in a restricted area would promote survival over the two or more years it might take to gain a nest site. And, second, being close to one or more established nest sites and thus being able to repeatedly assess whether nesting opportunities exist would increase the chance of acquiring a breeding site when one became available through death of a resident breeder (Bruinzeel and van de Pol 2004).

3.8 Parasite Loads

Research by Proudfoot in the early 2000's has indicated that pygmy-owl nests often host a variety of parasites. It is likely that the microclimate of nest cavities is favorable for occupancy by parasites. Several body parasites have also been identified in fledglings, but their overall effect on pygmy-owl health is not completely understood. In Texas, no blood parasites (Hematozoa—e.g., *Haemoproteus* spp., *Leucocytozoon* spp.) were found in 63 individuals examined (Proudfoot and Radomski 1997). Hippoboscid flies are common in nestlings ≤3 weeks old in Texas and less common in adults; mites and lice are common in wing axilla of nestlings and less common in adults. In addition to these, other parasites documented include *Philornis mimicola* and *Ornithodoros concanensis* in Texas populations (Proudfoot *et al. 2*006c), and *Protocalliphora sialia* and *Hesperocimex sonorensis* in Arizona (Proudfoot *et al. 2*005). Known health consequences include blood loss and anemia (Proudfoot *et al. 2*006c). Parasite loads must be low in occupied nest cavities to reduce the likelihood of parasites impacting nestling and fledgling pygmy-owl health and fitness. Multiple available nest cavities within a pygmy-owl's home range provide alternate nest cavities which can be used if parasite loads are too high in a particular nest cavity.

CHAPTER 4. POPULATION NEEDS

For the purposes of this SSA report, we define "population" for pygmy-owls as the genetically and geographically separated eastern and western portions of the pygmy-owl's range. To remain ecologically functional, these populations need high levels of adult and juvenile survival and low levels of negative influences (stressors). High levels of adult survival, reproductive success, and juvenile survival can drive population growth and enable population groups and analysis units to recover from stochastic events such as extreme weather events that may reduce the availability of nesting substrates, prey, and adequate configurations of cover and habitat connectivity. This may lead to reduced productivity or reproductive failure through predation, reduced dispersal options, inability to thermoregulate, or food resource limitations that may reduce survival of all age classes of pygmy-owls.

In general, the viability of pygmy-owl populations is based upon resiliency (represented by their populations' ability to withstand stochastic events and their relatively high abundance), redundancy (represented by the wide distribution of interconnected, viable population groups and high number of resilient populations), and representation (represented by variations they display in selecting nesting habitat and prey species, and in genetic differentiation across analysis units and populations).

At the population level, we used the best available information to assess the resources, circumstances, and demographics that most influence the resiliency of a cactus ferruginous pygmy-owl population. Resiliency describes the ability of a species to withstand stochastic disturbance. Resiliency is positively related to population size and growth rate, and may be influenced by connectivity among populations. If a species is resilient, we assume there exists sufficient suitable, occupied habitat to support large and stable populations such that the species can withstand stochastic events. Stochastic events that may be experienced by pygmy-owls include fires, hurricanes, flooding, or disease outbreaks. A variety of factors may regulate pygmy-owl population levels. These factors may be density-dependent (e.g., habitat quality, habitat abundance) or density-independent (e.g., climate). The population needs that are being considered for this SSA include adult survival, reproductive rates, dispersal, and juvenile survival.

Figure 4.1 is a conceptual model that shows how the individual needs discussed in the previous section influence the population needs, which ultimately affect population resiliency. Resiliency is discussed at the population level and representation and redundancy are discussed at the subspecies level.

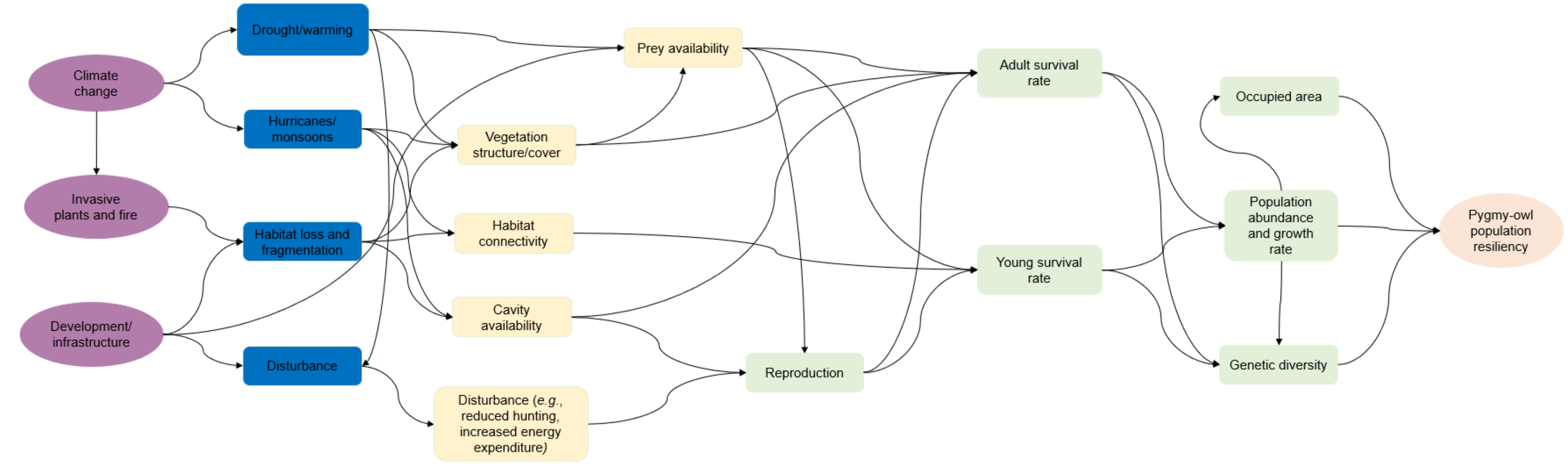


Figure 4.1 Core conceptual model showing interactions among anthropogenic factors (purple), key stressors (blue), habitat factors (yellow), demographic factors (green) and the resultant effects on population resiliency and viability (pink).*

---

*We recognize that this diagram is simplistic and doesn't capture the full range of interactions between anthropogenic factors, stressors, habitat, and demographic factors. However, to preserve the readability of the graphic, we have simplified these interactions.

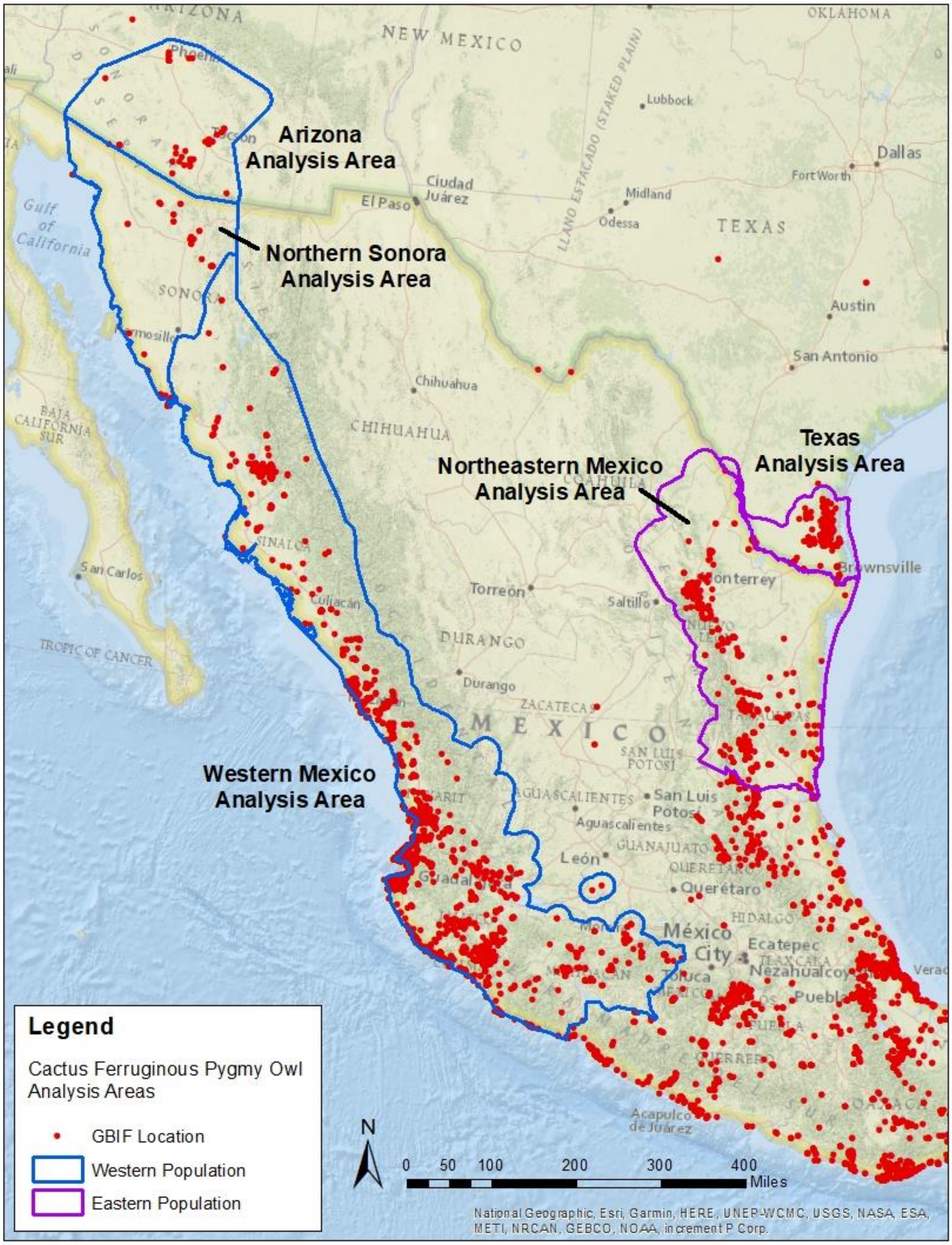
In this chapter, we consider the historical distribution of the cactus ferruginous pygmy-owl, its current distribution and abundance, and what the two populations need to maintain resiliency. In the following chapter, we will review the conceptual needs of the subspecies as a whole, including population resiliency, redundancy, and representation to support viability and reduce the likelihood of extinction.

4.1. Historical and Current Range, Distribution, Abundance

The pygmy-owl is known to occur historically in all five of the defined analysis units (Figure 4.2). General information related to both the eastern and western populations of the pygmy-owl are available from a few of sources. For example, the International Union for Conservation of Nature and Natural Resources (IUCN) Red List of Threatened Species provides information on the ferruginous pygmy-owl. As a subspecies of the ferruginous pygmy-owl, the distribution of the cactus ferruginous pygmy-owl is much reduced by comparison (Figure 4.3). The range of the cactus ferruginous pygmy-owl accounts for approximately four percent of the overall range of the ferruginous pygmy-owl.

The description of the ferruginous pygmy-owl in the IUCN Red List classifies the ferruginous pygmy-owl as a species of Least Concern, based primarily on its large geographic range and overall large population size (BirdLife International 2016, unpaginated). However it is important to keep in mind that the cactus ferruginous pygmy-owl constitutes only about four percent of the overall range of the ferruginous pygmy-owl, so this basis for determination as Least Concern did not consider subspecies and may not apply when looking strictly at the *cactorum* subspecies. The IUCN does indicate that the population trend is declining, but they do not believe the decline is sufficiently rapid to place it in the Vulnerable category (BirdLife International 2016, unpaginated). They indicate that this decline is based on habitat destruction (BirdLife International 2016, unpaginated).

The Birds of the World account of the ferruginous pygmy-owl indicates that there have been few studies of this species and that density estimates are limited. Some data exist on current population densities in Arizona and Texas, but historical accounts of ferruginous pygmy-owl populations generally contain only anecdotal evidence, so the rates of population shrinkages are difficult to calculate. However, this species is considered common throughout most of its range. For example, in Mexico and Central and South America, the ferruginous pygmy-owl is considered a common resident; fairly common to locally common in Panama and Colombia, and fairly common in Costa Rica; and, in some countries, it is the only common pygmy-owl. They also indicate that the ferruginous pygmy-owl occurs in a considerable number of protected areas in most countries throughout its extensive range (Proudfoot *et al. 2*020, unpaginated).



National Geographic, Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

Figure 4.2 Historical and current locations of pygmy-owl in the eastern and western populations. Analysis unit boundaries are also included to clarify observations within those analysis units as discussed below. Observations based on Global Biodiversity Information Facility (GBIF) occurrences.

Figure 4.3 Range of the cactus ferruginous pygmy-owl compared to the overall range of the ferruginous pygmy-owl.

The cactus ferruginous pygmy-owl is the northernmost subspecies of the ferruginous pygmy-owl. As such, the pygmy-owls population groups that occur in Arizona and Texas are at the northern periphery of the current geographic extent the species and represent peripheral population groups. Some have suggested that pygmy-owls in Arizona have never been common and experience population fluctuations due the fact that they occur at the northern extent of the range and occupy marginal habitats (Johnson and Carothers 2008, pp. 30 – 31). Indeed, a species' range may be limited by a number of factors including genetics, extent of habitat, climatological tolerances, and competition. While the issue of what is limiting pygmy-owls in the northern extent of their range has been the subject of some debate, it is an accepted principle of conservation biology that disjunct or peripheral populations of species may be genetically impoverished, but they are also likely to be genetically distinct from core populations (Noss 1994, p. 8). This well-documented pattern is the direct consequence of reduced gene flow to isolated or marginal populations. While this may reduce the priority of such areas for conservation or recovery, it can also be important to conservation because disjunct or peripheral populations are likely to have diverged genetically from core populations due to genetic drift, adaptation to local environments, or both (Lesica and Allendorf 1995). If there is a concern about maintaining opportunities for speciation (future biodiversity), then conservation of peripheral and disjunct populations is critical (Noss 1994, p. 8).

To reiterate, genetic divergence tends to occur at the periphery of a species' range (Lesica and Allendorf 1995). This genetic divergence enables adaptation of the species as a whole in the face of environmental change. Loss of genetic diversity translates into a loss of fitness (reproductive success) for the species (Meffe and Carroll 1997). The peripheral nature of the Arizona and Texas analysis units increase the potential for those population groups to diverge from populations in in Mexico. The loss of this genetic difference, as peripheral population groups, could be meaningful with regard to genetic divergence within the subspecies. Hence, protection and management of peripheral populations may be important to the survival and evolution of species. Resistance to environmental change and genetic distinction often enables peripheral populations to persist when core populations are extirpated (Channell and Lomolino 2000a, 2000b; Lomolino and Channell 1995). In the face of changing environmental conditions, what constitutes a peripheral population today could be the center of the species' range in the future (Nielsen *et al. 2*001). Peripheral populations survive more frequently than do core populations when species undergo dramatic reductions in their range (>75%; Channell and Lomolino 2000a).

Historical and current populations of the pygmy-owl are discussed below in greater detail by analysis unit. Table 4.2 provides summarized information on these populations and analysis units. In general, more information is available regarding the Arizona, Texas, and Northern Sonora analysis units than in the remainder of Mexico because they have been the subject of various research and monitoring studies.

4.1.1 Western Population

4.1.1.1 Arizona

Historical records for the pygmy-owl in Arizona span at least five counties in southern and south-central Arizona, including Maricopa, Pima, Pinal, Santa Cruz and Yuma Counties (Johnson *et al. 2*003, p. 394). Historically (i.e., late 1800s and early 1900s), pygmy-owls occupied areas of south-central Arizona – from New River, about 56 km (35 mi) north of Phoenix, south to the United States/Mexico border, west to Agua Caliente near Gila Bend and Cabeza Prieta Tanks, and east to Tucson, and rarely the San Pedro River (Bent 1938; Monson and Phillips 1981; Johnson *et al. 2*003). Most of the historical (pre-1900) and recent (post-1990) records are from Pima County. Between 1872 and 1971, a total of 56 published records or specimens were recorded for Arizona. Of those, almost half (27) were from Pima County (Johnson *et al. 2*003, pp. 392–395). Although the pygmy-owl was historically recorded primarily from lowland riparian habitats, all recent records are from upland and xeroriparian (vegetation community in drainages associated with seasonal or intermittent water) Sonoran desertscrub (Abbate *et al. 2*000, pp. 15–16; FWS 2009b, p. 1; FWS 2011, p. 1).

Some information provided to the FWS by the public during previous public comment solicitation suggested that the pygmy-owl is an obligate wet riparian species in south-central Arizona and a preferential wet riparian species in southern Arizona, tying its distribution to these types of areas. In addition, the information stated that recent records in upland habitats have occurred primarily in areas associated with “cultivated riparian” habitats resulting from the human influences of irrigation and ornamental plantings, such as in suburban areas of Tucson (Johnson and Carothers 2008, pp. 13–14). We agree that riparian ecosystems provide important pygmy-owl habitat within its range. However, we disagree with the suggestion that pygmy-owls are wet riparian obligates, and thus limited in occurrence to these areas. For example, there are numerous recent locations in which pygmy-owls were detected in Sonoran desert uplands and semi-desert grasslands of southern Pinal County, Avra Valley, Altar Valley, Cabeza Prieta National Wildlife Refuge, Organ Pipe Cactus National Monument, and northern Sonora that are not in proximity to “cultivated riparian” or naturally occurring hydro- or mesoriparian (wet riparian) habitats. However, woodlands found along intermittent or ephemeral washes do provide important pygmy-owl habitat as evidenced by its presence at a majority of occupied pygmy-owl sites in Arizona and northern Sonora (Abbate *et al. 2*000; Flesch 2003).

Historical records of pygmy-owls give us very little information with regard to actual numbers of pygmy-owls documented. Most historical reports of pygmy-owls use subjective language when talking about the abundance of pygmy-owls. For example, the northernmost historical record for the pygmy-owl is from New River, Arizona, about 35 miles north of Phoenix, where Fisher (1893) reported the pygmy-owl to be "quite common" in thickets of intermixed mesquite and saguaro cactus. According to early surveys referenced in the literature, the pygmy-owl, prior to the mid-1900s, was "not uncommon," "of common occurrence," and a "fairly numerous" resident of lowland central and southern Arizona in cottonwood forests, mesquite-cottonwood woodlands, and mesquite bosques along the Gila, Salt, Verde, San Pedro, and Santa Cruz rivers and various tributaries (Breninger 1898; Gilman 1909; Swarth 1914).

Historical accounts of pygmy-owl are primarily from early military or exploration expeditions that included some documentation of biological resources of the areas covered by these expeditions. We do not discount the ability of early naturalists and ornithologists to find and identify pygmy-owls. However, finding pygmy-owls was not the objective of the trips reported in the literature, and unfortunately, most of these early reports do not contain enough information for us to determine that the effort was adequate to find pygmy-owls if they were present or that the absence of documentation of pygmy-owls truly means that no pygmy-owls were encountered.

Early records certainly provide information that shows that the range of the pygmy-owl has contracted in Arizona; however, this conclusion relies on anecdotal reports because population estimates and regular, targeted pygmy-owl surveys were not available until recent decades. . However, although not specifically measured, our observations do not support an increase in pygmy-owl densities in Arizona within the reduced range of the pygmy-owl. Therefore, the logical assumption may follow that pygmy-owl numbers are likely reduced as well. However, these early records do not have enough specific information for us to quantify historical pygmy-owl population numbers in a way that allows comparison to our current information. It is clear, however, that pygmy-owls and historical habitat is gone from many areas where it occurred historically. It also cannot be ignored that some of these detections in the past could have been northern pygmy-owl (*Glaucidium gnoma*). Subsequent monitoring by the Arizona Game and Fish Department on credible pygmy-owl detections in Arizona have resulted in detection of northern pygmy-owls as they can be found in most of the sky islands of southern Arizona. In addition, this species sometimes moves to lower elevations during the winter and can be found adjacent to mesoriparian habitats (Lowery 2020, pers. comm.). This is probably a localized phenomenon.

In summary, because the early records found in the literature provide no basis for consistent interpretation, the statements that the pygmy-owl was “not uncommon,” “of common occurrence,” and “fairly numerous” in lowland central and southern Arizona may be as appropriate as other interpretations that the pygmy-owl was never common in Arizona. The bottom line is that the characterizations of occurrence in these terms in the early records provide no real quantifiable information on which to base trends in pygmy-owl populations. Consequently, we must base our evaluation of the current pygmy-owl status on the best available scientific and commercial data, which is the information that minimally provides some ability to quantify pygmy-owl population numbers. Regardless of the lack of quantified historical data, the early records found in the literature give us some idea of the historical distribution of the pygmy-owl in Arizona that, when compared to the current distribution, has unquestionably been reduced.

With regard to what the current numbers and distribution of pygmy-owls are, FWS files contain information we received from various agencies and municipalities that contained survey results from Arizona indicating that the pygmy-owl is likely absent from some areas of pygmy-owl habitat in Maricopa and Pima Counties. Survey data submitted by the USDA Forest Service covering over 4,050 hectares (ha) (10,000 acres (ac)) in a 6-year period on the Tonto National Forest in Maricopa County detected no pygmy-owls (USFS 2008, pers. comm.). The Arizona Game and Fish Department (AGFD) indicated that they had conducted three years of surveys in Maricopa County without any pygmy-owl detections (AGFD 2008c, pers. comm.). Annual pygmy-owl surveys have been conducted by the Air Force on the Barry M. Goldwater Range of southwestern Arizona from 1993 to approximately 2008 with no verified pygmy-owl detections (Uken 2008, pers. comm.). The Pima County Department of Transportation conducts pygmy-owl surveys for their capital improvement projects. These pygmy-owl surveys are associated with specific projects, and do not represent systematic surveys throughout Pima County. Through approximately 2008, they conducted 383 surveys at 152 locations in Pima County with no pygmy-owl detections (Pima County 2008, pers. comm.). Some of the above surveys, and other negative surveys conducted throughout Arizona since 1997, occurred in areas where the pygmy-owl was historically located. More recently, surveys coordinated by the AGFD in 2020 failed to detect pygmy-owls in the same locations as these historical surveys and, additionally, failed to document occupancy by pygmy-owls in Organ Pipe Cactus National Monument for the first time in several decades (AGFD 2020, pers. comm.). Specifically, the National Park Service in 2019-2020 conducted surveys at most of the sites of known historical occurrence for pygmy-owls in Organ Pipe Cactus National Monument (OPCNM), resulting in a single call response that biologists were unable to confirm visually or with additional call responses (D. Martin, pers. comm.). When considered in total, this provides strong evidence that the current range of the pygmy-owl in Arizona has contracted when compared to historical occurrences of the owl.

Monson and Philips (1981) give a description of the pygmy-owl summarizing its status approximately 40 years ago. They indicate that, at that time, the pygmy-owl was a seldom seen owl in Arizona. It was apparently a local and sparse resident of Lower Sonoran Zone in saguaros and along desert washes. It could also be found in riparian trees of central southern and central Arizona, from the mouth of the Verde River, Superior, and Tucson (and possibly Sonoita Creek below Patagonia, where it was reported 6 June 1975 by G.S. Mills) west to desert ranges of southern Yuma Co. (at least to Cabeza Prieta Tanks, 10 Apr. 1955). They described the pygmy-owl as having declined considerably in numbers and potentially range since about 1950, to the point in 1980 of being absent from the state except possibly in the Organ Pipe Cactus National Monument region .

Beginning in 1993, the AGFD began surveying for pygmy-owls in southern Arizona in an effort to gather information on the pygmy-owl in response to a petition to list the owl as endangered under the ESA received by the FWS in 1992. This effort represents the most complete documentation of pygmy-owls numbers and distribution in Arizona in the 1990’s and 2000’s. In

1994, this survey effort resulted in the first pygmy-owl documentation in southern Arizona in over a decade. Subsequent to finding that first pygmy-owl in 1994, the AGFD initiated a pygmy-owl survey and monitoring effort that ran until the pygmy-owl was delisted in 2006. Survey efforts in 1996 produced more detections than previous survey efforts completed from 1993 to 1995. This detection success occurred despite the reduction in number of survey routes and area of calling coverage. Results in 1996 included 17 initial and 48 general detections of pygmy-owls during formal survey efforts, including the discovery of one nest, and represents more pygmy-owl activity than all previous survey years combined (Abbate *et al. 1*996).

Breeding season population surveys resulted in six detections in 1997 and six in 1998. All of these initial detections were territorial males calling in response to taped call broadcasts. In 1997, all formal survey detections occurred in the northwest Tucson area and represented four different territories. During formal surveys in 1998, four detections represented four known territories in northwest Tucson and included the territory held by a dispersing juvenile of the previous breeding season. Two other detections were recorded from the Marana/Redrock area where we located two new territories with the help of private consultant biologists (Harris Environmental Group, Inc., Tucson). In addition, one nest site was confirmed in 1997 and three nest sites were documented in 1998. All nest sites were located in northwest Tucson (Abbate *et al. 1*999).

One pygmy-owl nest in 1997 produced four young that successfully fledged and survived through dispersal. Observations of nesting adults, young, and solitary birds at different territories by AGFD resulted in confirmation of eight individual pygmy-owls in 1997. Two additional individuals were detected briefly by residents at a territory where a nest was located in 1995 in the Marana/Redrock area. Though not confirmed by AGFD, these detections were by observers with extensive observation experience of pygmy-owls and their nesting behavior and are considered reliable (Abbate *et al. 1*999).

In 1998, three nests closely monitored by AGFD successfully fledged a total of 11 young. Nine young (81.8% of total fledged) were regularly observed until dispersal. Fecundity (mean number of young fledged per nest site) in northwest Tucson during 1998 was 3.66. Fecundity for both 1997 and 1998 (N=4) was 3.75. When all nests with known number of fledglings were combined (1996-1998, N=6) fecundity was 3.66. The mean number fledged at the only nest site where we have productivity data for both years was four. AGFD observations of nesting adults, surviving young and unpaired males at other territories resulted in confirmation of 20 individual pygmy-owls in 1998. The combined number of fledglings for all years was 22. The known number surviving through dispersal for all sites was 19 (dispersal success= 86.4%) (Abbate *et al. 1*999)

The final report on the AGFD pygmy-owls survey and monitoring effort was published in 2000. In this report, a variety of methods where used and population survey efforts by AGFD using tape broadcast and look and listen type surveys resulted in 21 initial detections from 4 January to 23 June 1999. Eighteen were territorial males calling in response to a tape broadcast or calling spontaneously during the surveyor's visit. Two females were detected in the vicinity of their mates calling in response to the tape broadcast or reacting to the male's response. One detection appeared to be a female using the one-note territorial call and other sounds, but, while there was visual observation of this pygmy-owl, sex could not be confirmed. Ten detections were from eight known territories. Five of these territories contained successful nesting pairs in previous years. Three other territories were established by dispersing juveniles at the end of the 1998 breeding season. The remaining eleven detections are considered separate territories and were located for the first time during 1999. Follow-up-visits in response to owl reports by other agencies and contract biologists resulted in confirmation of 12 additional detections. These included 7 territorial males responding to tape broadcasts. Five of these males were eventually found to be paired with females after multiple monitoring visits and capture attempts. Two additional detections were reported by experienced surveyors and though not confirmed by AGFD, are considered reliable. AGFD confirmed a total of 35 initial detections of pygmy-owls during 1999 (Abbate *et al. 2*000)

AGFD survey and monitoring efforts in 1999 resulted in confirmation of 25 occupied territories prior to dispersal of young. In cooperation with FWS' contract biologists and National Park Service biologists at OPCNM, we located 11 active pygmy-owl nests. AGFD recognized 28 total territories when pre and post-dispersal sites are combined (Abbate *et al. 2*000).

Use of radio telemetry enabled AGFD to document exchange between pygmy-owl population groups in Arizona (Abbate *et al. 2*000, p. 30). A young of the year from a nest site in NW Tucson dispersed north for approximately 12 miles crossing into Pinal County. The transmitter failed at this point and it is unknown if the juvenile continued to disperse. The final location we recorded for this juvenile was in the general vicinity of an occupied pygmy-owl nesting territory. Coincidentally, another young of the year from the nest in Pinal County dispersed south into NW Tucson, ending up approximately 13 miles from its nest site. This exchange of dispersing juveniles between population groups indicates that juveniles can disperse relatively long distances through unfragmented, habitat.

Since pygmy-owls do not migrate, the opportunity to expand the range of the pygmy-owl and to provide interchange among pygmy-owl population groups primarily occurs as a result of juvenile dispersal. Therefore, habitat connectivity is needed to support these dispersal movements across the landscape. Some efforts have been made in Arizona to maintain habitat connectivity. Specifically, The Tucson Mitigation Corridor and other parcels were acquired by the Bureau of Reclamation as mitigation associate with the development of the Central Arizona Project, with the primary objective to provide habitat conservation and connectivity. The Tucson Mitigation corridor (2, 514 acres) and two additional parcels (totaling just over 81 acres) support habitat for the pygmy-owl and occur in an area that provides important habitat connectivity for pygmy-owl movements through the Avra Valley and between the Tucson and Roskruge mountains west of Tucson (Heath 2020, p. 2).

In addition to the work done by AGFD, Flesch *et al.* (2017) conducted analysis on occupancy data from pygmy-owl monitoring that was completed in Arizona during the period 2000 to 2016 by AGFD and FWS. This analysis included looking at a total of 288 occupancy surveys at 39 territory patches in years following the initial discovery of each territory. Effort was greatest in 2014 when 37 territory patches were surveyed and lowest in 2008 when only 4 patches were surveyed. Over time, an average of 18.0 ± 2.9 patches was surveyed each year. Annual territory occupancy averaged 39.8% among years and ranged from 71.4 ± 17.1% in 2011 to 11.1 ± 6.1% in 2003. Survey effort was sporadic across time. Number of territory patches within watershed regions averaged 10.6 ± 1.4 and ranged from 4 to 19 (Flesch *et al. 2*017). As a result of this analysis in Arizona, populations in two of three watershed regions we considered declined to extinction, whereas occupancy increased across time in a third region. Such results indicate the importance of consistently monitoring populations of conservation concern across time and space so that short-term changes in populations can be distinguished from systematic declines over the long term. Additionally, it is also important to include long-term evaluations of new sites and sites not studied recently to help document sites recently occupied by pygmy-owls as population groups move and change over time (Enríquez 2021, pers. comm.).

Large interactive effects of climatic flux and land-use change combined with anticipated environmental change suggest declines in some watershed units did occur and that declines in other units could develop in the future that may be masked by overall stability across a broader region.   For example, two of the three subpopulations included in the analysis by Flesch *et al.*(2017, p. 12) in Arizona experienced varying dynamics, with two decreasing to extirpation while a third that was located in an intervening region increased markedly across time. In the southernmost region in Arizona (upper Brawley), such dynamics may have been driven by low habitat quality and quantity due to a scarcity of nesting substrates at these relatively high elevations, and by reductions in landscape connectivity with larger populations in Mexico linked to development along the United States-Mexico border. In northwest Tucson, in contrast, such changes were likely driven by major increases in landscape disturbance linked to urban development, as well as the potential barrier of Interstate 10 which divides the extirpated northern population groups from the extant southern population group. For pygmy-owls, landscape disturbance can disrupt dispersal movements in ways that reduce colonization success, functional connectivity, and local rates of patch occupancy (Flesch *et al. 2*010; Flesch *et al. 2*017). Thus, despite relatively high regional abundance and increasing occupancy in a neighboring region (lower Brawley), which could provide an important source population, landscape degradation in and around northwest Tucson, including Interstate 10, likely reduced dispersal movements into this region at a time when immigrants were needed to offset the impacts of drought and other stressors.

In the 1990’s and early 2000’s, the pygmy-owl was found only in portions of Pima and Pinal Counties (Figure 4.6). The Arizona Breeding Bird Atlas reports confirmed occurrences of the pygmy-owl in only three blocks distributed in Pima and Pinal Counties (Arizona Breeding Bird

Atlas (ABBA) 2005, p. 219). Twelve other blocks recorded probable (3) or possible (9) occurrences, but none occurred outside of Pima and Pinal Counties (ABBA 2005, p. 219). During this time period, surveys indicated that probably fewer than 50 adult pygmy-owls existed in the state, with 10 or fewer nest sites on an annual basis (Abbate *et al. 2*000, pp. 15–16; AGFD, unpublished data). However, since the pygmy-owl was delisted in 2006 (71 FR 194521; April 14, 2006), surveys, monitoring, and other research on pygmy-owls has declined. Limited survey and monitoring in Arizona from 2009 to 2011 documented that pygmy-owls still occupy historical locations in the Altar Valley, Avra Valley, and Organ Pipe Cactus National Monument, all within Pima County (FWS 2009b, p. 1; Tibbitts 2011, pers. comm.; FWS 2011, p. 1). Comprehensive surveys have not been conducted on the Tohono O'odham Nation (Nation), which is located in the central portion of both the historical and current distribution of pygmy-owls in Arizona. However, historically, a number of surveys have been completed for various utility projects on the Nation, and the pygmy-owl is known to occur there. While data related to the number of detections were made available, the Nation, as a sovereign entity, chose to limit the extent of the data from these surveys that is distributed outside of the Nation and these data are therefore not available for analysis. There are large areas of habitat on the Nation, but the information we have indicates that pygmy-owls are patchily distributed, just as in other areas of the State, and occur at similar densities.

Figure 4.4 Pygmy-owl nest saguaro in Pima County, Arizona. (Photo credit: Paul Bannick)

Extensive pygmy-owls surveys were conducted in Arizona in the spring of 2020 giving us a clearer picture of the current distribution of pygmy-owls in Arizona (AGFD 2020, pers. comm.).

During the spring of 2020 the Arizona Game and Fish Department, U.S. Fish and Wildlife Service and Audubon Society volunteers surveyed 17 geographic areas for pygmy-owls in southern Arizona (Figure 4.5). The protocol used a 6-minute con-specific broadcast/listening sequence at call points spaced a minimum of 400 m apart. Each call point was surveyed once from early March to early May of 2020. A total of 808 call points were surveyed and two new nesting territories were found (Table 4.1). In addition, 56 call points were sampled on the Tohono O'odham Nation lands and four pygmy-owls were detected. Personal communication with Tribal staff indicates that pygmy-owls continue to be found on the Tohono O'odham Nation, although comprehensive surveys have not been conducted and information on specific locations of pygmy-owls is not released by the Tohono O'odham nation (Verwys 2020 and 2021, pers. comm.)

Additionally, in 2020 pygmy-owl nest territory monitoring was conducted at territories that were historically active in 2005 – 2007 nesting seasons (AGFD 2020, pers. comm.). Monitoring of historically active nest sites was conducted by OPCNM, Pima County Office of Sustainability and Conservation (PCOSC), and AGFD. The AGFD initially started with a database representing 37 historically active nest sites, OPCNM monitored 12 historically active territories and PCOSC monitored all 21 pygmy-owl territories that were active in 2017 within lands owned and managed by the Pima County (Figure 4.5).

Of the territories monitored by AGFD six were duplicate records from the 2005 – 2007 monitoring seasons where the same saguaro was utilized for nesting during multiple years. The total number of sites that were initially monitored for nesting was reduced to 31. During the monitoring sessions, male and female pygmy-owl digital playback calls were utilized to solicit a response from the respective monitoring territories. In addition, surveys were conducted within the extent of a 400 m radius of the historical nest site to identify alternative nesting saguaros in the area. If a pygmy-owl response was detected beyond the 400m survey areas, those birds were pursued and provided a new territory designation. A total of 19 additional sites were added to the 31 historical sites based on call back response from territory monitoring and additional spot checks by high grading habitat in the landscape. This additional effort resulted in 50 territories that were visited at a minimum of 3 times by AGFD staff. Of the additional 19 sites, two were as a result of range wide population surveys which identified two new territories on the northern extent of their range along the Ironwood Forest National Monument (IFNM).

The AGFD efforts in monitoring 50 territories resulted in 11 of the original 31 historical territories vacant, 31 territories occupied by a pair (15 of the 31 historical sites) and 8 territories occupied by a single bird (3 of the 31 historical sites), often a male.

PCOSC documented 10 nests, but nest searches were only conducted at ~50% of occupied areas (PCOSC 2021, pp. 5 – 6).

AGFD conducted follow-up monitoring in 2021 for many of the sites that were active in 2020 and that data has been entered into the Heritage Data Management System (HDMS) (AGFD 2021b, pers. comm.). In total, within southern Arizona, over 100 territories were monitored resulting in at least 57 active nest sites with a pair present, and 12 sites occupied by a single bird. This extended stakeholder survey effort identified declines in populations in some locations, new population groups novel to managers and some of the highest nesting records for the state. AGFD’s survey and monitoring efforts in 2020 and 2021 did not provide any information on productivity or survival at these sites. Currently, the known abundance of pygmy-owls is higher in Altar Valley than it was in the previous decade, likely due to increased survey and monitoring under the Pima County Multi-Species Conservation Plan and by the AGFD (Flesch 2018a, entire; AGFD 2020, pers. comm.; PCOSC 2021, entire). However, occupancy in the Altar Valley appeared to be down in 2022, potentially in response to the dry winter of 2021–2022 and ongoing drought conditions (AGFD 2022, unpublished data; FWS 2022, unpublished data; NDMC 2022, unpaginated).

However, despite the changing regulatory environment and inconsistent availability of resources, survey and monitoring activities provide important information on the abundance and distribution of pygmy-owl across its range and, with that information, managers can more effectively and efficiently work to conserve the pygmy-owl.

Figure 4.6 shows the change in distribution of pygmy-owls in Arizona from the 1800’s to present day.

Table 4.1 Summary of Cactus Ferruginous Pygmy-owl survey efforts in Arizona, 2020 (BMGR=Barry M. Goldwater Range; IFNM=Ironwood National Monument). The site numbers correspond to their general locations in Figure 4.5.

Site Name	Site Number	Number of Call Points	Pygmy-owl Detections
Cabeza Prieta	1	44	0
Organ Pipe	2	79	0
Ajo	3	56	0
Why	4	19	0
BMGR-E	5	22	0
Table Top	6	46	0
North IFNM	7	24	0
Mid IFNM	8	12	0
South IFNM	9	93	2
Samaniego/Ragged Top	10	40	0
Arivaca	11	47	0
Tubac	12	21	0
West Tucson	13	67	0
NW Tucson	14	67	0
Park Link/Florence	15	106	0
Mammoth	16	30	0
South Rincon	17	35	0
Sub-total		808	2
Tohono O’odham Nation		56	4
TOTAL		864	6

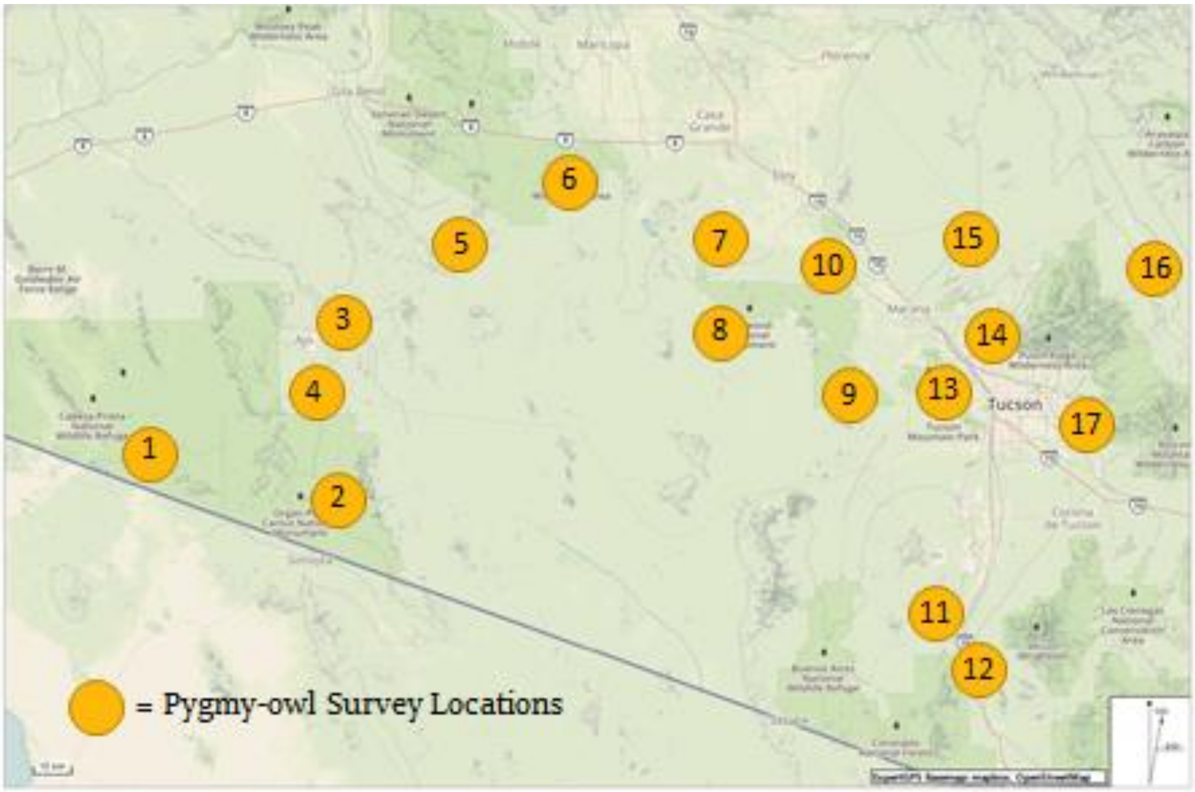


Figure 4.5 Locations of areas where pygmy-owl surveys were conducted in the spring of 2020.
*Please note that PCOSC survey locations are not indicated on this map. Their surveys were primarily conducted in the northern Altar Valley to the west/northwest of Number 11 on the map.

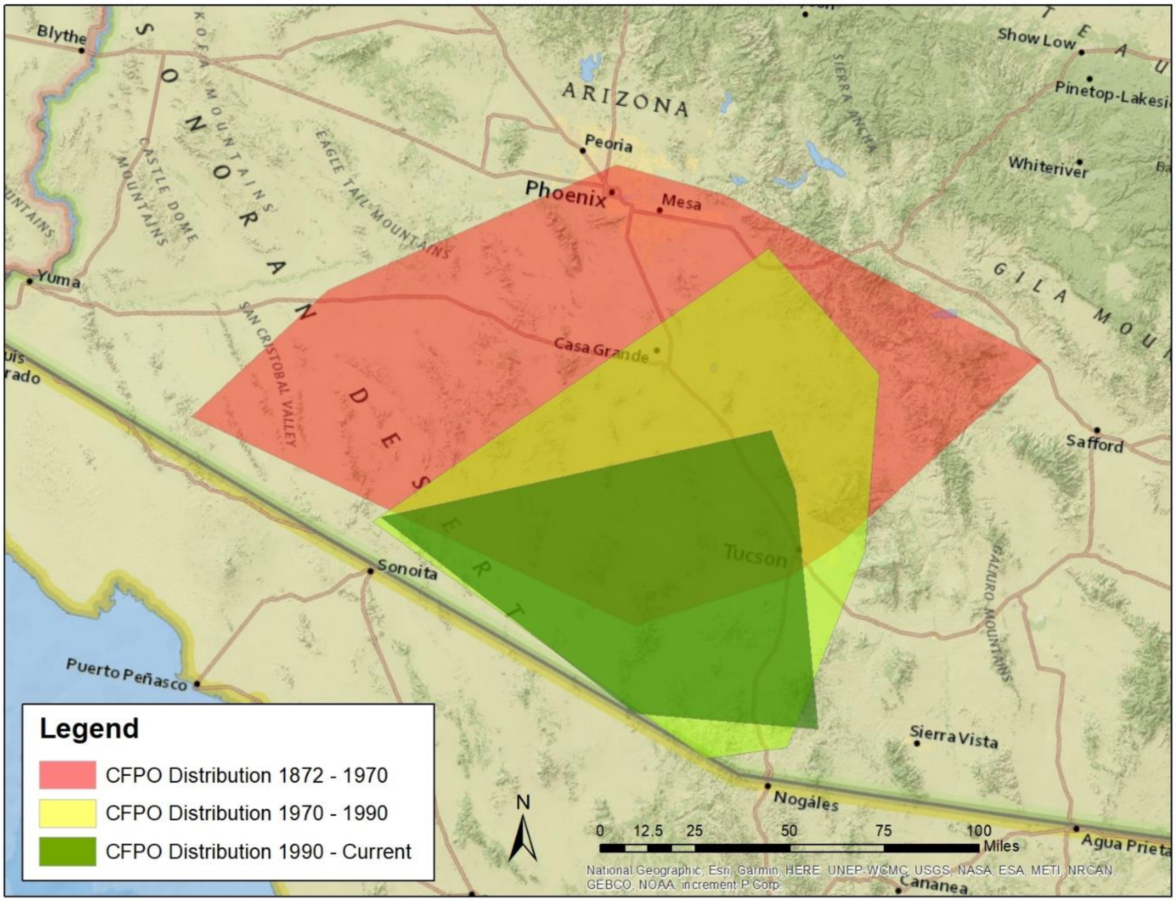


Figure 4.6 Change in distribution of cactus ferruginous pygmy-owls in Arizona. Data provided by the Arizona Game and Fish Department.

4.1.1.2 Northern Sonora

As recent as the 1990’s, the pygmy-owl was thought to be uncommon throughout much of Sonora but these findings were highly limited by lack of systematic effort and limited work in the north prior to recent studies (Russell and Monson 1998, p. 141; Hunter 1988, pp. 1–6). However, recent surveys and capture efforts have shown that the pygmy-owl regularly occurs in both northern and southern Sonora, but are less common in central Sonora in a broad transition zone where large columnar cacti are rare between more temperate desertscrub in the north and subtropical forest to the south (Flesch 2003, p. 39; AGFD 2008a, pers. comm.; FWS 2009a, p. 1; Flesch 2021, entire; Cobbold et al. 2021, entire; Cobbold et al. 2022a, entire). Flesch (2003, p. 39) documented 438 males, 74 females, and 12 pygmy-owls of unknown sex along 1,113 km (692 mi)) of randomly placed transects in lowland Sonora, and an additional 112 pygmy-owls incidentally detected.

Although not comparable to Flesch’s randomized survey effort, during capture efforts in 2008, AGFD (2008a, pers. comm.) documented multiple pygmy-owls commonly responding at capture sites in the thornscrub and tropical deciduous forests of southern Sonora. In contrast, in areas of central Sonora sampled by AGFD, some sites had no pygmy-owl responses, but responses increased as sampling moved into northern Sonora. These results are similar to patterns of occupancy documented by Flesch with higher abundance of owls in northern and southern Sonora, and fewer owls in central Sonora (2003, p. 40). It is also clear that the number and density of pygmy-owls is higher in the tropical deciduous forests in southern Sonora than in the Sonoran desert of northern Sonora. This occurrence and distribution agrees with conclusions found in the literature (Hunter 1988, p. 7; Russell and Monson 1988, p. 141).

Within 150 km of Arizona, pygmy-owls were rare to locally common between Saric and Sonoyta, rare west of Mexico Route 2, and absent west of Sonoyta and north of Magdalena. Owls occurred at elevations between 10 and 1,100 m, but only above 1,000 m in northern Sonora (Sasabe and east of Magdalena), and only below 30 m in extreme southwestern Sonora or along large drainages (Rios Yaqui and San Ignacio) (Flesch 2003). Figure 4.7 shows the distribution of owls occurrences in northern Sonora based on Flesch (2003, p. 39).

Flesch (2003, entire) sampled 145 landscapes statewide, of which, 95 (65.5%) harbored >l pygmy-owl. Pygmy-owls occurred along 48% of transects at a density of 0.82 ± 0.37 males/100 ha statewide. Relative abundance ranged from 0 to 1.25 males/station and averaged 0.13 ± 0.04 statewide. Density (males/100 ha) was high in Sinaloan Deciduous Forest (2.00 ± 0.82) and Arizona Upland desertscrub (1.47 ± 0.61), moderate in Semidesert Grassland (0.99 ± 0.45), Sinaloan Thornscrub (0.85 ± 0.37), and Plains of Sonora desertscrub (0.56 ± 0.31), and low in Lower Colorado River Valley (0.26 ± 0.13) and Central Gulf Coast (0.08 ± 0.04) desertscrub. Density in the Sonoran Desert was slightly lower than statewide estimates (0.67 ± 0.32).

Relative abundance was higher on the Coastal Plain (0.18 ± 0.02 males/station, n = 297) and adjacent foothills and valleys (0.14 ± 0.04, n = 41) than in interior foothills and valleys of the Sierra Madre Occidental (0.003 ± 0.033, 11 = 50) ($F_{2, 285} = 12.26$, P < 0.0001). On the Coastal Plain, owls occurred along 52.4% of transects compared to only 2.0% of transects (n = 1 of 50) in the interior (Flesch 2003).

Relative abundance was high in northern and southern Sonora and low in central Sonora. Although pygmy-owls were thought to be absent or rare in northern Sonora, they range from rare to locally common along a portion of the border with Arizona. In northern Sonora, pygmy-owls were most common between 600 and 800 m elevation and near the ecotone between Arizona Upland desertscrub and Semidesert Grasslands. Although all previous nesting records were from the extreme southern Sonora (Russell and Monson 1998), Flesch (2003) located 35 nests within 10 km of Arizona. This number of nests increased to approximately 100 nest sites as a result of further work in Sonora (Flesch *et al.* 2015, p. 11).

Pygmy-owls were distributed in relatively few areas of high abundance, with abundance more similar at nearby sites than at distant sites. In other words, pygmy-owls were found to be patchily distributed across the landscape, similar to their distribution in Arizona. Although abundance is predicted to be greatest near the center of a species' geographic range and to decline gradually toward the edges (Hengeveld and Haeck 1982; Rapoport 1982; Brown 1984), abundance patterns of pygmy-owls did not conform to this prediction. Instead, a bimodal pattern with peaks in northern and southern Sonora separated by central Sonora was revealed, where columnar cacti large enough to support nesting cavities were rare and upland vegetation structure often dense and short (Flesch 2003). Such an exception is anticipated when one or more important environmental factors exhibit spatial variation (Brown 1984; 1995). Although unimodal patterns of abundance are often expected, the spatial arrangement of important environmental factors, dispersal potential, and biotic interactions can potentially produce a myriad of patterns (Flesch 2003).

Subsequent studies by Flesch (2008, entire) estimated that abundance of pygmy-owls within 75 km of Arizona has declined by an average of approximately four percent or 28% over eight years. Similarly between 2002 and 2007, territory occupancy within 110 km of Arizona has declined by an average of approximately 3.4% per year or 17% over six years. Despite these declines, the author documented that there was some degree of variation in trends among regions. In the Upper Rio Plomo watershed for example, abundance has increased markedly since an eight-year low in 2004. Abundance declined most precipitously in the Upper Rio Altar watershed and near Sasabe, regions that are closest to Arizona and, therefore, most relevant to management and recovery in Arizona (Flesch 2003).

The value of long-term monitoring projects became evident as Flesch *et al.* (2017, entire) summarized overall trends in pygmy-owl abundance in northern Sonora based on seventeen years of study. Long-term monitoring of 18 survey transects in northern Sonora between 2000 and 2016 (n = 123 stations/year) recorded an estimated total of 573 detections of male pygmy-owls on territories. The study conducted 1,346 occupancy surveys at 112 territory patches in years following the initial discovery of each patch. Aside from 2012, when no data were gathered, effort was greatest in 2009 when 108 territory patches were surveyed and lowest in 2001 when only 31 patches were surveyed due to identification of few territories during initial efforts in 2000. Over time, the study surveyed an average of 89.7 ± 5.7 (± SE) patches per year. Annual territory occupancy averaged 59.7% among years and ranged from 80.1 ± 7.1% in 2001 (± binomial SE) to 45.4 ± 4.8% in 2009.

Although there was high temporal variation in abundance, there was little evidence of systematic declines over the 16 years of study. Observed abundance was high initially (55 males in 2000), declined steadily to 2008 (21), increased in 2009-2011 (34-39), decreased somewhat in 2013 and 2014 (28-31), and then increased markedly during the final two years of study to near initial levels (49-51) (Flesch *et al. 2*017).

Despite marked declines in abundance of ferruginous pygmy-owls in northwestern Mexico reported in some years (Flesch and Steidl 2006; Flesch 2014a), Flesch *et al.*(2017, entire) found no evidence of systematic declines between 2000 and 2016 due to relatively high numbers of detections in years 2015 and 2016. Similarly, there was little evidence of systematic declines in territory occupancy across an overlapping but much larger area of northern Sonora, Mexico and portions of adjacent Arizona between 2001 and 2016. Instead, spatial variation in population dynamics was more complex with the direction and magnitude of trends widely across space among various watershed regions. Despite these somewhat more auspicious patterns, had abundance and occupancy not increased markedly in Sonora 2015 and 2016, Flesch *et al.*(2017, entire) would almost certainly have found significant declines in both parameters across time based on recent analyses (Flesch 2014b). Further, despite the relative stability of population units in several regions in Sonora, there was little evidence occupancy increased in any region. Such results indicate the importance of consistently monitoring populations of conservation concern across time and space so that short-term changes in populations can be distinguished from systematic declines over the long term. Despite the absence of systematic declines across the broad region considered here, large interactive effects of climatic flux and land-use change combined with anticipated environmental change suggest declines could develop in the future (Flesch *et al. 2*017). Additional monitoring of the 18 transects in northern Sonora is scheduled for spring 2021 to further assess population trends and possibly revise current estimates (Flesch 2020, pers. comm.).

Threats resulting in reduced vegetation condition and increased habitat fragmentation have been documented in northern Sonora (Flesch 2014, entire; Flesch et al. 2015, entire; Flesch et al. 2017, entire; Flesch 2021, entire; Wild Sonora 2021, unpaginated). In 2012, a climate change study was published predicting a reduction in saguaros in the Sonoran Desert (Thomas et al. 2012, p. 43). Saguaros are the key nesting substrate for pygmy-owls in the Sonoran Desert of northern Sonora. In addition, a retired Service biologist who led the Sonoran Joint Venture provided updated information on the status of land use and impacts to pygmy-owls in Sonora, including the reduction of pygmy-owl habitat related to water use and pumping (Mesta 2020, pers. comm.).

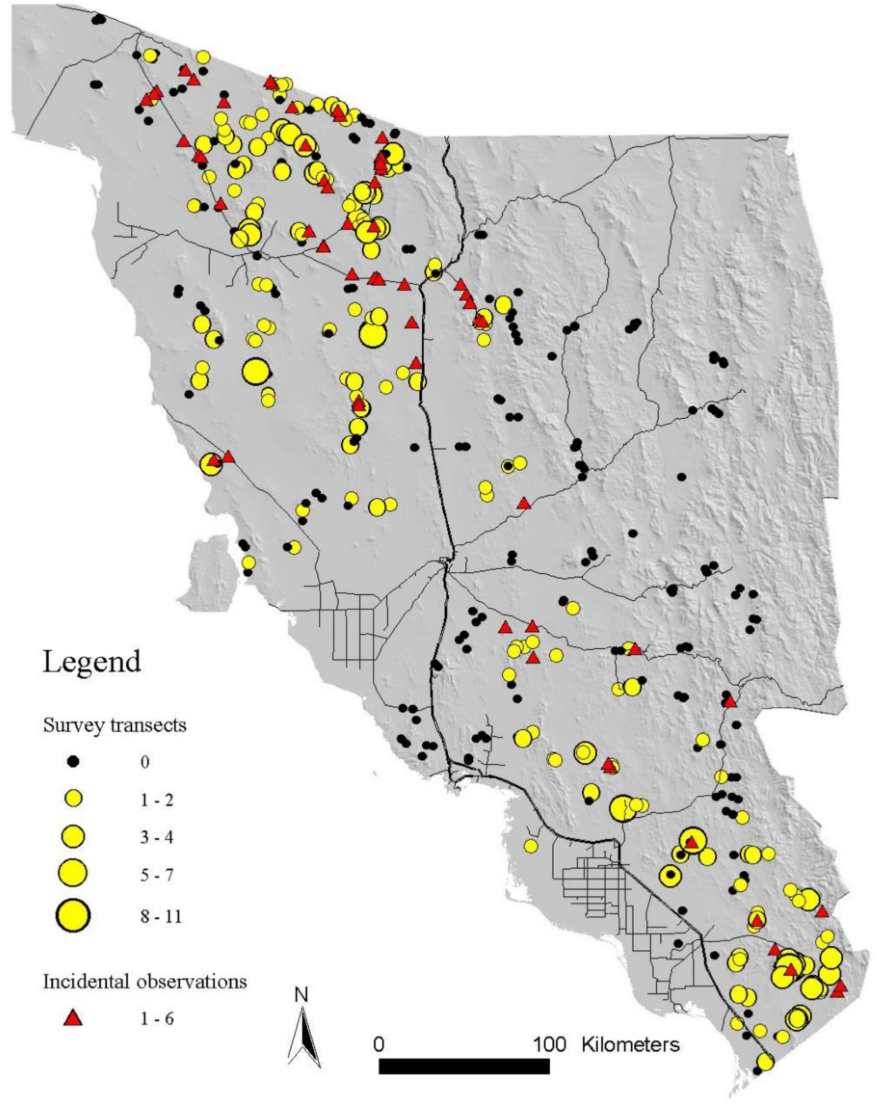


Figure 4.7 Distribution and numbers of pygmy-owls in Sonora, Mexico from Flesch 2003. Reproduced with permission from Aaron Flesch.

4.1.1.3 Western Mexico

Specific data related to numbers and distribution of the pygmy-owl in the Western Mexico analysis unit are lacking. There are no recent pygmy-owl survey or monitoring data for the western Mexico, so we continue to have no recent, verified data on abundance or occupancy. We used eBird, iNaturalist, and museum specimen records to get a general scope of occurrences in these areas, but did not use these records to estimate abundance (GBIF 2020, unpaginated; Johnston et al. 2021, p. 1266). Very general information we have from the literature for the Western Mexico analysis unit indicates that pygmy-owls are one of the most common birds collected in these areas (Cartron *et al.* 2000, p. 5; Enríquez-Rocha *et al.* 1993, p. 154; Binford 1989, p. 132; Hunter 1988, p. 7; Johnsgard 1988, p. 161; Oberholser 1974, p. 451; Schaldach

1963, p. 40). It is important to note, however, that most of these references apply to the ferruginous pygmy-owl as a species and not to the *cactorum* subspecies specifically and may include areas outside of this analysis unit. Enríquez-Rocha *et al.* (1993) indicated that the greatest number of museum specimens from Mexico were of the ferruginous pygmy-owl (*Glaucidium brasilianum*), indicating that the ferruginous pygmy-owl was the most collected owl species in Mexico. One thousand one hundred thirty-one specimens from 23 states were recorded, but we do not know how many of these came from the Western Mexico analysis unit.

However, studies conducted in the early 2000's that included some areas of the Western Mexico analysis unit indicated that the highest densities of pygmy-owls in Sonora occurred in the Sinaloan deciduous forest of southern Sonora (Flesch 2003, p. 42). Additionally, in subtropical environments of southeastern Sonora, pygmy-owls may be more limited by biotic factors such as competition rather than physical factors (Pianka 1970; Gross and Price 2000). At higher elevation and lower longitude, Colima pygmy-owls (*Glaucidium palmarum*) replaced ferruginous pygmy-owls on steeper slopes and in upper elevation tropical forest. In southern Sonora, pygmy-owls were common in tropical forest and thornscrub between 10 and 500 m elevation (Flesch 2003).

Additional information for the northern portions of the Western Mexico analysis unit come from capture efforts in 2008 when AGFD (2008a, pers. comm.) documented multiple pygmy-owls commonly responding at capture sites in the thornscrub and tropical deciduous forests of southern Sonora. In contrast, areas of central Sonora sampled by AGFD had some sites where they had no pygmy-owl responses, but responses increased as sampling moved into northern Sonora. These results are similar to patterns of occupancy documented by Flesch (2003, p. 40), with higher owl abundance in northern and southern Sonora, but low abundance in central Sonora. However, it is clear that the number and density of pygmy-owls is higher in the thornscrub and deciduous forest community types than in the Sonoran desert community type. This occurrence and distribution agrees with conclusions found in the literature (Hunter 1988, p. 7; Russell and Monson 1988, p. 141; Shaldach 1963, p. 40). A total of 119 pygmy-owls were captured by AGFD over 15 days of trapping in northern Sinaloa and Sonora, with most of the owls captured in southern Sonora and Sinaloa (AGFD 2008a, pers. comm.).

The most current information we have with regard to locations of pygmy-owls in the Western Mexico analysis unit comes from the *Global Biodiversity Information Facility* or GBIF databases (GBIF 2020). This occurrence information includes data from iNaturalist, eBird, and various museum specimens. These data cover a wide time period but, while this is the best available information regarding pygmy-owl occurrence records, they do not correlate with actual numbers of pygmy-owls in the analysis unit, nor does it represent an estimate of actual owl numbers. Records within these databases my represent multiple reports of the same pygmy-owl occurrence in the same or over a range of years or in other ways that do not allow for estimating actual numbers of pygmy-owls. These data only represent information from areas where those reporting the data looked for or observed pygmy-owls. It does not represent a comprehensive effort to document the numbers and distribution of the pygmy-owl. Given those limitations, the GBIF databases provided documentation of 8,280 pygmy-owl locations in the Western Mexico analysis unit. Figure 4.2 shows the distribution of these records within the Western Mexico analysis unit.

The conservation of pygmy-owls is complicated by the fact that this analysis unit includes several states in Mexico (Sonora, Sinaloa, Nayarit, Colima, Jalisco, and Michoacan). The administration of land use in Mexico depends not only on the Federal government that implements, for example, Natural Protected Areas, but also the policies of each state and even municipal governments (Enríquez 2021, pers. comm.). This represents a wide range of management, conservation, and natural resource use approaches that affect pygmy-owl conservation in this analysis unit as a result of inconsistent policies and implementation of conservation activities and differing priorities for conservation and other land uses. Enríquez (2021, pers. comm.) also states that it is important to study the pygmy-owl across its range in Mexico to determine the variables and local, state, and regional threat factors that contribute to the current condition of the pygmy-owl population in Mexico.

4.1.2 Eastern Population

4.1.2.1 Texas

Pygmy-owls historically occurred in south Texas primarily within a six-county area including Brooks, Kenedy, Willacy, Cameron, Hidalgo, and Starr counties (TBBA 2006). Griscom and Crosby (1926, p. 18) reported that the pygmy-owl was considered a “common breeding species” in the Brownville region of southern Texas. Even as late as 1950, Friedman *et al.* (1950, p. 145) considered the pygmy-owl to be “a very common breeding bird.” Although once thought to be common in the mature riparian mesquite-ebony (*Prosopis glandulosa-Ebenopsis ebano*) forests of the Rio Grande (in Cameron, Hidalgo, and Starr counties) (but see discussion in the Arizona section above related to observations by early explorers and naturalists), the cactus ferruginous pygmy-owl is no longer considered a common resident there. From the 1920’s until the early 1970’s, over 90 percent of pygmy-owl habitat in the Lower Rio Grande Valley (LRGV) of Texas was cleared for agricultural and urban expansion (Oberholser 1974, p. 452). Other avian species that specialize in mature riparian forest have also declined in the LRGV due to habitat loss (Leslie 2016, p. 36). By the 1970s, the pygmy-owl was encountered only rarely in Texas. At best, pygmy-owls are now only intermittently found along the Rio Grande with no recent nesting documented. Changes in hydrology to the lower segment of the Rio Grande have depleted and altered the riparian woodlands to the extent that they are likely no longer favorable to these owls. Several dams along the Rio Conchos in Mexico and the Rio Grande itself, namely Falcon Reservoir in Texas, plus various irrigation canals for farming have stopped the normal up-and-down flow of water into the woodlands and oxbows (aka "resacas") adjacent to the river. Thus, there's been a slow xerification of those woodlands that once flourished in a more mesic setting due to natural flooding events (Shackelford 2020, pers. comm.). In general, pygmy-owl population groups have also been shrinking in most of Texas since the 1920's (Davis 1966; 1974; Oberholser 1974; Wauer *et al.* 1993; Mays 1996; Lockwood and Freeman 2004), particularly along the peripheries of habitation.

Most of the pygmy-owls in Texas now occur on private ranches up to at least 129 km (80 mi) north of the Rio Grande in south Texas, within Brooks, Hidalgo, Kenedy, and Willacy counties. The habitat used in these locations are not riparian woodlands but are oak mottes and oak woodlands scattered within an area known as the "Wild Horse Desert" within the Tamaulipan Brushland Bird Conservation Region 36 (NABCI 2021, unpaginated). Mesquites are also used regularly in this area by pygmy-owls (Proudfoot 2021, pers. comm.). Texans often refer to that area as a sub-ecoregion known as the Kenedy Sand Sheet, some of which resembles an erg landform. The dominant canopy tree in these mottes and woodlands is southern live oak (*Quercus virginiana*) named for the green leaves they hold year-round (Figure 4.8). The ranchers will usually strongly protect them as they are not only aesthetically pleasing but they also provide much needed shade to livestock and wildlife. Cattle ranching and hunting for both big and small game are very popular on those ranches so protection of those oaks is important, and the oaks typically are spared when development, such as wind farms or oil and gas operations, is proposed. Ranches will sometimes remove oaks as part of their ranching operations (Proudfoot 2021, pers. comm.). These oaks are slow-growing mostly atop sand and gravel thus are very strong and have survived many hurricanes. A more recent threat to pygmy-owls and pygmy-owl habitat has emerged in Texas in recent years and that threat is extended, deep freezes that can potentially effect pygmy-owls themselves, pygmy-owl prey, and pygmy-owl habitat in areas that have not historically been affected by such prolonged cold weather (Bond 2022, unpaginated).

Figure 4.8 Oak motte habitat on the King Ranch in Texas (Photo credit: Glenn Proudfoot)

In 1999, Hurricane Bret stripped practically all the leaves off the branches of the oaks in this area, but most quickly bounced back (Shackelford 2020, pers. comm.). However, the role of hurricanes and other natural events has been linked to pygmy-owls population declines. For example, major droughts between 1994 and 2016, especially 2005-2006, resulted in significant mortality of oak trees (Proudfoot 2021, pers. comm.). Relatively recent concern about the populations in Texas has been raised because of an apparent decline in the number of pygmy-owl nestlings banded as part of an ongoing nest box study in Texas (Figure 4.9). The numbers of nestlings banded at more than 200 nest boxes in 2003 and 2004 were 84 and 96 respectively. Ongoing monitoring then suggests a steady decline from 2004 to 2010, with 25 and 24 nestlings banded in 2009 and 2010, respectively (Proudfoot 2010, pers. comm.). This represents an approximate 70 percent decline in the number of nestlings banded over an 8-year period. Proudfoot (2011b, pers. comm.) indicates this decline is likely the result of the loss of habitat around nest boxes due to recent hurricanes and fires. Without a more comprehensive survey effort in southern Texas, we cannot definitively state that the overall population of pygmy-owls in south Texas matches the decline of nestlings documented during this nest box study. However, it does raise our level of concern for this population. More work is needed in Texas to determine the overall population status and the extent of habitat loss and fragmentation. It may simply be that the pygmy-owls in these areas have moved to adjacent habitat as former habitat and the associated nest boxes have been destroyed.

Figure 4.9 Pygmy-owl nest boxes installed on the King Ranch in Texas. (Photo credit: Glenn Proudfoot)

This nest box work was conducted on five ranches, as well as some land tracts in the Lower Rio Grande Refuge System, but was initiated on the Norias Division of the King Ranch, in Kenedy County, which has been the study site for cactus ferruginous pygmy-owl research from the mid-1990’s to the mid-2000’s (Mays 1996; Proudfoot 1996; Proudfoot and Beasom 1997; Proudfoot 2006a; Proudfoot 2006b; Proudfoot 2006c). Nest box studies began on the Norias in 1994 and expanded to El Tecolote Ranch in 1995. Work was completed on the Norias in 2013 and on the El Tecolote in 2016. Both ranches had approximately the same number of nest boxes (Proudfoot, 2021. Pers. comm.). The Norias Division has been isolated by agricultural expansion, which has restricted dispersal (Oberholser 1974). According to Mays (1996), the isolation of population groups in Brooks and Kenedy counties leaves the genetic health of the south Texas pygmy-owls in question.

The pygmy-owls in Kenedy County were first referenced in Oberholser’s 1974 account (reporting sightings in 1968 and 1969). It is unknown if this sub-population represents a northward expansion of the Rio Grande birds or if the two areas were connected and part of a single, larger subpopulation prior to land clearing and other habitat changes. Limited connectivity may still exist on the east side of Hwy. 77 (Proudfoot 2021, pers. comm.) Because almost 96% of Texas is privately owned (Leslie 2016, p. 45), access is limited and this may have delayed the discovery of this subpopulation (Mays 1996). Nonetheless, Wauer *et al.* (1993, pp. 1074-1076) indicate that private ranches in Kenedy, Brooks, and Kleberg counties in Texas support a "large and apparently thriving population of ferruginous pygmy-owls." Through interviews, Tewes (1993) received information indicating some pygmy-owls still exist in southern Texas and may possibly be locally abundant in a few locations. He indicated that Mr. Roland Wauer has been censusing pygmy-owls in Kleberg County and believes >100 owls, and possible as many as 2,000-3,000 may occur in the oak communities found in this area (Tewes 1993, p. 24).

A number of other descriptions of this population group exist in the literature. During the Texas Breeding Bird Atlas (BBA) project (1987–1992), only 2 nest sites confirmed below Falcon Dam in Starr Co., TX, and 6 probable sites between Rio Grande and 27°N (TBBA 2006) (Figure 4.10). It is important to understand that work for the Texas Breeding Bird Atlas may not have access to many of the large tracts of private land in Texas. Other work documents occupancy in Brooks and Kenedy Counties on the King Ranch and adjacent ranches in Texas (Proudfoot 1996, p. 6; Mays 1996, p. 29). Mays (1996) states that the distributional patterns and population size estimates calculated from her study suggest that the cactus ferruginous pygmy-owl population occupying the Wild Horse Desert region is larger and more widespread than known populations along the Rio Grande in Texas.

Population estimates in Texas include estimates of 654 pairs in Kenedy, Brooks, and Willacy Counties (Wauer *et al. 1*993, p. 1074), 745 to 1,823 pygmy-owls on ranches in Kenedy and Brooks Counties (Mays 1996, p. 32), 111 pairs in Badeno Pasture in the Norias Division of the King Range, 654 pairs in all of Kenedy, Brooks, and Willacy counties (Wauer *et al. 1*993), and broadcast surveys in Brooks and Kenedy Counties in 1994 recorded 66 owl responses (TBBA 2006).

Threats to the pygmy-owl and pygmy-owl habitat from drought, as well as fire, freezes, and hurricanes (Harvey in 2017, Hanna in 2020, and Ida in 2021) have all continued in Texas over the past decade (EPA 2016, unpaginated; Bhatia et al. 2019, entire; Shackelford 2020, pers. comm.; Inciweb 2021, unpaginated; Bond 2022, unpaginated; NDMC 2022, unpaginated; NIFC 2022, unpaginated; NWS 2022, unpaginated). Many of these effects are the result of climate change (Romero-Lankao, et al. 2014, p. 1459; EPA 2016, unpaginated; Gonzalez et al. 2018, entire). Urbanization and agricultural development in both Texas and northeastern Mexico (Texas Land Trends 2019, entire; USGS 2022, unpaginated; Texas Comptroller 2021, entire) have continued, likely resulting in increased isolation of the Texas population from those in Mexico. Growth of urban areas in Texas is expected to result in a decrease of rural land uses, further fragmenting habitats in this region (Texas Land Trends 2019, entire).

In March 2020, the Texas Parks and Wildlife Department used NatureServe's Rank Calculator (NatureServe 2020, unpaginated) using Biotics v.1 software to review the state conservation status ranking for the ferruginous pygmy-owl (Shackelford, pers. comm.). The resulting conservation status rank for ferruginous pygmy-owl in Texas is S2: Imperiled, defined as "at high risk of extirpation in the jurisdiction due to restricted range, few populations or occurrences, steep declines, severe threats, or other factors" (TPWD 2019, unpaginated). If finalized, this would be a change from the previous conservation rank of S3: Vulnerable, defined as "at moderate risk of extirpation." The draft change from S3 to S2 represents a move from a moderate risk to a high risk of extirpation. The reviewers listed extended drought as a threat to the live oak woodland habitat in Kenedy County where the majority of this species occurs in Texas. The reviewers estimated 1,000 individuals to exist in this core area of the species' Texas range (TXNDD 2020). Figure 4.2 above shows other documented occurrences of pygmy-owls in Texas.

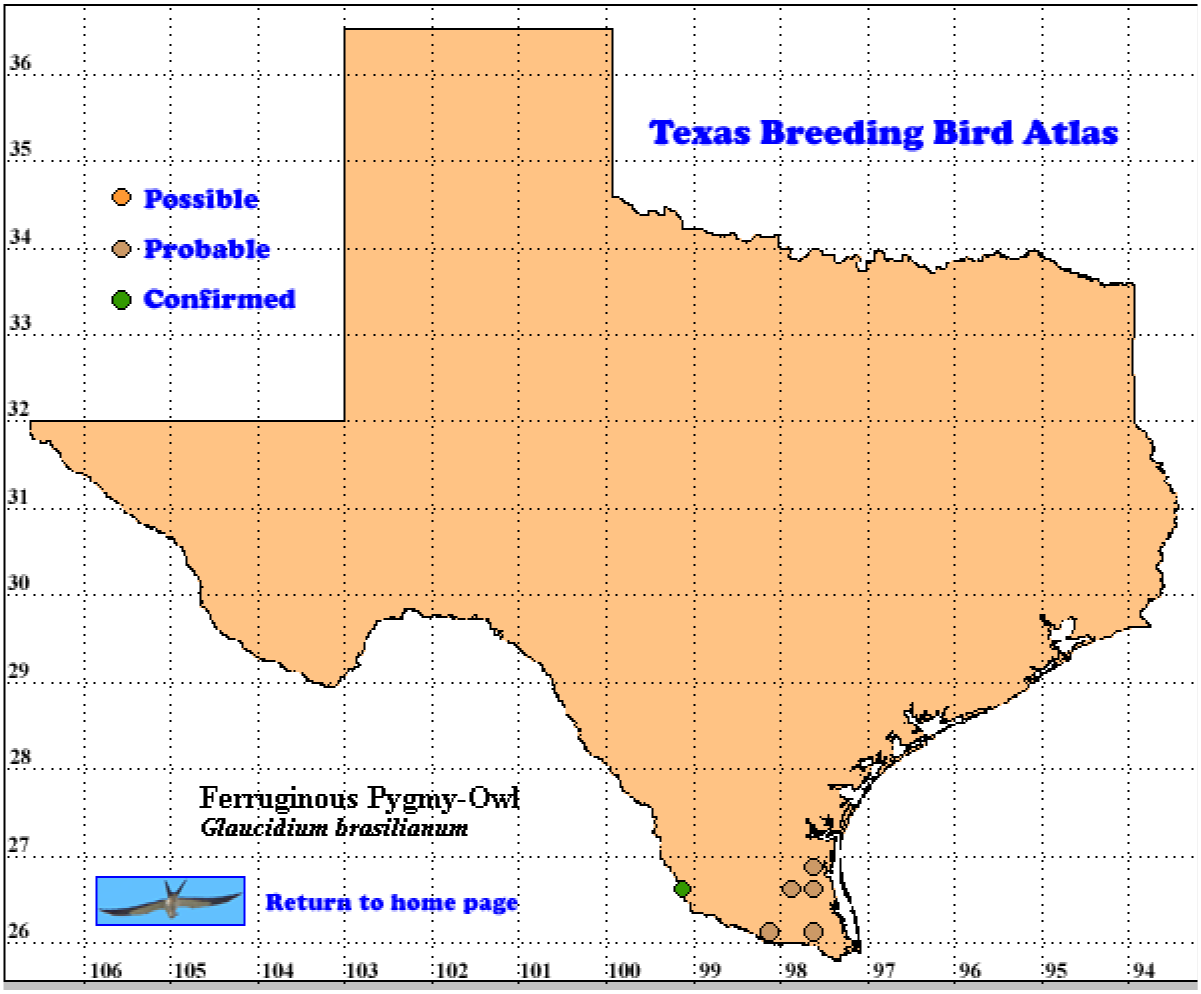


Figure 4.10 Breeding occurrences of the pygmy-owl in Texas based on the 2006 Texas Breeding Bird Atlas (TBBA 2006)

4.1.2.2 Northeastern Mexico

There are no recent pygmy-owl survey or monitoring data for the northeastern Mexico, so we continue to have no recent, verified data on abundance or occupancy. We used eBird, iNaturalist, and museum specimen records to get a general scope of occurrences in these areas, but did not use these records to estimate abundance (GBIF 2020, unpaginated; Johnston et al. 2021, p. 1266). Tewes (1993, p. i) indicated that the pygmy-owl appears to be more prevalent in eastern Mexico than in Texas, but that of 58 individuals contacted, only 12 provided information about the ferruginous pygmy-owl, indicating the perhaps the owl was not commonly observed or that not that many people were conducting work that would have provided owl sightings. Most contacts provided sighting records, but only a few provided more detailed information on the pygmy-owl (Tewes 1993, p. 10).

Tewes (1993, pp. 15–16) provides the most current information on pygmy-owls in northeastern Mexico. During surveys in 1991, he visited 142 plots covering 27 sites in Mexico and 98 plots covering 11 sites in Texas. Owls responded at 12 sites, all of which were in Mexico. At these 12 sites, he estimated 96 pygmy-owls (Tewes 1993, pp. 15–16). He concludes that no published empirical evidence suggests any change in the distribution of this subspecies in Texas or northeastern Mexico, although the likelihood of finding pygmy-owls is low in some historically occupied areas (Tewes 1993, p. 22). However, similar to loss of habitat in Texas, Tewes (1993, p. 29) also indicated that the population of pygmy-owls in northeastern Mexico may be experiencing similar effects. Pygmy-owls were found along the foothills of the Sierra Madre Oriental. The pygmy-owl now appears to occur in two centers of abundance within the distribution in northeast Mexico and southern Texas. Tewes (1993, p. 27) reached the conclusion that the status of this subspecies most likely relates to the availability of cavities in which to nest. Available nesting cavities in Mexico are likely being reduced due to forest management and the destruction of cavities by poachers stealing nestling parrots due to the illegal parrot trade (Monterrubio-Rico and Escalante-Pliego, 2006, pp. 67 – 68). With regard to forest management, secondary forests are rapidly replacing primary forests in temperate and tropical regions of Mexico. Most forestry practices include intensive and selective logging of large commercial trees and the removal of large standing snags as ‘‘sanitary procedures’’. Secondary forests do not possess the specific structural properties required by most cavity nesting species, due to the majority of standing trees have small dimensions for cavity formation (Monterrubio-Rico and Escalante-Pliego, 2006, p. 68).

Population group numbers adjacent to Texas in northeastern Mexico do not appear to provide an adequate recruitment base for Texas. A few widely scattered locations in Nuevo Leon and Tamaulipas are all that are known. The most “regular” population group in northeastern Mexico is apparently near Cerralvo, Nuevo Leon (Wauer *et al. 1*993, p. 5).

While not specific to the Northeastern Mexico analysis unit, Enríquez-Rocha *et al.*(1993) indicate that the greatest number of museum specimens for owls in Mexico were of the ferruginous pygmy-owl (*Glaucidium brasilianum*). Ferruginous pygmy-owls appear to be the most collected owl species in Mexico. One thousand one hundred thirty-one specimens from 23 states were recorded. They do not indicate how many of these specimens were from the Northeastern Mexico analysis unit, but Tewes (1993, p. 13) received approximately 350 museum specimens from requests he made while studying the pygmy-owls in northeastern Mexico.

The most current information we have with regard to locations of pygmy-owls in the Northeastern Mexico analysis unit comes from the *Global Biodiversity Information Facility* or GBIF databases (GBIF 2020). This occurrence information includes data from iNaturalist, eBird, and various museum specimens. These data cover a wide time period but, while this is the best available information regarding pygmy-owl occurrence records, they do not correlate with actual numbers of pygmy-owls in the analysis unit, nor does it represent an estimate of actual owl numbers. Records within these databases may represent multiple reports of the same pygmy-owl occurrence in the same or over a range of years or in other ways that do not allow for estimating actual numbers of pygmy-owls. These data only represent information from areas where those reporting the data looked for or observed pygmy-owls. It does not represent a comprehensive effort to document the numbers and distribution of the pygmy-owl. Given those limitations, the GBIF databases provided documentation of 1,827 pygmy-owl locations in the Northeastern Mexico analysis unit. Figure 4.2 shows the distribution of these records within the Northeastern Mexico analysis unit.

Table 4.2. Historical and current cactus ferruginous pygmy-owl populations in the United States and Mexico.

Analysis Unit	**Historical Documentation**	**Most Current Status**	**Estimate of Current Magnitude of Number of Pygmy-owls**
Arizona (Abbate *et al.* 2000, entire; AGFD 2020, pers. comm.; AGFD 2021b, pers. comm.)	Uncommon overall, but distributed as far north as the Phoenix area.	Distribution is currently limited to Pima County, but appears stable in the Altar Valley of that county. Extirpated or declining in areas outside of Altar Valley. Status on the Tohono O'odham Nation is unclear. Surveys in the early 1990's and in 2020 documented occupied pygmy –owl locations, but the majority of the Tohono O'odham Nation remains unsurveyed. Based on the information we do have, the numbers and distribution appear to be consistent with those found in similar habitats elsewhere in Arizona.	Low hundreds
Northern Sonora (Flesch 2003, entire; Flesch *et al.* 2017, entire)	Thought to be uncommon.	Found to be more common than historically indicated. Periods of declining numbers and occupancy documented, but currently appears stable.	High hundreds
Western Mexico (GBIF 2020)	Most commonly collected owl in Mexico (Enríquez-Rocha *et al.* 1993, p. 156)	Appears to still be found in historical locations, but actual numbers and density is unknown.	Tens of thousands
Texas (Proudfoot 1996, entire; Mays 1996, entire)	Was common historically along the Rio Grande, but that was the only location of regular occurrence in Texas	Almost extirpated along Rio Grande, but more common now in areas of Kenedy and Brooks counties.	High hundreds
Northeastern Mexico (GBIF 2020)	Historical numbers unknown, but was indicated to be more common in Northeastern Mexico than in Texas.	Current status unknown, although historical areas appear to be currently occupied.	Tens of thousands

CHAPTER 5. SPECIES NEEDS

As discussed in Chapter 1, for the purpose of this assessment, we define viability as the ability of the species to sustain populations in the wild over time (in this case, 30 years). Based on anecdotal observations, pygmy-owl can live to approximately 10 years, although they typically do not live this long; average lifespan is probably 3 – 5 years (Proudfoot 2009, pers. comm.; AGFD 2009b, pers. comm.). Therefore, we chose 30 years to encompass multiple generations and environmental variation (e.g., drought cycles). Using the SSA framework, we describe the species' viability by characterizing the status of the species in terms of its resiliency, redundancy, and representation. In order to maintain resilient populations, pygmy-owls need sufficient resources (available cavities, appropriate configuration of habitat and adequate cover, prey, etc.) to support abundance, survival rate, and reproductive success (Figure 4.1). In order to adapt to changing physical and biological conditions, the species needs to maintain a certain number or distribution of resilient populations and population groups across its range (redundancy), and its ecological, behavioral, and genetic diversity (representation). In this section, we analyze what the species needs in terms of population resiliency and species representation and redundancy.

5.1 Population Resiliency

For the cactus ferruginous pygmy-owl to maintain viability, its populations or some representative portion thereof must be resilient (i.e., withstand stochastic events arising from spatially and temporally random factors, as well as normal fluctuations in the environment). Stochastic events that have the potential to affect cactus ferruginous pygmy-owl generally include extreme weather events like floods, fires, drought, hurricanes, or monsoon storms, but could also include things like disease outbreaks or prey die-offs. The pygmy-owl will likely be more resilient if large populations exist in high-quality habitat that is distributed throughout the range of the subspecies in such a way as to capture the environmental variability found within the range of the subspecies. A number of factors influence the resiliency of cactus ferruginous pygmy-owl populations, including abundance, occupancy, and productivity. Influencing those factors are habitat characteristics that determine whether populations can grow to maximize habitat occupancy, thereby increasing the resiliency of populations. Habitat connectivity contributes to the resiliency of the pygmy-owl populations by providing demographic support (rescue effect) for separated population groups. These factors and habitat elements are discussed below and shown in Figure 4.1 of the previous chapter.

Population Resiliency Factors

While there are multiple factors that can affect population resiliency of the cactus ferruginous pygmy-owl, we focused on those factors that influence the population and for which we have some data. The population resiliency factors listed below are the population-level influences we use in our assessment of the current and future condition of the populations.

Abundance

Larger populations have a lower risk of extinction than smaller populations (Pimm *et al.* 1988, pp. 773 – 775; Trombulak *et al.* 2004, p. 1183). In contrast, small populations are less resilient and more vulnerable to the effects of demographic, environmental, and genetic stochasticity and have a higher risk of extinction than larger populations (Trombulak *et al.* 2004, p. 1183). Small populations may experience increased inbreeding, loss of genetic variation, and ultimately a decreased potential to adapt to environmental change (Trombulak *et al.* 2004, p. 1183; Harmon and Braude 2010, p. 125; Benson *et al.* 2016, pp. 1 - 2). The abundance of pygmy-owls within each analysis unit must be high enough to support persistence of pygmy-owl population groups within the analysis unit. This is accomplished by having adequate patches of habitat to support multiple nesting pairs of pygmy-owls and their offspring, have adequate habitat connectivity to support establishment of additional territories by dispersing young, and supply floaters within each pygmy-owl population group to offset loss of breeding adults and to provide potential mates for dispersing juveniles.

One aspect of abundance that must be considered is the opportunity for pygmy-owls to be able to move and disperse among population groups of nesting pygmy-owls. The overall abundance of pygmy-owls within an analysis unit or population is functionally reduced if pygmy-owls are not able to move among population groups across the landscape to provide demographic support (rescue effect). In this way, the functional abundance of pygmy-owls populations is tied to habitat connectivity.

Occupancy

Resilient pygmy-owl populations must occupy large enough areas such that stochastic events and environmental fluctuations that affect individual pygmy-owls, or population group of pygmy-owls, do not eliminate the entire population. Pygmy-owls are patchily distributed across the landscape in population groups of nesting owls. Each of these population groups must be occupied by large enough numbers of pygmy-owls to enable the population group to persist on the landscape over time. Enough occupied population groups of pygmy-owls must also exist on the landscape, with interconnected habitat supporting movement among population groups, so that each population group can receive or exchange individuals with any given adjacent population group. Habitat is an important factor in pygmy-owl occupancy, but occupancy is also driven by demographic factors such the number of owls in a population group. Occupied habitat must also be able to support large enough population numbers to provide floaters in the population so that replacement breeders are available if either or both members of an existing breeding pair are lost and to provide available mates to dispersing pygmy-owls. Our observations indicate that if a site is occupied by a breeding pair, they will breed. Survival of adults also affects occupancy. We have observed some occupied sites that are abandoned if one of the adult breeders perishes. These sites have been reoccupied in the future when floaters or dispersing birds move into the area.

Evidence of reproduction

Resilient pygmy-owl populations must also reproduce and produce sufficient amount of young such that recruitment equals or exceeds mortality. However, the necessary reproductive rate needed for a self-sustaining population is unknown. Ideally, we would know key demographic parameters of the pygmy-owl (i.e., survival, life expectancy, lifespan, productivity, etc.) to estimate the percentage of juveniles required in a population to achieve population stability or growth. It would also be beneficial to know the levels of productivity and dispersal needed to maintain a sufficiently genetically diverse and resilient population. Because we currently do not know any of these parameters, we are using the evidence of reproduction as an important demographic factor influencing resiliency (Figure 5.1).

Figure 5.1 Nestling pygmy-owls appear at the nest cavity entrance just days before fledging. (Photo credit: Paul Bannick)

Current population size and abundance reflects previous influences on the population and habitat, while reproduction and recruitment reflect population trends that may be stable, increasing or decreasing in the future. Resilient populations of the pygmy-owl must be productive enough to result in populations that have sufficient numbers of individuals to replace members of breeding pairs that have been lost and to support persistent population groups of nesting pygmy-owls through dispersal. We do not have data with regard to productivity of pygmy-owls across its range. However, evidence of reproduction can be determined through documented active nests, presence of eggs or nestlings, fledglings, and persistence of occupied territories and population groups of pygmy-owls over consecutive years. Thus, evidence of reproduction on a consistent basis over time likely indicates a resilient population.

Habitat Elements that Influence Resiliency

Similar to population resiliency, there are multiple habitat factors that can affect resiliency of individual pygmy-owls. Here we focus on important habitat factors for which we have some data. These factors include areas of habitat that are of adequate size to enable pygmy-owls to persist on the landscape and that provide sufficient prey availability, vegetation cover, and woody species canopy cover.

Habitat intactness

Resilient pygmy-owl populations need intact habitat that is large enough to support year-round occupation, as well as connectivity between habitat patches to enable dispersal. Pygmy-owls are patchily distributed across much of their geographic range. Similar to metapopulations, these pygmy-owl population groups are dependent on interchange of individuals in order to maintain adequate numbers and genetic diversity on the landscape. Habitat connectivity is crucial to maintaining pathways for the interchange of individuals (rescue) among pygmy-owl population groups.

Annual precipitation

Adequate prey availability is a key component for maintaining resilient pygmy-owl populations. While year-round prey availability is essential throughout the range of the pygmy-owl, portions of the range are characterized by seasonally available prey resources. For example, in the more northern analysis units, summer prey items such as lizards, insects, and some small mammals are only available during the warm months of the year. Insects, lizards, and small mammals all reduce their activity levels during the cooler winter months. Therefore, during the colder months, prey availability may be limited to primarily bird species. Regardless, many of these prey species are influenced directly by annual and season precipitation, and indirectly through vegetation cover and diversity that is influence by precipitation. Resilient pygmy-owl populations require adequate precipitation to support year-round prey availability. This includes appropriately timed precipitation to support seasonally available preys such as lizard, insects, and small mammals. Pygmy-owl prey abundance and productivity is influence by annual precipitation patterns (Flesch 2014a, pp. 113 – 116; Flesch *et al. 2*015, p. 26).

Vegetation health and cover

Resilient pygmy-owl populations require adequate vegetation to provide cover for predator avoidance, thermoregulation, and hunting, as described in Chapter 3 and 4 of this SSA. Of primary importance for cover is the presence of woody vegetation canopy, which often occurs along rivers, ponds, stock tanks, washes, and areas of increased precipitation. Habitat that includes this woody vegetation canopy, as well as overall structural and species diversity, also provides higher quality resources for the diverse prey upon which the pygmy-owl depends. Additionally, adequate numbers of cavities for nesting are provided by healthy populations of columnar cacti and large tree species. Ongoing reproduction of these large vegetation structures to replace lost nest cavity substrates is a key to maintaining adequate vegetation components on the landscape. Additionally, repeated fires in areas characterized by increasing occurrence and densities of invasive, non-native grass species may render the area unsuitable for pygmy-owls and other native wildlife due to the loss of trees and columnar cacti, and reduced diversity of cover and prey species (Brooks and Esque 2002, p. 336).

In summary, habitats with low levels of fragmentation and appropriate levels of annual precipiation and vegetation health and cover are considered to contribute to resiliency, while those habitats with levels outside of the appropriate ranges are considered to provide less resiliency.

5.2 Species Representation

Maintaining genetic and ecological diversity is important to maintain the capacity of the cactus ferruginous pygmy-owl to adapt to future environmental changes. As discussed earlier in this document, recent genetic work indicate there is substantial genetic diversity across the range of the pygmy-owl (Proudfoot *et al. 2*006a, entire; 2006b, entire). Such genetic diversity appears to be the result of isolation-by-distance, as well as because of geographic barriers. Specific analysis units are characterized by unique genetic haplotypes that provide genetic diversity to support adaptation to environmental conditions. Discussion in Sections 2.2 (Genetic Composition and Diversity) and 2.5 (Habitat/Defining Analysis Units) provide specific documentation of the genetic diversity across the pygmy-owl's range. Maintaining genetic diversity across the range of the pygmy-owl is key to maintaining species representation and thus, population viability.

With regard to ecological diversity, with such a large range, the pygmy-owl occupies a diverse range of ecological settings. Such diverse ecological settings are the result of geographic gradients of vegetation, climate, elevation, topography, and other landscape elements. Such ecological diversity could help the pygmy-owl adapt to and survive future environmental changes, such as warming temperatures or decreased precipitation from climate change. At a minimum, we need to retain resilient populations in each area of ecological diversity to maintain representation throughout the current range of the subspecies to maintain the capacity of pygmy-owl to adapt environmental changes over time. This is particularly crucial where natural and anthropogenic actions result in stressors on different portions of the pygmy-owls range. Without adequate representation, the pygmy-owl loses the ability to adapt to changing conditions to maintain the viability of the subspecies.

5.3 Species Redundancy

To ensure redundancy, multiple resilient pygmy-owl population groups distributed throughout its range are needed. The more populations and population groups, and the wider the distribution of those populations and population groups, the more redundancy the species will exhibit. Because the pygmy-owls range is so large and diverse, it is important to have redundancy of population groups within each of the five identified analysis units. Redundancy reduces the risk that a large portion of the subspecies will be negatively affected by a catastrophic natural or anthropogenic event at a given point in time. Redundancy of populations may be needed to provide a margin of safety for the species to withstand catastrophic events. This does not mean that any portion that provides redundancy is a significant portion of the range of the species. The idea is to conserve enough areas of the range such that random perturbations in the system act on only a few population groups. Therefore, each area must be examined based on whether that area provides an increment of redundancy important to the conservation of the subspecies. Subspecies well distributed across their native range are less susceptible to extinction than species confined to small portions of their range (Noss 1994, p. 6). The idea here is that a widely distributed subspecies will be unlikely to experience a catastrophe, disturbance, or other negative influence across its entire range at once. For instance, with regard to the pygmy-owl, a hurricane, fire, or drought may severely impact the suitability of pygmy-owls habitat in local areas for several years in a row while other areas are unaffected. If pygmy-owl population groups did not occur outside of the affected local areas, it may become extinct. However, if pygmy-owls are distributed broadly, at least some areas within its range are likely to contain adequate amounts of unaffected habitat that remain to support population viability. Over time, pygmy-owls can slowly recolonize affected areas where it had been eliminated if sufficient connectivity among habitat patches exists. Therefore, maintaining redundant population groups across the range of a subspecies is a reasonable approach to increase resiliency within the subspecies. Exchange of individuals among analysis units relies on redundancy in a similar manner as it does among population groups. Research and monitoring have documented exchange of individual cactus ferruginous pygmy-owls among population groups within the Arizona, northern Sonora, and Texas analysis units, and between the Arizona and northern Sonora analysis units (Abbate *et al. 2*000, p. 30; Flesch and Steidl 2007, p. 37; Proudfoot *et al. 2*020, unpaginated; AGFD 2022, unpublished data).

While the numbers and densities of pygmy-owls appear to be lower in some analysis units, these portions of the range do contribute in a meaningful way to the overall pygmy-owl populations. All analysis units contribute to the total range-wide population, and population groups within each analysis unit provide population support for that analysis unit and adjacent portions of the range. If an analysis unit is self-sustaining it provides redundancy across the range and may provide emigrants to support adjacent analysis units if the available habitat within an analysis unit is saturated. In addition, each analysis unit contains substantial amounts and types of pygmy-owl habitat that are limited elsewhere within the range, which can increase each analysis unit's contribution to redundancy across the range of the pygmy-owl.

CHAPTER 6. CURRENT CONDITIONS

In this chapter, we consider the current conditions of the cactus ferruginous pygmy-owl in terms of population resiliency, redundancy, and representation. The available information suggests that pygmy-owls currently occupy all five analysis units, but that pygmy-owls are more common in the southern portions of the western population than they are in the northern portions and, similarly, that they are more common in the southern, or Mexican, portion of the eastern population than they are in Texas, or northern portion of the eastern population. None of the analysis units or populations have population estimates for the pygmy-owl. However, based on the available information, we estimate the general population status for each analysis unit for our discussion below (Table 4.2 above).

6.1 Unknowns and Assumptions

Following our review of the best available scientific and commercial information on the ecology, abundance, distribution, and natural history of the pygmy-owl, we identify the following list of unknowns and assumptions for this analysis:

6.1.1 Unknowns

- We do not have a current range-wide population estimate of pygmy-owls. This subspecies has a large distribution, occurs in a variety of habitats with varying degrees of accessibility, and is not being studied throughout most of its range or studies that have occurred are not currently ongoing. Current data that are available from sources such as eBird and iNaturalist cannot be used to estimate population numbers. Because of these factors, it is difficult to get current, range-wide population numbers for the pygmy-owl.

- Survival rates of all age classes are not known. Banding and telemetry studies that could collect survival data have been limited in geographic and temporal scope and are currently not occurring.

- While there is some anecdotal information suggesting demographic support (rescue effect) is needed and has been documented locally, no work has been completed nor is any currently ongoing that would allow us to know what level of exchange of individuals occurs among population groups, nor what level of interchange among population groups is needed over time to maintain population viability.

- Range-wide productivity is not known. Again, there has been some work done in the past that has looked at local productivity, but the sample size is small (AZ) or restricted in geographic scope (Texas and northern Sonora). There is currently no work ongoing that would gather range-wide productivity data.

- Long-term studies that follow individual pygmy-owls and their offspring are lacking. Consequently, we do not know important information related to population viability such as the number of breeding pairs needed per population group to maintain viability, the number of owls overall needed to maintain population viability, or the patch sizes of habitat needed to support viable population groups or populations.

6.1.2 Assumptions

- We assume data gathered in a specific local area can help us understand and, perhaps, project what is happening in other areas with similar habitat, climate, and threats.

- We assume pygmy-owls are more numerous in the southern portions of its Mexican range than it is in the United States and northern Sonora, based on some first-hand observations and from general reports from birders, etc.

- Most data related to pygmy-owl numbers, habitat use, and life history descriptions that are available to us are from the early 1990’s to the early 2000’s and is over two decades old. We recognize that the information contained within these reports is a snapshot in time and conditions have likely changed to some extent and some to a significant extent; however, we view this information as the best available scientific and commercial information regarding the current and future status of the pygmy-owl for some of the analysis units and populations range-wide.

- We assume general population viability and conservation biology principles and practices apply to the pygmy-owl across its range.

- We assume that, if pygmy-owls have persisted in an area or analysis unit for multiple years, reproduction and demographic support (rescue effect) is occurring. This is particularly true for portions of Mexico for which we lack any demographic data. Included in this assumption is the additional assumption that eBird and iNaturalist data, while not adequate to estimate population numbers, can give us at least some idea of areas that continue to be occupied by pygmy-owls.

- Because we lack specific habitat measurements across the range of the pygmy-owl that describe each of the habitat conditions within specific analysis units, we assume that remote sensing data and GIS data layers that describe habitat conditions across the range of the pygmy-owl will appropriately inform our analysis of pygmy-owl habitat conditions across the range of the pygmy-owl (Appendices 1, 2, and 3 for a specific description of how we used available data to analyze pygmy-owl habitat conditions now and in the future). These data are not directly comparable to available habitat; that is, reported suitable vegetation, intactness, NDVI categories, etc. do not consider all aspects of pygmy-owl habitat and are not reported as pygmy-owl habitat areas, but rather as appropriate vegetation areas. However, in the absence of range-wide habitat suitability information, assessing the trends or conditions in these remote sensing data is helpful in understanding trends in vegetation conditions affecting the pygmy-owl. In other words, changes or conditions in this context are related to the conversion of these surrogate factors into conditions that are likely related to habitat quality for pygmy-owls.

- Because we do not have data that allow us to know the extent of habitat fragmentation, prey availability, or the extent and nature of important cover variables contributing to the overall condition of pygmy-owl population groups and analysis units across the range of the pygmy-owl, we assume that the surrogate variables that we can remotely measure appropriately portray the conditions within analysis units with regard to these factors for pygmy-owls.

6.2 Current Population Resiliency

Methodology

To summarize the overall current conditions of cactus ferruginous pygmy-owl populations, we sorted them into three categories (high, moderate, and low) based on the population/distribution factors (abundance, occupancy, and evidence of reproduction) and habitat factors (vegetation intactness, annual precipitation, and vegetation health and cover) discussed in Chapter 5 (section 5.1 Population Resiliency) (Tables 6.1 and 6.2). We assigned a numerical value to the condition categories, High = 5, Moderate = 3, and Low = 1, so we could calculate an overall score for the current condition of each analysis unit within both populations of pygmy-owls. Scores for each factor were summed for each analysis unit.

The current condition category is a qualitative estimate based on the analysis of the three population and distribution factors and three habitat factors. Based on the total score for each analysis unit, we then rated the resiliency of that analysis unit as High (a score of 22 - 28), Moderate (a score of 15 – 21), or Low (a score of 8 - 14). These ratings are defined by the likelihood of pygmy-owl persistence over the next 30 years. An analysis unit with a high rating has a higher probability of persistence over 30 years than an analysis unit with a moderate or low rating. Conversely, an analysis unit with a high rating has a low (<15 percent) chance of extinction over the next 30 years. An analysis unit in low condition has a 40 – 100 percent chance of extirpation over the next 30 years (see Table 6.3).

Demographic Factors

Abundance

Pygmy-owls tend to be patchily distributed across the landscape in population groups that consist of multiple breeding pairs of pygmy-owls within relatively discreet geographic areas defined by differences in habitat or impediments to movement such as highways, mountains, development, etc., within analysis units. There have not been any systematic and comprehensive surveys occurring on a regular basis in any of the analysis units that would allow us to estimate actual numbers of pygmy-owls. However, work has been done over the past two decades in Arizona, Texas, and northern Sonora where periodic checks of population groups have occurred to determine if historical sites still contained nesting pygmy-owls. In addition, some new occupied sites have been documented in these same areas. Data from eBird and iNaturalist also indicate areas of occupied population groups from which we can assume persistence. Therefore, in order to gain some sort of a measure of abundance for analysis units using the best available data, we will use our best professional estimates of the magnitude of pygmy-owl numbers within each analysis unit, based on existing data at various scales and intensities for occupied population groups from past and current observations at these and new sites from research and monitoring, as well as assumption of persistence of population groups from sources such as eBird and iNaturalist. These data and our estimates are found in Table 4.2 above. Abundance is ranked as high (estimated numbers in the tens of thousands), moderate (estimated numbers in the high hundreds to low thousands), and low (estimated numbers in the low to mid hundreds). These estimates of the magnitude of abundance should not be construed as actual population estimates. We lack sufficient data to make any statistically meaningful estimates of population numbers for any of the analysis units. Rather, these estimates of the magnitude of pygmy-owl abundance are used as a tool to compare the general abundance of pygmy-owls in each analysis unit. In other words, we used these estimates to compare the relative magnitude of pygmy-owl abundance, based on the best available information, in the context of ranking the resiliency of each analysis unit.

Occupancy of Population Groups

As described elsewhere in this SSA, because of the lack of ongoing comprehensive and regular survey and monitoring of pygmy-owl population groups, difficulties occur when trying to identify a metric by which to measure pygmy-owl occupancy across its range. Similar to abundance, the best data available to describe occupancy come from the work done over the past two decades in Arizona, Texas, and northern Sonora, as well as by assuming the data from eBird and iNaturalist can provide us with at least a representation of ongoing occupancy in the areas where such data occur. Therefore, we looked at the available sources of information to determine the current occupancy of population groups within analysis units compared to historical occupancy. The metric used is the percentage of historical population groups that are currently considered occupied based on available data and applying our assumptions related to those data.

Evidence of Reproduction

Similar to our other measures of demographic condition, productivity data for pygmy-owls across their range is lacking. Some relatively short-term local studies looked at pygmy-owl productivity in Arizona, northern Sonora, and Texas, but these studies were conducted over a decade ago and are not likely applicable to population groups in the remainder of Mexico. Nonetheless, some limited data on productivity is available from northern Sonora. Flesch et al. (2015, pp. 22 – 26) provides some data on reproductive output. Importantly, their data show the influence of weather and habitat impacts on productivity because, in years of drought and high temperatures, pygmy-owl pairs produce only approximately one young from active nests in such years. They additionally estimate that the number of young that actually survive to dispersal is only about ~0.5 young per pair in years with poor precipitation and hotter temperatures that affect habitat conditions and prey availability. However, they note that, even in these poor years, almost all pygmy-owl pairs will attempt to nest, but with poor results.

Given this lack of data on productivity, and the effects of weather and habitat on productivity, we considered what measure of productivity would be readily determinable based on the general data available on abundance and occupancy and would be a reasonable surrogate for productivity that would inform demographic resiliency of population groups and analysis units. We consider evidence of reproduction to be a reasonable surrogate for productivity that is more easily observed than measuring actual productivity at nest sites. Evidence of reproduction includes the observation of active nests, recent fledglings, or any other observation that confirms that reproduction has occurred within territories occupied by a breeding pair of pygmy-owls. We also assume that, for population groups that persist over multiple consecutive years, persistent occupancy over time reasonably provides evidence of ongoing reproduction within that population group.

Habitat Factors

Vegetation Intactness

Pygmy-owls use a variety of habitats that are relatively intact, but they are sensitive to high levels of habitat fragmentation (Oberholser 1974; Johnsgard 1988; Millsap and Johnson 1988; Wauer *et al. 1*993; Tewes 1993; Abbate *et al. 1*999, p. 59; Abbate *et al. 2*000, p. 29; Flesch *et al. 2*010; Flesch 2017, p. 5). Due to a lack of data regarding the level of habitat fragmentation throughout the geographic range of the pygmy-owl, we developed a GIS model (Appendix 1) to provide a quantitative index of vegetation intactness within each of our analysis units.

To determine the extent of vegetation intactness within each of the five analysis units we first identified suitable vegetation types below 4000 feet (1220 meters) elevation. We then classified these land cover types based upon the level of intactness (e.g. intact, disturbed, developed, etc.) and were then able to add road layers to the analysis as another source of fragmentation. The resulting product classified land cover types on a scale of one to ten, with one being intact natural vegetation and ten being more highly fragmented (Figures 6.1 and 6.2, also see Appendix 1 for our complete methodology). For our condition category table (Table 6.1), we looked at the percentage of high suitability vegetation that was intact (amount of suitable vegetation classified as a one in our analysis) within each analysis unit (see Appendix 1 for more discussion of intactness).

It is important to understand that this vegetation intactness model does not represent pygmy-owl habitat intactness. We do not have the understanding or data to analyze what actually constitutes pygmy-owl habitat fragmentation nor how pygmy-owls use habitats that have are fragmented, both naturally and as a result of human activities. The coarseness of this model is not able to include fine scale contributions to habitat fragmentation, nor is it fine enough to tease out the natural fragmentation of certain vegetation communities like the oak motte habitat of Texas. According to the model we used, Texas has a low extent intact vegetation. However, in the oak motte habitat where pygmy-owls occur, the oak mottes are naturally widely spaced and lack tree canopy connectivity. Such areas show a low level of intactness in our model, but pygmy-owls are known to be able to move from oak motte to oak motte despite this lack of connectivity. Further, pygmy-owls do not likely move through large open areas of non-native, invasive grasslands, but such areas are not picked up in our model of vegetation intactness. Additionally, projects such as mesquite removal or burning may increase the fragmentation of pygmy-owl habitat, but the scale of projects such as this are not picked up by our model of intactness. Because we lack specific data related to the level of fragmentation that impacts pygmy-owls, we used available data layers for land cover and development that we could analyze across the range of the pygmy-owl to develop the best possible surrogate for habitat fragmentation. For the purposes of our vegetation intactness analysis, intact areas are those area of vegetation cover identified as suitable for pygmy-owl use and are not characterized by areas of urban and agricultural development, roadways, and unusable/sparse vegetation communities. We acknowledge that this approach is not without drawbacks and is incomplete, but, where we have the information related to other types of factors that introduce fragmentation on the landscape, or show how pygmy-owls can use fragmented landscapes, we tried to incorporate these as we determined the overall condition score of the analysis units where we have additional data.

Climate Moisture Deficit (Hargreaves Aridity Index)

Pygmy-owl prey availability has not been described or measured in a consistent or comprehensive manner across its range. Therefore, we looked for variables that could act as a surrogate for prey availability within the range of the pygmy-owl. The status of many of the pygmy-owl's prey species are affected by precipitation and drought (Flesch 2008, p. 5; Pearce-Higgins *et al. 2*015, p. 6; Flesch et al 2017, entire; Deguines et al 2017, pp. 262 – 263). This effect is, in part, related to the condition of the vegetation cover and vegetation species diversity that is affected by both heat and precipitation. We considered mean annual temperature, mean annual precipitation, and heat moisture indices in our evaluation of variables that could influence prey availability. Because using precipitation alone does not account for the effects of heat on moisture availability for vegetation and prey species, we also looked at variables that could account for the interaction between heat and moisture. The mean annual heat moisture index and the mean summer heat moisture index include the synergistic effect of heat and precipitation on available moisture.

In determining the current condition for these factors, we compare a historical baseline value to the current condition. For the data source we used, the best match for a baseline value was 1981 to 2010. Similarly, the best match to describe the current condition was the data source's 2011 to 2040 time period. We acknowledge that this later range goes beyond the current year, but, for the available data, this is the best approximation of the current conditions we are evaluating. Appendix 2 describes the data used and the output we considered regarding those factors within each analysis unit.

While all of these factors were considered as we analyzed the current condition of each analysis unit, we ultimately chose the Hargreaves Climate Moisture Deficit Index, which is an aridity index, as the factor and metric to act as a surrogate for prey availability within our condition category tables for the pygmy-owls (Table 6.1 and Table 6.2). The Hargreaves approach considers monthly evapotranspiration rates based on temperature and compares that to monthly precipitation (Wang *et al.* 2016, pp. 6 – 7). Some have noted that the Hargreaves approach does tend to overestimate evapotranspiration under a warming climate and may provide a more exaggerated view of future drought stress (Dewes *et al.* 2017, p. 17), but it was the best data available to us to help us appropriately understand drought stress from both a water supply and demand (evapotranspiration) aspect. Thus, this variable seems to address in a more appropriate and complete manner the moisture availability needed by both pygmy-owl prey and the associated vegetation conditions needed to support prey species. We use the Hargreaves index as a surrogate measure of prey availability for both current and future conditions within analysis units. We used the time period from 1981 to 2010 as the baseline time period. The current climate moisture deficit for analysis units is determined by calculating the change from this baseline period to the current time period (2011 to 2040). Figure 6.3 shows an example of the percent change in the Hargreaves index from baseline to current and future conditions for the range of the pygmy-owl. Specific information for each analysis unit with regard to the difference in Climate Moisture Deficit and the percentage of change compared to baseline is found in Appendix 2 (Figure A4.2 – A4.4).

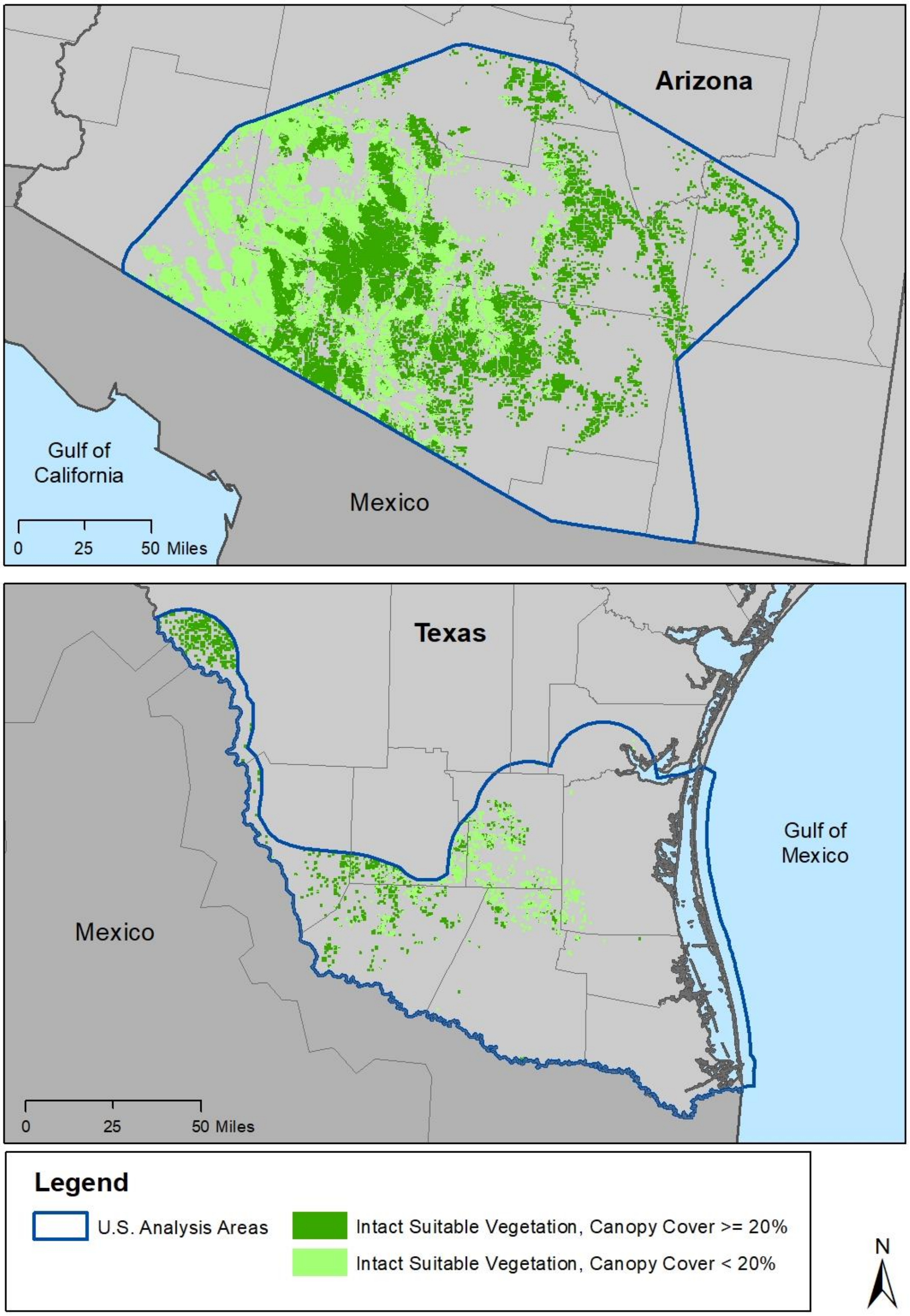


Figure 6.1 Vegetation intactness for analysis units within the United States.

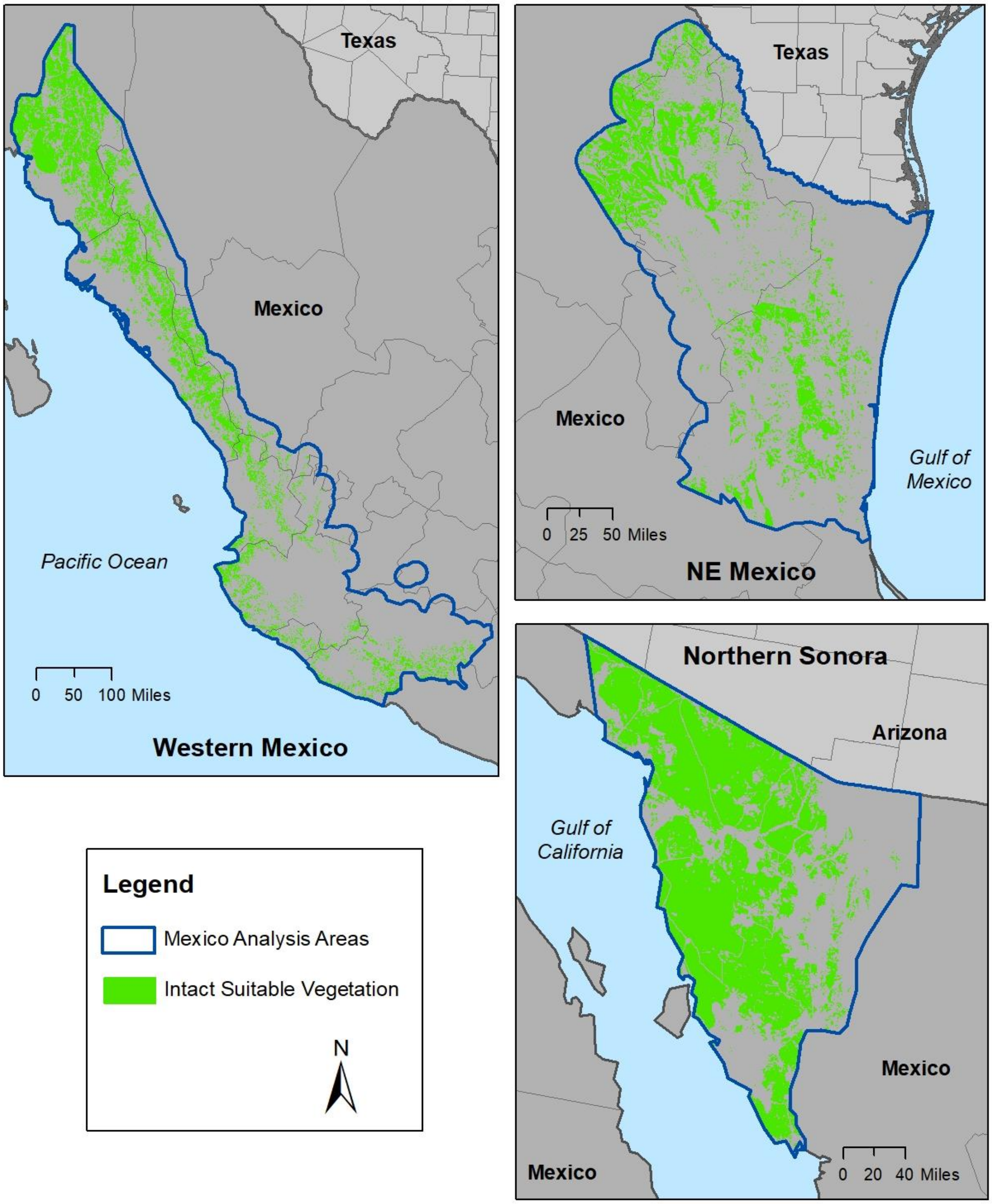


Figure 6.2 Vegetation intactness for analysis units within Mexico.

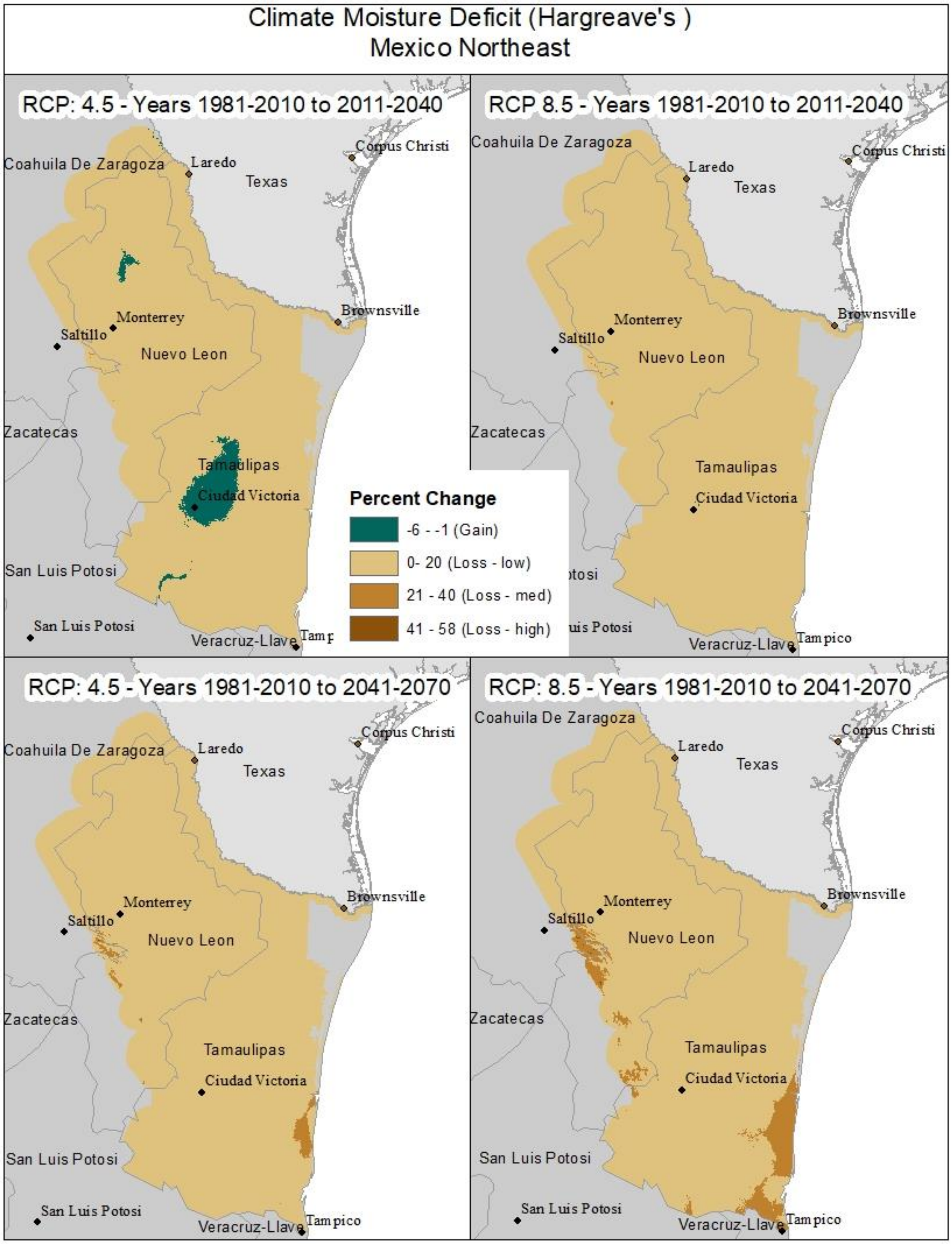


Figure 6.3 Example of climate moisture deficit (Hargreaves Index) for the Northeastern Mexico analysis unit based on percent change from baseline to current and future conditions. Negative (green) numbers indicate no moisture deficit relative to baseline condition. Positive numbers and increasing darkness of the brown areas indicate increased moisture deficit relative to baseline conditions.

Vegetation Health and Cover

Due to a lack of on-the-ground data regarding habitat conditions throughout the majority of the analysis units, we used the Normalized Difference Vegetation Index (NDVI) as a proxy for vegetation health and cover. NDVI is a measure of reflectance of red and near-infrared light by a surface, as measured from a satellite, and is correlated with net primary production (Pettorelli *et al.* 2011, p. 16). Though we acknowledge that NDVI cannot give us information about the species composition, complexity or structure of vegetation cover (e.g., if the vegetation is a single story canopy or multistoried) we determined that it was a suitable representation of the health of the vegetation and vegetation cover at a resolution of 30 meters.

For our analysis, we first obtained monthly NDVI values from 1981 until December 2019 (NOAA CDR 2014, unpaginated) and then calculated NDVI anomaly for every month over the most recent 10 years of data (January 2010 - December 2019). NDVI anomaly ($NDVI_{anomaly}$) is the difference between the NDVI for a particular month ($NDVI_{month}$; e.g. January) and the average NDVI for the same month ($NDVI_{mean}$; e.g. January) over the 39 years for which we have data and is calculated as:

$$NDVI_{anomaly} = \frac{(NDVI_{month} - NDVI_{mean})}{NDVI_{mean}} * 100$$

We then used seasonal-trend decomposition with locally estimated scatterplot smoothing (LOESS) to remove the effect of seasonality from the data using a floating 13-month window to smooth the data (Appendix 3; as described in Cleveland *et al. 1*990, entire). We were then able to calculate average annual NDVI anomaly for each of the five analysis units, while accounting for time-window bias (Appendix 3). NDVI anomaly values less than zero indicate a drought, or conditions in which greenness is below average. NDVI anomaly values less than -10 indicate a moderate to very severe drought, or a moderate to very severe deviation from the average greenness (Appendix 3).

In addition to the NDVI analysis described above, we also considered mean annual precipitation, mean annual temperature, and an annual mean heat moisture index (a climate variable that combines the effects of mean annual temperature and mean annual precipitation) in our analysis of cover conditions within each of the analysis units. This information provided additional input to supplement our description of cover conditions contributing to predator avoidance, thermoregulation, and other life history requirements of the pygmy-owl.

Table 6.1 Population and habitat characteristics used to create condition categories in Table 6.2.

	Demographic Factors			**Habitat Factors**		
Condition category **(viability over 30 years)**	**Abundance**	**Occupancy (in most current available data)**	**Evidence of reproduction (including nest, nestlings, fledglings)**	**Vegetation intactness (fragmentation)**	**Climate Moisture Deficit (CMD; prey availability, cover)**	**Vegetation health and cover (vegetative greenness)**
HIGH	Magnitude of pygmy-owl numbers is estimated to be in the tens of thousands (See Table 4.2)	>90% of monitored population groups are occupied	Yes	>70% of suitable vegetation within the analysis unit is intact	>50% of the analysis unit has a percent change in the CMD that is 0 or negative (no moisture deficit) between the 1980 – 2010 time period and the 2011 – 2040 time period	Average annual NDVI was below the 39 year average in 0 to 3 of the last 10 years
MODERATE	Magnitude of pygmy-owl numbers is estimated to be in the high hundreds to low thousands (See Table 4.2)	>50-90% of monitored population groups are occupied	Yes	30-70% of suitable vegetation within the analysis unit is intact	>50% of the analysis unit has a percent change in the CMD that is > 0 to 40% between the 1980 – 2010 time period and the 2011 – 2040 time period	Average annual NDVI was below the 39 year average in 4 to 6 of the last 10 years
LOW	Magnitude of pygmy-owl numbers is estimated to be in the low hundreds (See Table 4.2)	0-50% of monitored population groups are occupied	No	<30% of suitable vegetation within the analysis unit is intact	>50% of the analysis unit has a percent change in the CMD that is >40% between the 1980 – 2010 time period and the 2011 – 2040 time period	Average annual NDVI was below the 39 year average in 7 to 10 of the last 10 years

Table 6.2 Resiliency of cactus ferruginous pygmy-owl populations. Information used to determine the states of these factors are discussed above in Chapter 4, describing each population.

		Demographic Factors			Habitat Factors			
	Analysis Unit	**Abundance**	**Occupancy (in most current available data)**	**Evidence of reproduction (including nest, nestlings, fledglings)**	**Vegetation intactness (fragmentation)**	**Climate Moisture Deficit (CMD; prey availability, cover)**	**Vegetation health and cover (vegetative greenness)**	**Current Condition**
Western Population	**Arizona**	Low[1]	Moderate	Yes	Moderate	Moderate	Low	Low
	Northern Sonora	Moderate	Moderate	Yes	Moderate	Moderate	Low	Moderate
	Western Mexico	High	Unknown[2]	Yes	Moderate	Moderate	High[3]	High
Eastern Population	**Texas**	Moderate	Moderate	Yes	Low	High	Moderate	Moderate
	Northeast Mexico	High	Unknown[2]	Yes	Low	Moderate	Moderate	Moderate

[1] No comprehensive survey effort has been completed on the Tohono O'odham Nation.

[2] Presumed common due to anecdotal evidence; will assume Moderate condition for this category for analysis purposes.

[3] Western Mexico is on the low end of high for vegetation greenness and there has been a decline in recent years (Appendix 3).

Table 6.3 Presumed probability of persistence of current condition categories.

Likelihood of Persistence:	**High**	**Moderate**	**Low**
Range of Presumed Probability of Persistence over ~30 years	**>85 – 100%**	**>60 – 85%**	**0 – 60%**
Range of Presumed Probability of Extirpation over ~30 years	**0 – ≤15%**	**15 – ≤40%**	**>40 – 100%**

Results

Overall, only one analysis unit is considered to be in high condition. This is a result of high pygmy-owl numbers and reduced effects of climate change. Thus, four out of five analysis units have a reduced resiliency, primarily due to the demographic factors for Arizona (low numbers of pygmy-owls and reduced occupancy) and habitat factors (reduced vegetation intactness, soil moisture, and vegetation health) for the remaining analysis units. The analysis unit in the best current condition is the Western Mexico analysis unit, which is rated as being in high condition (Table 6.2). This analysis unit had both a demographic and a habitat factor rated as high. Three analysis units (Northern Sonora, Texas, and Northeastern Mexico) were classified as being in moderate condition. Northern Sonora was primarily classified as being in moderate condition for demographic and habitat factors, while Texas and Northeastern Mexico had high condition in certain factors tempered by other factors classified in low condition (Table 6.2). Every analysis unit, with the exception of Western Mexico, had at least one condition factor that rated as low. Figure 6.4 shows a map of all analysis units depicting their current condition as determined by the analysis above. Specific discussion of the current condition of each analysis unit follows.

The Arizona analysis unit currently has the lowest pygmy-owl abundance of all analysis units, which is estimated to be in the low hundreds. Habitat fragmentation and loss from urbanization and increases in invasive species such as buffelgrass (*Cenchrus ciliaris*) have reduced the availability and connectivity of habitat in this analysis unit. Additionally, climate conditions have reduced prey availability and vegetative cover through increased temperatures and drought. Environmental characteristics within the Sonoran Desert have likely resulted in the reduced abundance and densities of pygmy-owls found in this area (Abbate et al. 1999, entire; Abbate et al. 2000, entire; Flesch 2003, pp. 36 – 92) and this continues to be true in more recent years (Flesch et al. 2017, entire; Cobbold et al. 2021, entire; Cobbold et al. 2022a, entire). These factors result in a reduced capacity for this analysis unit to withstand stochastic events and result in a low resiliency.

The northern Sonora analysis unit has an estimated pygmy-owl abundance in the high hundreds. However, this analysis unit is affected by habitat fragmentation from urbanization, agricultural development, and associated infrastructure (Flesch 2021, p. 12). These stressors increase water use and, in conjunction with climate conditions, result in a reduction in the quality and availability of pygmy-owl habitat. Similar to Arizona, environmental characteristics within the Sonoran Desert of northern Sonora have likely resulted in the reduced abundance and densities of pygmy-owls found in this area (Flesch 2003, pp. 36 – 92) and this continues to be true in more recent years (Flesch et al. 2017, entire; Cobbold et al. 2021, entire; Cobbold et al. 2022a, entire). Abundance of pygmy-owls in the Sonoran Desert in northwest Mexico, for example, declined about 19–27 percent over a 12-year period, and change in owl abundance was highly associated with variation in precipitation and temperature. In addition, hot, dry conditions influence the behavior and health of prey species the owl relies upon for food. For example, lizards are both less abundant and move less frequently as temperatures rise, making it more difficult for owls to spot and capture them (Flesch 2021, entire). Due to moderate owl abundance and some decrease in habitat availability and connectivity, the northern Sonora analysis unit has a moderate level of population resiliency.

The western Mexico analysis unit is estimated to have tens of thousands of pygmy-owls. This analysis unit has some habitat fragmentation from urbanization, agricultural development, and deforestation of the tropical deciduous forests. Overall, the western Mexico analysis unit has high population resiliency due to high abundance of pygmy-owls and healthy vegetation cover, likely as a result of high levels of precipitation in the region.

The Texas analysis unit has an estimated pygmy-owl abundance in the high hundreds. Land ownership within this analysis unit has resulted in habitat fragmentation and, due to agricultural development and wood harvesting within the Rio Grande Valley, this analysis unit is somewhat genetically isolated from the rest of the geographic range of the subspecies. Due to moderate pygmy-owl abundance, fragmentation of habitat, and some genetic isolation, the Texas analysis unit has a moderate level of population resiliency.

The northeast Mexico analysis unit is estimated to have tens of thousands of pygmy-owls. However, this unit has high levels of habitat fragmentation due to urbanization and agricultural development. Overall, the northeast Mexico analysis unit has a moderate level of population resiliency with some capacity to withstand stochastic events. Rangewide, current condition of the pygmy-owl populations indicate that three analysis units are maintaining a moderate level of population resiliency, one analysis has low resiliency, and one analysis unit has high resiliency.

It is important to understand that these resiliency ratings represent the Current Condition of pygmy-owls in each of the analysis units. Chapter 7 will discuss those factors affecting the viability of pygmy-owl populations and Chapter 8 will discuss how we believe the future condition of the analysis units will be affected by the factors discussed in Chapter 7. Therefore, the future viability of pygmy-owls populations will be discussed in Chapter 8.

6.3 Current Species Representation

We consider the pygmy-owl to currently have representation across its range in the form of genetic diversity (section 2.2) and ecological diversity (section 2.5 and 3.3). This primarily occurs as a result of the large geographic area covered by the range of the pygmy-owl, resulting in genetic isolation by distance and its occurrence in a wide variety of habitat types ranging from southern Arizona, through western Mexico, and in northeastern Mexico to southern Texas. Vegetation communities where the pygmy-owl is found range from Sonoran desert scrub to thornscrub and tropical deciduous forests in the west, and oak-mesquite woodlands and riparian communities to Tamaulipan thornscrub and secondary forests in the east. The overall range of the pygmy-owl is also characterized by two genetically distinct populations: the eastern and western populations. Within both the eastern and western populations of the pygmy-owl, genetic variation among the various analysis units also occurs (Proudfoot 2006a, entire; Proudfoot

2006b, entire). The representation areas are approximately depicted in Figure 4.2 above. Representation occurs on two scales. First, at the population scale, representation is needed within both the eastern and western populations of the pygmy-owl. Representation at this scale currently occurs because pygmy-owl population groups are documented throughout both the eastern and western populations. These populations are defined based on geographic separation and genetic differences. The second scale at which representation is important is at the analysis unit scale. Representation within the analysis units contributes to overall representation within the two populations. Representation at the analysis unit scale occurs due to either genetic differences or ecological variation among analysis units. In summary, pygmy-owls occupy a diversity of habitat types throughout the geographic range of the subspecies and maintain substantial genetic diversity. It is possible that representation boundaries could be adjusted in the future after further investigation of the genetic and ecological diversity of the subspecies.

6.4 Current Species Redundancy

Given that pygmy-owls occur in all five analysis units, redundancy currently occurs at the range-wide scale for pygmy-owls (Figure 4.2 above). Each analysis unit within the geographic range of the subspecies maintains a network of population groups that are connected both within and between analysis units. These population groups have the potential to recolonize areas where other population groups are lost to catastrophic events. As a result, pygmy-owl population groups provide redundancy to withstand catastrophic events were they to occur in any given part of the pygmy-owl’s overall range. However, maintaining the redundancy can be affected by reduced numbers of population groups within a given analysis unit, loss of habitat connectivity among population groups or analysis units such that the potential for demographic support (rescue effect) is eliminated or reduced significantly, or resiliency within analysis units declines. Conversely, if land management improves habitat connectivity and conservation actions improve demographic factors, redundancy within and among analysis units will improve. Currently, these types of factors are affecting a number of the analysis units. For example, population groups within the Arizona analysis unit have likely become extirpated based on the lack of detections over multiple consecutive years. Habitat connectivity between the Arizona and Northwest Mexico analysis units, as well as between the Texas and Northeastern Mexico analysis units may be affected by the construction of border walls and associated effects like vegetation clearing, lighting, patrols, and interdiction activities. New, taller border walls have been constructed along all border areas occupied by pygmy-owls in Arizona (DHS 2020, unpaginated). The resiliency of all analysis units is being reduced through ongoing habitat loss and fragmentation. Despite existing habitat fragmentation, research and monitoring have documented that exchange of individual pygmy-owls between population groups and between some analysis units is still occurring. Maintaining habitat connectivity will be important for preserving this redundancy throughout the subspecies’ range. So, while redundancy currently exists across the range of the pygmy-owl, continued redundancy is not certain when considering the factors affecting redundancy within analysis units.

Figure 6.4 Current resiliency of the cactus ferruginous pygmy-owl.

CHAPTER 7. INFLUENCES ON VIABILITY

Now that we have defined the current condition for both pygmy-owls populations and all five analysis units, in this chapter, we evaluate the past, current, and future influences that may affect what the cactus ferruginous pygmy-owl needs for long term viability. These are activities or issues which must be considered as we analyze future scenarios and the future viability of pygmy-owls populations. Current and potential future effects, along with current expected distribution and abundance, determine present viability and, therefore, vulnerability to extinction. We organized these influences around the stressors (i.e., changes in the resources needed by the pygmy-owl) and discuss the sources of those stressors. Those risks that are not known to have effects on pygmy-owl populations, such as overutilization for commercial and scientific purposes, are not discussed in this SSA report. It is important to note that stressors categorized as "unknown" may have negative effects on pygmy-owl population resiliency, both currently or in the future. However, at this time information is not available on whether these stressors are adversely affecting the subspecies to the degree that they are reducing its long-term viability. This is why they are not considered in this version of the SSA report. As additional information and research occur in the future, we may receive additional information on these stressors and they may be considered in future versions of the SSA report.

While there are many complex influences on pygmy-owl viability, the primary ones we have identified are: 1) climate change and climate conditions, 2) habitat loss and fragmentation, and 3) human activities and disturbance. These are discussed below.

7.1. Climate Change and Climate Conditions

Drought and Climate Change

Climate change can influence pygmy-owl habitat conditions and availability, including availability of nesting cavities. Climate change affects vegetation and cover that influence pygmy-owl survival and productivity through prey availability, predator avoidance, and thermoregulation. Climate change and drought also influence habitat loss and fragmentation, including the influences of non-native invasive plants and alteration of historical fire regimes.

"Climate" refers to an area's long-term average weather statistics (typically for at least 20- or 30-year periods), including the mean and variation of surface variables such as temperature, precipitation, and wind, whereas "climate change" refers to a change in the mean and/or variability of climate properties that persists for an extended period (typically decades or longer), whether due to natural processes or human activity (IPCC 2007, pp. 2, 104). Although changes in climate occur continuously over geological time, changes are now occurring at an accelerated rate. For example, at continental, regional and ocean basin scales, recent observed changes in long-term trends include: a substantial increase in precipitation in eastern parts of North American and South America, northern Europe, and northern and central Asia, and an increase in intense tropical cyclone activity in the North Atlantic since about 1970 (IPCC 2007, p. 30); and the annual average temperature over the contiguous United States has increased by 1.2 °F (0.7 °C) for the period 1986–2016 relative to 1901–1960 and by 1.8 °F (1.0 °C) based on a linear regression for the period 1895–2016 (very high confidence) (Vose *et al. 2*017, pp. 185 – 206).

Examples of observed changes in the physical environment include: ocean warming, sea level rise, shrinking glaciers, as well as decreases in the extent of Northern Hemisphere spring snow cover (IPCC 2013, pp. 8-11); substantial and accelerating reductions in Arctic sea-ice (Comiso *et al. 2*008, p. 1; IPCC 2013 p. 8), and a variety of changes in ecosystem processes, the distribution of species, and the timing of seasonal events (USGCRP 2009, pp. 79-88).

The Intergovernmental Panel on Climate Change (IPCC) used Atmosphere-Ocean General Circulation Models and various greenhouse gas emissions scenarios to make projections of climate change globally and for broad regions through the 21st century and reported these projections with a framework for characterizing certainty (IPCC 2014a, entire). Examples include: (1) It is very likely more heat waves will occur and they will last longer; (2) it is very likely that extreme rainfall events will increase in frequency and intensity in many areas; (3) it is virtually certain that there will be more frequent hot and fewer cold temperature extremes over most land areas; (4) there is high confidence that the feedback between climate change and the carbon cycle will amplify global warming (IPCC 2014a, pp. 56-62).

We have analyzed drought and the risk of future drought in a limited way using the data available to us (NDVI and Hargreaves Climate Moisture Deficit Index). We did not look at every possible measure of drought and did not comprehensively look at the different aspects associated with the severity of future droughts. We focused on the modeled projects related to climate change associated with changes in emissions over time.

All models (not just those involving climate change) have some uncertainty associated with projections due to assumptions used, data available, and features of the models; with regard to climate change this includes factors such as assumptions related to emissions scenarios, internal climate variability and differences among models. Despite this, however, under all global models and emissions scenarios, the overall projected trajectory of surface air temperature is one of increased warming compared to current conditions (IPCC 2014b, p. 8; Meehl *et al. 2*007, p. 762; Prinn *et al. 2*011, p. 527). Climate models, emissions scenarios, and associated assumptions, data, and analytical techniques will continue to be refined, as will interpretations of projections, as more information becomes available. For instance, some changes in conditions are occurring more rapidly than initially projected, such as melting of Arctic sea ice (Comiso *et al. 2*008, p. 1; Polyak *et al. 2*010, p. 1797), and since 2000 the observed emissions of greenhouse gases, which are a key influence on climate change, have been occurring at the mid- to higher levels of the various emissions scenarios developed in the late 1990’s and used by the IPCC for making projections (Manning *et al. 2*010, Figure 1, p. 377; Pielke *et al. 2*008, entire; Raupach *et al. 2*007, Figure 1, p. 10289). Also, the best scientific and commercial data available indicate that average global surface air temperature is increasing and several climate-related changes are occurring and will continue for many decades even if emissions are stabilized soon (Church *et al. 2*010, pp. 411-412; Gillett *et al. 2*011, entire; IPCC 2014b, p. 16; Meehl *et al. 2*007, pp. 822-829).

Changes in climate can have a variety of direct and indirect impacts on species, and can exacerbate the effects of other threats. Rather than assessing “climate change” as a single threat in and of itself, we examine the potential consequences to species and their habitats that arise from changes in environmental conditions associated with various aspects of climate change. For example, climate-related changes to habitats, predator-prey relationships, disease and disease vectors, or conditions that exceed the physiological tolerances of a species, occurring individually or in combination, may affect the status of a species. For example, with regard to factors impacting the viability of pygmy-owls, precipitation drives rapid changes in plant and insect biomass which, in turn influences abundance of lizards, small mammals, and birds. These indirect effects on prey availability and direct effects on prey activity affect nestling growth, development and survival. When precipitation affects food supply and temperature affects prey activity, reduced pygmy-owl productivity may have implications with regard to reduced pygmy-owl resiliency (Flesch *et al. 2*015, p. 26). Vulnerability to climate change impacts is a function of sensitivity to those changes, exposure to those changes, and adaptive capacity (IPCC 2007, p. 89; Glick *et al.* 2011, pp. 19-22). Climate change will increase the risk of extinction for a large proportion of species in the next century, through both direct effects of climate change and the interaction of climate change on other stressors (IPCC 2014b, p. 13). In the development of a SSA, the Service uses the best scientific and commercial data available, and this includes consideration of direct and indirect effects of climate change.

While projections from global climate model simulations are informative and in some cases are the only or the best scientific information available, various downscaling methods are being used to provide higher-resolution projections that are more relevant to the spatial scales used to assess impacts to a given species (Glick *et al*. 2011, pp. 58-61). With regard to the area of analysis for the pygmy-owl, there is unequivocal evidence that the earth’s climate is warming, based on observations of increases in average global air and ocean temperatures, widespread melting of glaciers and polar ice caps, and rising sea levels (IPCC 2014b, pp. 2-4). Furthermore, the Intergovernmental Panel on Climate Change (IPCC 2014a, p. 7) summarized the likelihood of general future trends in several climatic variables, projecting: (1) warmer and fewer cold days and nights over most land areas; (2) warmer and more frequent hot days and nights over most land areas; (3) more frequent warm spells/heat waves over most land areas; (4) changes in precipitation patterns favoring an increased frequency of heavy precipitation events (or proportion of total rainfall from heavy rainfalls) over most areas; and (5) an increase in area affected by droughts. In many parts of the world, climate change has also resulted in increased tree mortality and increased frequency and intensity of wildfire (IPCC 2014a, p. 51). Climate change scenarios project that drought will occur more frequently and increase in severity, with a decrease in the frequency and increase in severity of precipitation events (Seager *et al. 2*007, p. 9; Cook *et al. 2*015, p. 6; Pascale *et al. 2*017, p. 806; Williams *et al. 2*020, p. 317). These global climate changes will influence climate patterns at regional and local scales within the range of the pygmy-owl. Downscaled climate change projections relevant to the pygmy-owl occur in Karmalkar *et al.* (2011, entire), Bagne and Finch (2012, entire), Coe *et al.* (2012, entire), and

Jiang and Yang (2012, entire). These projections show that increasing temperatures, decreasing precipitation, and increased intensity of weather events are likely. We, therefore, project that this will reduce the suitability and availability of pygmy-owl habitat and will directly and indirectly reduce pygmy-owl productivity.

Changes in climate have been projected to result in increased atmospheric concentrations of carbon dioxide; increased surface temperatures; changes in the amount, seasonality, and distribution of precipitation; more frequent and severe climatic extremes (USNCA 2014, unpaginated); and greater climate variability (Easterling *et al.* 2017, entire; Vose *et al. 2*017, pp. 185–206). Increased severity of extremes can also feed into increased frequency of extremes. Climate extremes may be more important that mean climatic measures with regard to impacts to sensitive species (Germain and Lutz 2020, pp. 590 – 593) and there is further evidence that climate has become, and is projected to become, more extreme within the range of the pygmy-owl (Bagne and Finch 2012, entire; Cook et al. 2015, p. 6; Diffenbaugh et al. *2*017, entire; Easterling et al. 2017, entire; BOR 2021, entire). Multiple models project that the Sonoran Desert Ecoregion will be drier through the 21st century and that the transition to a more arid climate is likely already under way (Seager *et al. 2*007, p. 1181). Future drought is projected to occur under warmer temperature conditions as climate change progresses. Seager *et al.*(2007, p. 1181) project that the recent multiyear droughts, the Dust Bowl, and 1950s drought conditions will become the new climatology of the American Southwest with a timeframe of years to decades. A more recent assessment of the impacts of climate change in the southwest also indicated reduced precipitation, increased frequency of climatic extremes, and ecosystem tranformations (Gonzalez *et al.* 2018, entire).

Although specifically looking at pinyon-juniper communities, Breshears *et al.*(2005, pp. 15147–15148) showed that a particular concern under these drought conditions is regional-scale mortality of overstory trees, which rapidly alters ecosystem type, associated ecosystem properties, and land-surface conditions for decades. Woodlands providing important pygmy-owl habitat, including meso- and xeroriparian trees, thornscrub, and tropical deciduous forests may respond in a similar manner. Gitlin *et al.* (2006, p. 1482) documented increased mortality of *Populus fremontii* (Fremont cottonwood) (an important riparian tree in Sonoran Desert mesoriparian communities) during drought periods. In Texas, due to historical drought beginning about 1880 (cf. Dobie, 1929), the Encino Live Oak (*Quercus virginiana*) was literally decimated in some areas of the South Texas Plains whereas the drought-resistant brush was not damaged at all and indeed increased (Crosswhite 1980, p. 171). Encino Live Oak is the same species that makes up the oak motte habitat in Kenedy County where the pygmy-owl is primarily found currently in Texas.

Proudfoot (2020, pers. comm.) estimated it would take around three years of continuous drought to result in conditions from which pygmy-owl population groups would have a difficult time recovering. Such continuous drought conditions would affect cavity-bearing tree regeneration, prey availability, and cover for thermoregulation and predator avoidance.

Northern areas of Mexico are most vulnerable to droughts and desertification because erosion and drought severity will increase with higher temperatures and rainfall variations in these arid and semi-arid regions (Conde and Gay 1999, p. 2). The three Mexican regions most vulnerable to climate change are, in order of importance, Central, Northern (in areas occupied by pygmy-owls), and the Tabasco Coast (Conde and Gay 1999, p. 2). Magana and Conde (2000, p. 183) showed the vulnerability of northern Mexico, specifically Sonora, to inter-annual climate variability and climate change. They found that future major challenges that will result from climate change are increasing demand for water, competition among water users, and decline in water quality, along with the resultant loss or reduction of riparian woodlands and other pygmy-owl habitat elements. Smith *et al.*(2000, p. 79) noted the following with regard to nonnative grass invasions and climate change, "This shift in species composition in favor of exotic annual grasses, driven by global [climate] change, has the potential to accelerate the fire cycle, reduce biodiversity, and alter ecosystem function in the deserts of western North America."

In general, increasing annual precipitation in the Sonoran Desert had a positive effect on productivity (Flesch *et al. 2*015, p. 26). Changes in the timing of precipitation due to climate change may have effects related to pygmy-owl prey availability and abundance. Flesch (2008, p. 5) found that timing and quantity of precipitation affected both lizard and rodent abundance in ways that suggested rainfall is an important driver of population and community dynamics. In general, cool-season rainfall had a positive correlation with rodent populations and warm-season rainfall was positively correlated with lizard populations. Because various climate change models project that climate conditions will become more variable, lizard species that are most affected by variations in precipitation will tend to decline in abundance across time. This is an important finding given that lizards are the primary prey item for pygmy-owls during the warm months of the year. In general, data and results from northern Sonora line up suggesting lower pygmy-owl reproduction results in lower pygmy-owl abundances a year later. Both high temperatures and reduced precipitation have marked negative and interactive effects on pygmy-owl productivity. When conditions are dry and hot, reproduction declines substantially to what is very likely below replacement levels (Flesch *et al. 2*015, p. 26).

In northern Sonora, the summer monsoon's precipitation (or lack thereof) has a significant effect on whether or not juvenile pygmy-owls reach adulthood, as the lizards preferred by these owls are more abundant when summer precipitation does not fall below normal levels. Climate change has made the amount of summer precipitation more variable than it used to be. Average summer monsoons in the Sonoran Desert produce 2.43 inches of rain. In years like 2019 and 2020, however, when summer rainfall was significantly below average (0.66 inches and 1.0 inches respectively), there was less prey for juveniles to eat as they entered adulthood, and thus fewer owls survived. In years like 2015–2016, when the amount of precipitation from the summer monsoon was above average, more juveniles survived to adulthood and owl population levels in those years did not decline (Flesch 2021, entire).

Climate change impacts to the pygmy-owl likely include loss of vegetation cover, reduced prey availability, increased predation, reduced nest site availability, and vegetation community change. Of particular concern is the projection that the distribution of habitat for saguaros, the primary pygmy-owl nesting substrate within the Sonoran Desert Ecoregion, will decrease anywhere from 23–77 percent over the next 50 years under a moderate climate change scenario (Thomas *et al. 2*012; p. 43). A similar substantial decrease in the abundance of saguaros is anticipated by Weiss and Overpeck (2005, p. 2074) as a result of climate change. The majority of the current range of the pygmy-owl occurs in tropical or subtropical vegetation communities that may be reduced in coverage if climate change results in hotter, more arid conditions. The Sonoran Desert Ecoregion is already characterized by hot, arid conditions, and pygmy-owls in this portion of the range are already adapted to the hotter, more arid conditions that may prevail in the future. This adaptation may be important to the continued existence of the subspecies as desertification spreads in response to climate change, but may be offset as some if future model scenarios project a reduction in columnar cacti densities, the primary pygmy-owl nesting substrate within the Sonoran Desert Ecoregion (Weiss and Overpeck 2005, p. 2074). Already studies have documented a noticeable shift north of bird species in association with changing climates. Christmas Bird Count data show a shift northward in 56 percent of the 305 most widespread, regularly occurring wintering bird species (NABCI 2010, entire). This report indicates that bird species that are rare or nonexistent in the United States at present will expand their ranges into our country from the south (NABCI 2009, p. 15).

The past decade has been characterized by ongoing climate impacts to pygmy-owl populations and their habitats (Bagne and Finch 2012, entire; Coe et al. 2012, entire; Jiang and Yang 2012, entire; Romero-Lankao, et al. 2014, p. 1443; Melillo et al. 2014, entire; USGCRP 2018, chapters 23 and 25). Impacts resulting from climate change such as ongoing drought (habitat and prey impacts), increased temperatures (decreased productivity), reduced vegetation health and associated impacts to pygmy-owl prey availability, and increased fire occurrence (habitat and prey impacts) have resulted in negative effects to pygmy-owl abundance and distribution, as well as in loss of habitat and increased habitat fragmentation (Melillo et al. 2014, entire; Vermote et al. 2014, unpaginated; Cook et al. 2015, p. 6; Easterling et al. 2017, pp. 207–230; USGCRP 2018, chapters 23 and 25; Gonzalez et al. 2018, entire; Breshears et al. 2018, p. 1; Williams et al. 2020, p. 317, Inciweb 2021, unpaginated; IPCC 2022, entire).

Climate change, in and of itself, may affect pygmy-owls, but the magnitude of those impacts remain uncertain. However, enough time has passed since the early predictions of impacts of climate change that we have seen evidence of those predicted impacts on vegetation communities across the range of the pygmy-owl (Vermote et al. 2014, unpaginated; Romero-Lankao, et al. 2014, p. 1459; Williams et al. 2020, p. 317; IPCC 2022, entire). This SSA Report uses new climate models and projections, updated Normalized Difference Vegetation Index (NDVI) datasets, and an assessment examining pygmy-owl's vulnerability to climate change that have been completed since our last detailed analysis of the status of the pygmy-owl (our 2011

12-month finding; 76 FR 61856). These include Bagne and Finch 2012, pp. 67–73; Coe et al. 2012, entire; Jiang and Yang 2012, entire; IPCC 2014b, entire; Romero-Lankao, et al. 2014, entire; Melillo et al. 2014, entire; Vermote et al. 2014, unpaginated; AdaptWest Project 2015, unpaginated; Cook et al. 2015, entire; Pascale et al. 2017, p. 806; USGCRP 2018, chapters 23 and 25; Gonzalez et al. 2018, entire; Christensen et al. 2018, p. 5409; BOR 2021, entire; AdaptWest Project 2022, unpaginated; IPCC 2022, entire. These new analyses and projections continue to predict impacts at the same or increasing levels upon the landscape in areas where the pygmy-owl occurs.

However, we can conclude that climate change may have a significant negative impact on some pygmy-owl populations because it will exacerbate the current and ongoing effects discussed above. For example, drought has been documented in Arizona and northern Sonora to reduce juvenile pygmy-owl survival. Increasing temperatures during the pygmy-owl brooding season resulted in reduced productivity and the combination of reduced precipitation and increased temperatures contributed to an apparent ecological crunch characterized by low pygmy-owl productivity. Flesch *et al.*(2015, p. 17) indicated that productivity dropped to one young per year or less during the hot dry summers during drought, levels which may not replace losses in the local population group. Under the projected climate change scenarios, drought will occur more frequently and increase in severity. The invasion of nonnative species has been documented in the loss of pygmy-owl habitat and native vegetation communities. A common projection under climate change is for conditions that will favor the increased occurrence and distribution of nonnative species. Riparian areas, supported by both permanent and ephemeral water sources, support important pygmy-owl habitat elements such as thermal and predator cover, and increased prey availability. Precipitation events under most climate change scenarios will decrease in frequency and increase in severity. This may reduce available cover and prey for pygmy-owls by affecting riparian areas through scouring flood events and reduced moisture retention. However, the extent to which changing climatic patterns will affect the pygmy-owl is not known with certainty at this time; only that there will be an effect. Additionally, it may not be sufficient to simply look at temperature and precipitation. The effects of climate change interact with other factors affecting pygmy-owl resiliency such as conspecific competition and habitat selection (Flesch *et al. 2*015, pp. 28-30). A review of occupancy data from Arizona and northern Sonora shows that pygmy-owl occupancy declines markedly with warming winter minimum temperatures, but only in areas like northwest Tucson where land-cover change has been moderate to high, suggesting compounding effects of climate change on other factors. Increased evapotranspiration and reduced soil moisture could negatively impact prey species that pygmy owls depend on, reduce the amount and/or quality of vegetation necessary for roosting, thermoregulation, and predator avoidance, amplify fire risk and concomitant compromise of necessary woodland vegetation and availability of mature saguaro cacti, as well as lead to reduced nestling fitness if nest cavity temperatures rise too high (Flesch et al. 2015, p. 26; Service 2022a, chapter 6; Flesch 2021, entire; PCOSC 2022, pers. comm.). These interactive stressors and the potential for them should be considered in the context of climate change because it is likely that extinction risks will be greater than they would be considered independently (Flesch *et al.* 2017, pp. 14 – 16).

Hurricanes

Although not generally considered a historical impact to pygmy-owl habitat, the loss of habitat and nest structures as a result of hurricanes has been identified as a potential contributor to an apparent decline in pygmy-owl nestlings documented as part of a pygmy-owl nest box study in south Texas (Proudfoot 2011b, pers. comm.; Proudfoot 2010, pers. comm.). Hurricanes have impacted thousands of acres of occupied pygmy-owl habitat by removing trees and reducing cover and structural diversity. Such effects to birds are described in detail in Lynch (1991, entire) and in Wiley and Wunderle (1993, entire). Within the current range of the pygmy-owl, hurricanes are most likely to affect pygmy-owl habitat in southern Texas and northeastern Mexico, although hurricanes in the Pacific Ocean also have the potential to affect pygmy-owl habitat in western Mexico. Historically, major hurricanes have made landfall in southern Texas on average about once every decade. However, more recently, hurricanes (Erika in 2003, Dolly in 2008, Alex in 2010, Harvey in 2017, Hanna in 2020, and Ida in 2021) have occurred more often than in the past, suggesting that major hurricanes may be occurring more frequently now (Bhatia et al. 2019, entire). Hurricanes have also affected western Mexico that, while destructive in Mexico, their remnants can provide beneficial moisture to Arizona, such as Hurricane Nora in 2021 (Accuweather 2021, entire). If hurricanes continue to occur every few years, this frequency of hurricanes resulting in loss of woodlands may not allow some areas of previously suitable pygmy-owl habitat to regenerate trees of adequate size to support the cavities needed for nesting by pygmy-owls. However, the effects are expected to be localized within specific analysis units and not a range-wide effect. However, such effects at the analysis unit scale will affect the representation and redundancy within both pygmy-owl populations.

7.2 Habitat Loss and Fragmentation

Urbanization

Increasing human populations result in expanding urban areas. Urbanization causes permanent impacts on the landscape that potentially result in the loss and alteration of pygmy-owl habitat. Residential, commercial, and infrastructure development replace and fragment areas of native vegetation resulting in the loss of available pygmy-owl habitat and habitat connectivity needed to support pygmy-owl dispersal and demographic support (exchange of individuals and rescue effect) of population groups. Increasing human populations require additional water, and increasing water consumption can reduce available surface and ground water needed to support pygmy-owl and pygmy-owl prey habitats. Added human presence on the landscape can potentially lead to increased pygmy-owl mortality through introduced predators, collisions, etc. Appendix 6 of this SSA Report shows analysis done indicating the ongoing loss of pygmy-owl habitat related to urbanization and other human impacts. The following discussion presents the available information related to pygmy-owl habitat impacts associated with urbanization.

While there is not a direct correlation between acres of pygmy-owl habitat lost and human population growth, it is reasonable to find that, as human population grows, the amount of native habitat lost or fragmented will increase. We looked at recent population growth and projections in Arizona as an indication for future urbanization (OEO 2018, unpaginated; U.S. Census Bureau 2021a, unpaginated; EBRC 2021, unpaginated). Human population growth results in the expansion of urbanization (Travis *et al. 2*005, p. 2). Both Arizona and Texas (the states in the United States where the pygmy-owl is found) were in the top ten fastest growing states according to the U.S. Census Bureau (U.S. Census Bureau 2021b, unpaginated). Using the number of building permits as an index of population growth, Arizona has seen an increase in building permits of 31.8% compared to this time last year (University of Arizona 2021, unpaginated). From 2010 to 2020, population growth rates in Arizona counties where the pygmy-owl occurs, or recently occurred, have varied by county, but all are increasing: Pima (9.3 percent); Pinal (25.7 percent); and Santa Cruz (13 percent) (OEO 2021, unpaginated; World Population Review 2020, unpaginated).

Urban expansion and human population growth trends in Arizona are expected to continue into the future. The Maricopa-Pima-Pinal County areas of Arizona are expected to grow by as much as 132% percent between 2005 and 2050, creating rural-urban edge effects across thousands of acres of pygmy-owl habitat (AECOM 2011, p. 13). In another projection, the Arizona population is expected to grow by 38 percent in the next 30 years (OEO 2021, unpaginated). Many cities and towns within the historical distribution of the pygmy-owl in Arizona already experienced substantial growth (April 2010 – July 2019): Casa Grande (20.7 percent); City of Eloy (17.8 percent); City of Florence (7.7 percent); Town of Marana (41.9 percent); Town of Oro Valley (12.2 percent); and the Town of Sahuarita (20.9 percent) (U.S. Census Bureau 2021a, unpaginated).

This population growth has spurred a significant increase in urbanization and development in these areas. Regional development is projected to be high in certain areas within the distribution of the pygmy-owl in Arizona. In particular, a wide area from the international border in Nogales, through Tucson, Phoenix, and north into Yavapai County (called the Sun Corridor "Megapolitan" Area) is projected to have 11,297,000 people by 2050, an 132 percent increase from 2005 (AECOM 2011, p. 13). If build-out occurs as expected, it will encompass a substantial portion of the current and historical distribution of the pygmy-owl in Arizona.

Development pressure across Arizona slowed beginning in 2007 due to an economic downturn and decline in the housing market. However, development projects have increased over the past three to five years and development continues to increase across Arizona (University of Arizona 2021, unpaginated). We also recognize that economic trends are difficult to project into the future. The most recent draft Pinal County Comprehensive Plan (February 2019) acknowledges that the county is in the middle of the Sun Corridor Megapolitan and proposes four shorter-term growth areas in defining where development will likely occur over the next decade, but does not discourage growth outside of these areas (Pinal County 2019, p. 126). Areas within two of the four growth areas (West Pinal and Red Rock) have been historically occupied or recently occupied by pygmy-owls. As an indication that there is increasing demand for housing in Pinal County, a national homebuilder purchased 2,800 acres of State Trust lands in November of 2020. This will become a master planned community adding thousands of new residents to this area and all of the associated infrastructure. The news article describing this purchase also indicated that State Trust lands are important sources of land on which to build homes to keep up with the current demand (Gonzales 2020, unpaginated). State Trust lands are undeveloped lands administered by the State Land Department and make up a substantial amount of pygmy-owl habitat in southern Arizona.

Because most of the pygmy-owl habitat in Texas occurs on private ranch lands, the threat of habitat loss and fragmentation of the remaining pygmy-owl habitat due to urbanization is reduced when compared to other private lands more conducive to urbanization. Some housing, ranch facilities, roadways, and utilities will undoubtedly be constructed with changing ranch plans, and this may affect individual pygmy-owl territories. Regardless, urban growth in Texas is expected to result in a decrease of rural land uses (Texas Land Trends 2019, entire). For example, the human population in four of the six Texas counties with documented pygmy-owl occurrences have population growth estimated at 0 – 25% (Cameron and Starr counties) and 25 – 50% (Kenedy and Hidalgo counties) between 2010 and 2050 (TDC 2019, entire). The South Texas region’s estimated total population in 2019 was more than 2.4 million, or 8.4 percent of the state’s total population. This represented an increase of 7.4 percent (about 169,000 people) since the 2010 Census. In 2019, an estimated 35.6 percent of the region’s population was concentrated in Hidalgo County (which includes the city of McAllen).

From 2010 to 2019, the region’s population growth was slower than that of the state. While each county in the region saw a change during this period**)**, Hidalgo outpaced all others by growing by more than 12 percent, slightly lower than the state as a whole (Texas Comptroller 2021, entire).

However, urbanization is not the only factor that fragments habitat. Currently, Texas has the lowest amount of intact vegetation types of all the analysis units (Table 6.2 above). This is likely the result of agriculture, roads, and other factors beyond just urbanization. Urbanization and agriculture along the United State-Mexico border are likely to continue to isolate the Texas population of pygmy-owls by restricting movements between Texas and northeastern Mexico (TDC 2019, entire; Texas Land Trends 2019, entire; USGS 2022, unpaginated).

In Mexico, the greatest increases in population have occurred mostly in coastal resort areas, State capitals, and along the United States–Mexico international border. In the more general area of the Sonoran Desert Ecoregion of Mexico (a relatively homogeneous ecological area defined by similarity of climate, landform, soil, potential natural vegetation, hydrology, or other ecologically relevant variables). Urban expansion and human population growth trends are expected to continue in the Sonoran Desert Ecoregion. The Maricopa-Pima-Pinal County areas of Arizona are expected to see the population grow by as much as 132 percent between 2005 and

2050, creating rural-urban edge effects across thousands of acres of pygmy-owl habitat (AECOM 2011, p. 13).

When looking specifically at the United States–Mexico border region extending from Texas to California, the population is approximately 15 million inhabitants and this population is expected to double by 2025 (HHS 2017, p. 1). In Arizona, the border counties are projected to increase by 60 percent to 2.5 million by 2050 (OEO 2021, unpaginated). In 2020, the population of Sonora, Mexico, was 2.9 million (INEGI 2021, unpaginated) and is projected to reach 3.5 million by 2030 (CONAPO 2014, p. 25).

The United States–Mexico border region has a distinct demographic pattern of permanent and temporary development related to warehouses, exports, and other border-related activities, and patterns of population growth in this area of northern Mexico has accelerated relative to other Mexican States (Pineiro 2001, pp. 1–2). This pattern focuses development, and potential barriers or impediments to pygmy-owl movements, in a region that is important for demographic support (immigration events and gene flow) of pygmy-owl population groups, including movements such as dispersal. The Arizona–Sonora border region's population growth will affect cross-border movement by pygmy-owls and other important population linkages needed to provide interchange among pygmy-owl population groups. If urban expansion and development continues as expected, it will encompass a substantial portion of the current and historical distribution of the pygmy-owl in the Sonoran Desert Ecoregion.

Human activity, most notably in the past century, has dramatically altered the landscape of the Arizona-Sonora border, affecting both the quantity and quality of its ecological resources. Urbanization not only reduces the amount of open space, but impacts the biological value of areas (Walker and Pavlakovich-Kochi 2003, p. 3). When considering urban growth within individual biotic communities, the human population more than doubled in three of the seven major biogeographic communities of Mexico (Arizona Upland and Lower Colorado River Valley, Plains of Sonora, and Magdalena Plain) (Gorenflo 2002, p. 28), all of which provide important pygmy-owl habitat. Based on 1990 human population numbers, the land cover types currently most valuable to the pygmy-owl—Mesquite Bosque and Palo Verde-Mixed Cactus—were the most heavily human-populated in the Sonoran Desert Ecoregion. The Mesquite Bosque type makes up 8.2 percent of the area, but supports 10.4 percent of the human population. Similarly, the Palo Verde-Mixed Cactus type covers 29 percent of the area, but supports 49.4 percent of the population (Gorenflo 2002, p. 28).

The Sonoran border population has been increasing faster than that State's average and faster than Arizona's border population; between 1990 and 2000, the population in the Sonoran border municipios increased by 33.4 percent, compared to Sonora's average (21.6 percent) and the average increase of Arizona's border counties (27.8 percent). Urbanization has increased habitat conversion and fragmentation, which, along with immigration, population growth, and resource consumption, were ranked as the highest threats to the Sonoran Desert Ecoregion (Nabhan and Holdsworth 1998, p. 1).

One significant example of how urbanization and activities supporting urbanization can cause widespread impacts is related to urban and agricultural water withdrawal. Mesta (2020, p.1) indicated that aquifers in northeastern Mexico are beginning to dry up due to pumping by large industrial farms and, for the first time in Sonora’s history, a significant amount of water is being pumped from the Rio Yaqui drainage to supply the urban growth of Hermosillo. This became necessary due to the loss of aquifer water.

Urbanization has also affected pygmy-owl habitat in other parts of Mexico. Trejo and Dirzo (2000, p. 133) indicate that areas of dry subtropical forests, important habitat for pygmy-owls in southwestern Mexico, have been used by humans through time for settlement and various other activities. The long-term impact of this settlement has converted these dry subtropical forests into shrublands and savannas lacking large trees, columnar cacti, and cover and prey diversity that are important pygmy-owl habitat elements. In Mexico, dry tropical forest is the major type of tropical vegetation in the country, covering over 60 percent of the total area of tropical vegetation. About 8 percent (approximately 160,000 square km (61,776 square mi)) of this forest remained intact by the late 1970s, and an assessment made at the beginning of the present decade suggested that 30 percent of these tropical forests have been altered and converted to agricultural lands and cattle grasslands (Trejo and Drizo 2000, p. 134). The remaining forests are restricted to steep slopes where it is not likely that land will be cleared for additional agricultural or development purposes (Allnutt 2001, p.3). However, the information about the current extent and condition of dry tropical forests in Mexico is unclear due to confusion in their classification and difficulty using remote sensing to delineate intact dry forest (Allnutt 2001, p. 3). The best available information indicates that there are still expanses of dry tropical forest along the Pacific coast in Mexico, including some areas below 1,200 m (4,000 ft) where pygmy-owls are found, but there has been loss of this forest type throughout Mexico. However, Enríquez and Vazquez-Perez (2017, p. 545) indicate that the main threats to the conservation of owls in Mexico are the loss, degradation, and fragmentation of habitat. They indicate that Mexico has the second highest deforestation rates in the world, but that these rates vary by vegetation type, the region, and time period considered.

The actual effects of urbanization on biodiversity are many and mutually reinforcing, including the aggravation of the "urban heat island effect"; the channelization or disruption of riverine corridors; the proliferation of exotic species; the killing of wildlife by automobiles, toxins, and pets; and the fragmentation of remaining patches of natural vegetation into smaller and smaller pieces that are unable to support viable populations of native plants or animals (Ewing *et al*. 2005, pp. 1–2; Nabhan and Holdsworth 1998, p. 2). Human-related mortality (e.g., shooting, collisions, and predation by pets) increases as urbanization increases (Banks 1979, pp. 1–2; Churcher and Lawton 1987, p. 439). The above statements, while general in their nature, point out the vulnerability of habitats that support pygmy-owls and the impacts that urbanization can have on the extent and quality of available habitat. We would expect these types of impacts in areas that have experienced or are experiencing urban growth in or near pygmy-owl habitats. Not all areas in the United States and Mexico are experiencing this type of urban growth because most of the population is centered in existing urban areas. However, rural areas in both countries continue to be impacted by other activities affecting pygmy-owl habitat including agricultural development, mineral extraction, deforestation, and water extraction. Development of roadways and their contribution to habitat loss and fragmentation is a particularly widespread impact of urbanization (Nickens 1991, p. 1). Data from Arizona and Mexico indicate that roadways and other open areas lacking cover affect pygmy-owl dispersal (Abbate *et al. 1*999, p. 54; Flesch and Steidl 2007, pp. 6–7; Flesch 2021, pp. 12–14). Nest success and juvenile survival were lower at pygmy-owl nest sites closer to large roadways, suggesting that habitat quality may be reduced in those areas (Flesch and Steidl 2007, pp. 6–7).

Currently, most roadways in Sonora are relatively narrow. However, the Sonoran government is starting to implement plans to build new highways and other infrastructure improvements. Governor Bours of Sonora formed the Sonoran Strategic Projects Operator, in conjunction with other investors, to carry out the construction of highway improvements (Wild Sonora 2021, unpaginated). Of specific concern related to pygmy-owl threats is the recent improvement of the road between Saric, in the upper Rio Altar valley, and Sasabe, in the heart of the distribution of the pygmy-owl in northern Sonora. Instead of just paving the existing Altar/Sasabe road, a new highway was constructed resulting in an increase of habitat impacts and fragmentation (Wild Sonora 2021, unpaginated). In the United States, in Arizona, there is a new interstate highway proposal, Interstate 11, which is currently proposed to run through or adjacent to currently occupied pygmy-owl habitat and would be a significant effect to habitat loss and fragmentation in southern Arizona.

Significant human population expansion and urbanization in the Sierra Madre foothill corridor may represent a long-term risk to pygmy-owls in northeastern Mexico. In Texas, the pygmy-owl occurred in good numbers until approximately 90 percent of the mesquite-ebony woodlands of the Rio Grande delta were cleared in 1910–1950 (Oberholser 1974, p. 452). Habitat removal in northeastern Mexico is widespread and nearly complete in northern Tamaulipas (Hunter 1988, p. 8). Demographic support (rescue effect) of pygmy-owl population groups is threatened by ongoing loss and fragmentation of habitat in this area. Urbanization has the potential to permanently alter the last major landscape linkage between the pygmy-owl population in Texas and those in northeastern Mexico (Tewes 1993, pp. 28–29).

Human population growth in Sinaloa, Nayarit, Colima, and Jalisco, Mexico is ongoing. From 2010 to 2015, the population in Sinaloa grew at a rate of 9.3 percent, Nayarit grew at a rate of 13.9 percent, Jalisco grew at a rate of 13.6 percent, and Colima grew at a rate of 12.4 percent (DataMexico 2021, unpaginated). Growth rates in these areas will likely have some concurrent spread of urbanization despite the fact that most of the growth is taking place in the large cities rather than in the rural areas (Brinkhoff 2016, unpaginated). Additionally, these Mexican states have other threats to pygmy-owl habitat occurring such as agricultural development and deforestation that, in combination with habitat lost to urbanization, represent threats to the continued viability of the pygmy-owl in this area (Blackie et al. 2014, p. 1; Burquez 2022, pers. comm.; Mesa-Sierra et al. 2022, entire).

To summarize the effects of population growth and development in Mexico on the pygmy-owl, the main factors that cause this degradation and loss of habitat are extraction of natural resources, expansion of pastures and farms, as well as urban expansion. Generally, over the past decade, threats in Mexico have impacted the landscape and habitat of the pygmy-owl, including extraction of natural resources, increases in invasive species, use of pesticides, and the effects of climate change such as drought and increased evapotranspiration (Enríquez and Vazquez-Perez 2017, p. 546, DataMexico 2021, unpaginated; Murray-Tortarolo 2021; entire; Mesa-Sierra et al. 2022, unpaginated). Specifically, habitat loss and fragmentation has increased as a result of wood harvesting, agriculture, population growth and urbanization, and other land uses (CONAPO 2014, p. 25; Enríquez and Vazquez-Perez 2017, p. 546; DataMexico 2021, unpaginated; Burquez 2022, pers. comm.). Additionally, natural events like hurricanes, tropical storms, and droughts also are factors that modify and fragment environments. Enríquez and Vazquez-Perez (2017, p. 546) indicate that during the last 50 years, Mexico has seen drastic changes in land uses due to rapid urbanization and industrialization, which has been poorly planned. The result has been impacts to the natural environment, including the degradation and loss of biological diversity in Mexico. There has been limited work in Mexico, however, to understand what the direct impacts of these threats are on owl population losses and changes in distribution and abundance of species in long term (Enríquez and Vazquez-Perez 2017, p. 546).

Invasive Species

The invasion of nonnative vegetation, particularly nonnative grasses, has altered the natural fire regime over the Sonoran Desert ecoregion of the pygmy-owl range, in particular, but invasive species impact native habitats in other pygmy-owl analysis units as well (Esque and Schwalbe 2002, p. 165; Lyons et al. 2013, p. 71; Wied et al. 2020, entire). In areas composed entirely of native species, ground vegetation density is mediated by barren spaces that do not allow fire to carry across the landscape. However, in areas where nonnative species have become established, the fine fuel load is continuous, and fire is capable of spreading quickly and efficiently (Esque and Schwalbe 2002, p. 175; Wied et al. 2020, p. 48). As a result, fire has become a significant threat to the native vegetation of the Sonoran Desert. Sonoran Desert vegetation is not fire adapted, and many such vegetative communities in Arizona are no longer in a natural or historic state. Esque and Schwalbe (2002, pp. 180–190) discuss the effect of wildfires in the Arizona Upland and Lower Colorado River subdivisions of Sonoran desertscrub, which comprise the primary portions of the pygmy-owl's range within Sonoran desertscrub. Sonoran desertscrub communities and their fire dynamics have been inalterably changed by nonnative grasses and forbs, and in some areas by woody shrubs and trees (Gornish and Howery 2019, entire).

Nonnative plant communities are problematic not only for imperiled species such as the pygmy-owl, but also for land managers whose goals include forest stewardship and wildfire mitigation for public safety and natural resource protection. The Arizona Wildfire Risk Assessment Portal estimates that a substantial portion of the pygmy-owl range in Arizona (2,433,763 ha; 6,013,959 acres) has a moderate to high risk of experiencing adverse effects of wildfire in the foreseeable future. As discussed elsewhere in this SSA report, such adverse effects include the destruction of roosting and nesting substrate provided by mature trees and columnar cacti. Using conservative estimates from post-fire monitoring performed by the Tonto National Forest (ADFFM 2022, pers. comm.), the Arizona Department of Forestry and Fire Management (ADFFM) concluded that over 30 million saguaros could be lost and unlikely to regenerate if a large portion of the area under risk were to burn (ADFFM 2022, pers. comm.). Nonnative annual plants prevalent within the Sonoran range of the pygmy-owl include *Bromus rubens* and *B. tectorum* (brome grasses) and *Schismus* spp. (Mediterranean grasses) (Esque and Schwalbe 2002, p. 165). Sahara mustard (*Brassica tournefortii*) is an Old World forb that can cover 100 percent of the ground under certain conditions (ASDM 2021, entire). In 2006, fires that burned thousands of acres of Sonoran desertscrub in southwestern Arizona had Sahara mustard as the primary fuel. The increase in fire occurrence and severity due to non-native plant species continues currently and is evident form the 2020 fire season. The following major fires occurred in the summer of 2020 and all or portions of these fires burned in Sonoran desertscrub and semidesert grasslands that provide pygmy-owl habitat and were fueled, in large part, by non-native plant species: the Range Fire (3,286 acres), the Sawtooth Fire (24,729 acres), the Tortolita Fire (3,140 acres), the Bighorn Fire (119,987 acres), and the Bush Fire (193,455 acres) (Inciweb 2021, unpaginated). However, the nonnative species that is currently the greatest threat to vegetation communities in Arizona and northern Sonora, Mexico is the perennial *Cenchrus ciliaris* (buffelgrass), which is prevalent and increasing throughout much of the Sonoran range of the pygmy-owl (Burquez and Quintana 1994, p. 23; Van Devender and Dimmit 2006, p. 5; Lyons et al. 2013, pp. 68–69; Wied et al. 2020, pp. 47–48).

Buffelgrass is an Indo-African grass introduced to Mexico between 1940 and 1960 (Burquez *et al. 1*998, p. 25). The distribution of this grass has been supported and promoted by governments on both sides of the United States–Mexico border as a resource to increase range productivity and forage production. Buffelgrass is first established by stripping away the native desertscrub and thornscrub (Franklin *et al. 2*006, p. 69). Following establishment, it fuels fires that destroy Sonoran desertscrub, thornscrub, and, to a lesser extent, tropical deciduous forest; the disturbed areas are quickly converted to open savannas composed entirely of buffelgrass which removes pygmy-owl nest substrates and generally renders areas unsuitable for future occupancy by pygmy-owls. Buffelgrass is now fully naturalized in most of Sonora, southern Arizona, and some areas in central and southern Baja California (Burquez-Montijo *et al. 2*002, p. 131), and now commonly spreads without human cultivation (Arriaga *et al. 2*004, pp. 1509 – 1511; Perramond 2000, p. 131; Burquez *et al. 1*998, p. 26).

However, buffelgrass is adapted to dry, arid conditions and does not grow in areas with high rates of precipitation or high humidity, above elevations of 1,265 m (4,150 ft), and in areas with freezing temperatures. Areas that support pygmy-owls south of Sonora and northern Sinaloa typically are wetter and more humid, and the best available information does not indicate that buffelgrass is invading the southern portion of the pygmy-owl's range. Buffelgrass is most often located on steep, rocky, south-facing slopes, with poor soil development (Van Devender and Dimmitt 2006, pp. 25-26). Surveys completed in Sonora and Sinaloa in 2006 noted buffelgrass was present in Sonora and northern Sinaloa, but the more southerly locations were noted as sparse or moderate (Van Devender and Dimmitt 2006, p. 7). This was in comparison to northerly sites in Sonora that were rated as dense. As such, this nonnative species only significantly affects a portion of the pygmy-owl's range. The best available information indicates that buffelgrass is not significantly affecting areas in Mexico beyond Sonora, and northern Sinaloa.

Buffelgrass is not only fire-tolerant (unlike native Sonoran Desert plant species), but is actually fire-promoting (Halverson and Guertin 2003, p. 13; Lyons et al. 2013, p. 71). Invasion sets in motion a grass-fire cycle where nonnative grass provides the fuel necessary to initiate and promote fire. Nonnative grasses recover more quickly than native grass, tree, and cacti species and cause a further susceptibility to fire (D'Antonio and Vitousek 1992, p. 73; Schmid and Rogers 1988, p. 442). While a single fire in an area may or may not produce long-term reductions in plant cover or biomass, repeated wildfires in a given area, due to the establishment of nonnative grasses, are capable of ecosystem type-conversion from native desertscrub to nonnative annual grassland (Wied et al. 2020, p. 48). These repeated fires may render the area unsuitable for pygmy-owls and other native wildlife due to the loss of trees and columnar cacti, and reduced diversity of cover and prey species (Brooks and Esque 2002, p. 336; Wied et al. 2020, p. 48). Buffelgrass competes with neighboring native species for space, water, and nutrients (Halverson and Guertin 2003, p. 13; Williams and Baruch 2000, pp. 128–135; D'Antonio and Vitousek 1992, pp. 68–72). Buffelgrass conversion is associated with increased soil erosion and changes in nutrient dynamics and primary productivity (Abbot and McPherson 1999, p. 3). These changes make it more difficult for native vegetation to reestablish, even if the conversion process or fires are discontinued (Franklin *et al. 2*006, p. 69; Rogers and Steele 1980, pp. 17–18).

The establishment of nonnative grasslands has been identified as the most serious threat to the biological diversity of the Sonoran Desert (Burquez and Quintana 1994, p. 23). Economic subsidies from the State of Sonora and low-interest loans from banks made funds available for more widespread plantings of buffelgrass in the 1980s (Camou-Healy 1994). By 1997, more than 1 million ha (2.5 million ac) of desertscrub and thornscrub (both communities occupied by the pygmy-owl) had been cleared in central Sonora to plant buffelgrass, and more than 2 million ha (5 million ac) were scheduled for future vegetation conversion (Burquez and Quintana 1994, p. 23; Johnson and Navarro 1992, p. 118), often as part of government programs to support the ranching industry (Van Devender *et al.* 1997, p. 3). Researchers during this time period projected that, if not halted, this practice of buffelgrass planting will permanently change the landscape of the Sonoran desert and deplete its associated biological diversity (Burquez and Quintana 1994, p. 23). Also, given the government subsidies to establish exotic grasslands in order to maintain large cattle herds, and to support marginal cattle ranching, it is less likely that control measures will be implemented, and the desertscrub and thornscrub in Sonora will probably be replaced in the near term by ecosystems with significantly lower species diversity and reduced structural complexity (Burquez and Martinez-Yrizar 1997, p. 387).

More recent figures indicate that this is indeed occurring, with buffelgrass present in more than two-thirds of Sonora, and 1.6 million ha (4 million ac) having been deliberately cleared and seeded with the species (Burquez-Montijo *et al.* 2002, p. 132). A 2006 publication estimates that 1.8 million ha (4.5 million ac) have been converted to buffelgrass in Sonora, and that between 1990 and 2000, there was an 82 percent increase in buffelgrass coverage (Franklin *et al.* 2006, pp. 62, 66). Buffelgrass pastures have doubled in area in Sonora approximately every 10 years since 1973 (Franklin *et al.* 2006, p. 67). Data from 2020 provided by Saguaro National Park (SNP) in Arizona indicates they have approximately 1,500 acres infested with buffelgrass and other invasive species (Stonum 2020, p. 2). While SNP has made significant efforts to limit the spread of invasive species, funding is unstable from year to year and difficult to predict for the future. SNP also has a policy to extinguish all fires below 4,500 feet, which includes the areas of pygmy-owl habitat. Stonum (2020, p. 2) commented that with the proliferation of invasive species and increased aridity due to climate change, they expect the wildland fire risk in pygmy-owl habitat to increase in the coming years.

It is not only Sonoran desertscrub communities in Sonora and northern Sinaloa that is impacted by the spread of buffelgrass. Another unique vegetation community in this region, dry subtropical forests, are being lost and fragmented due to the planting of buffelgrass in association with cattle ranching, which results in vast tracts of forest being removed and replaced by buffelgrass (Allnut 2001, pp. 3–4).

Buffelgrass invasion in the United States is such an urgent and significant issue that the Governor of Arizona, and nearly all southern Arizona municipalities and agencies have joined together to address the issue. The Governor formed the Arizona Invasive Species Advisory Council in 2005, and the Southern Arizona Buffelgrass Working Group developed the Southern Arizona Buffelgrass Strategic Plan in 2008 (Buffelgrass Working Group 2008) in order to coordinate the control of buffelgrass. Because of its negative impacts to native ecosystems, buffelgrass was declared a noxious weed by the State of Arizona in March 2005. This buffelgrass working group is now led by the Arizona-Sonora Desert Museum (ASDM). The ASDM is currently mapping the extent, and control, of buffelgrass in southern Arizona in an effort to inform and direct management activities (ASDM 2022, unpaginated). These efforts are helping to manage buffelgrass invasion in southern Arizona.

The impacts of buffelgrass establishment and invasion are substantial for the pygmy-owl in the United States and Sonora because conversion results in the loss of all important habitat elements, particularly columnar cacti and trees that provide nest sites. Buffelgrass invasion and the subsequent fires eliminate most columnar cacti, trees, and shrubs of the desert (Burquez-Montijo *et al. 2*002, p. 138). This elimination of trees, shrubs, and columnar cacti from these areas is a potential threat to the survival of the pygmy-owl in the northern portion of its range, as these vegetation components are necessary for roosting, nesting, protection from predators, and thermal regulation. Because tree canopy cover is an important pygmy-owl habitat feature, the fact that buffelgrass fires reduce the number of tree-dominated patches and the recruitment opportunities for those native species dependent on them [such as saguaros] (Burquez and Quintana 1994, p. 11), is significant. Franklin *et al.* (2010, p. 7) report significant changes in vegetation structure as a result of creating buffelgrass pastures for grazing. There were 90 percent fewer trees and shrubs of the size used by pygmy-owls (2 to 5 m (6 to 15 ft) tall) in buffelgrass pastures as compared to native vegetation communities. Loss of diversity and availability of prey species due to conversion are also detrimental (Franklin *et al. 2*006, p. 69; Avila Jimenez 2004, p. 18; Burquez-Montijo *et al. 2*002, pp. 130, 135).

The distribution of pygmy-owl locations from Flesch (2003, Figure 2), AGFD (2008a, p. 1), and Westland Resources (2008, Figure 4), as well as the known pygmy-owl locations and the documented occurrence of buffelgrass in Tucson, Avra Valley, Altar Valley, Organ Pipe Cactus National Monument, Pinal County, the Tohono O'odham Nation, and Sonora and northern Sinaloa show that there is almost 100 percent overlap in the areas occupied by pygmy-owls and the areas under greatest threat from buffelgrass invasion in Arizona. One of the principle reasons that nonnative plants pose such a significant threat to the pygmy-owl, and the native plant communities on which they depend, is because few, if any, reasonable methods currently exist to control the ongoing invasion of these plants or to remediate areas where they are already established. Mechanical removal, herbicides, and fire have all been tested for their effectiveness in control of this nonnative grass. However, none have proven effective at the scale of the current invasion.

In some portions of the pygmy-owl's range, such as semi-desert grasslands, invasive species and fire are not as significant of a threat because the vegetation communities in these areas are adapted to periodic fire. However, while fire may not be a primary issue, nonnative species can cause other effects to pygmy-owl habitat elements. For example, in Texas, studies indicate that the spread and prevalence of the nonnative grass, *Bothriochloa ischaemum* (King Ranch bluestem), results in this grass dominating native grasses, forbs, and endemic species, thus decreasing plant and animal species diversity and altering the vegetative structure of the community (Davis 2011, p. 4). It is not known if these changes in plant community structure affect pygmy-owls. In addition to King Ranch bluestem, other non-native, invasive grasses include Kleberg bluestem (*Dichanthium annulatum*) and guineagrass (*Urochloa maxima*).

Conversion of Sonoran desertscrub to nonnative plant pastures composed of buffelgrass, and the subsequent change in the fire regime, has resulted in the loss of large areas of pygmy-owl habitat in the northern range of the pygmy-owl, and seriously threatens the remaining areas of pygmy-owl habitat in the Sonoran desert and tropical thornscrub/dry deciduous forest communities of Arizona, Sonora, and northern Sinaloa.

Similar issues occur in Texas. Buffelgrass is now one of the most abundant nonnative grasses in South Texas, and a prevalent invasive grass within the range of the pygmy-owl. During the 1950's, federal and state land management agencies promoted buffelgrass as a forage grass in South Texas (Smith 2010, p. 113; Lyons et al. 2013, p. 69). Buffelgrass is very well adapted to the hot, semi-arid climate of South Texas due to its drought resistance and ability to aggressively establish in heavily grazed landscapes (Smith 2010, p. 113; Wied et al. 2020, p. 48). Despite increasing awareness of the ecological damage caused by nonnative grasses, buffelgrass is still planted in areas affected by drought and overgrazing to stabilize soils and to increase rangeland productivity. Prescribed burning used for brush control typically promotes buffelgrass forage production in South Texas (Hamilton and Scifres 1982, p. 11). Buffelgrass often creates homogeneous monocultures by out-competing native plants for essential resources (Lyons *et al.*2013, p. 8). Furthermore, buffelgrass produces phytotoxins in the soil that inhibit the growth of neighboring native plants (Vo 2013, unpaginated). By 1985, P. ciliare was established on over 4 million ha in southern Texas, accounting for 90% of seeded pasture in the state south of San Antonio. Overall it is the dominant herbaceous cover on 10 million ha in southern Texas and northeastern Mexico (Williams and Baruch 2000; Wied *et al.*2020, p. 47).

The impacts of buffelgrass establishment and invasion are substantial for the pygmy-owl in the United States and Mexico because conversion results in the loss of important habitat features, particularly columnar cacti and trees that provide nest sites. Buffelgrass also reduces habitat diversity by creating monocultures of buffelgrass and out-competing native vegetation species (Lyons et al. 2013, pp. 66–67; Wied et al. 2020, p. 48), which decreases prey availability for the pygmy-owl by decreasing the habitat compositional and structural diversity. Buffelgrass invasion and the subsequent fires eliminate most columnar cacti, trees, and shrubs of the desert (Burquez-Montijo et al. 2002, p. 138). This elimination of trees, shrubs, and columnar cacti from these areas is a potential threat to the survival of the pygmy-owl in the northern part of its range, as these vegetation components are necessary for roosting, nesting, protection from predators, and thermal regulation. Invasion and conversion to buffelgrass also negatively affect the diversity and availability of prey species in these areas (Franklin et al. 2006, p. 69; Avila-Jimenez 2004, p. 18; Burquez-Montijo et al. 2002, pp. 130, 135).

Buffelgrass is adapted to dry, arid conditions and does not grow in areas with high rates of precipitation or high humidity, above elevations of 1,265 m (4,150 ft), or in areas with freezing temperatures. Areas that support pygmy-owls south of Sonora and northern Sinaloa typically are wetter and more humid, and conditions are not as favorable for the invasion of buffelgrass. Surveys completed in Sonora and Sinaloa in 2006 noted buffelgrass was present in Sonora and northern Sinaloa, but the more southerly locations were noted as sparse or moderate (Van Devender and Dimmitt 2006, p. 7). However, because buffelgrass was first introduced to Mexico in Tamaulipas and Neuvo Leon, and then subsequently to Sonora and Sinaloa (Lyons et al. 2013, pp. 68–69), buffelgrass and its associated impacts are found in all five of the pygmy-owl analysis units used in our analysis for this final rule.

In addition to invasive grasses, the invasive fire ant is a substantial problem in Texas. They are known to depredate bird nests, even those fairly high in trees, including cavity nests. Boal (2021, pers. comm.) indicates he and others in Texas have found invasive fire ants in raptor nests. Additionally, they have been found to be associated with decreases in insectivorous (e.g., bluebirds; *Sialia sialis*) and smaller predatory birds (e.g. loggerhead shrikes; *Lanius ludovicianus*) (Ligon *et al.* 2011, entire).

Agricultural Production and Wood Harvesting

Agricultural development and wood harvesting can result in substantial impacts to the availability and connectivity of pygmy-owl habitat. Conversion of native vegetation communities to agricultural fields or pastures for grazing has occurred within historical pygmy-owl habitat in both the United States and Mexico, and not only removes existing pygmy-owl habitat elements, but also can affect the long-term ability of these areas to return to native vegetation communities once agricultural activities cease. Wood harvesting has a direct effect on the amount of available cover and nest sites for pygmy-owls and is often associated with agricultural development. Wood harvesting also occurs to supply firewood and charcoal, and to provide material for cultural and decorative wood carvings. Appendix 6 of this SSA Report shows analysis done at a large scale indicating the ongoing loss of pygmy-owl habitat related to agricultural and wood harvesting impacts, as well as from other human impacts, throughout the pygmy-owl's range. While we do not have detailed information regarding the impacts of agricultural development and wood harvesting for all areas within the range of the pygmy-owl, the following provides a discussion of the extent of the impacts from these activities for areas for which we do have sufficient information.

The extent of agricultural development and woodcutting as a current or ongoing impact to pygmy-owl habitat differs between the United States and Mexico. For example, in the United States, habitat loss and conversion due to agricultural development is more of a historical issue because less area is being used currently for agriculture, and wood cutting is primarily for personal, rather than commercial use. However, impacts to pygmy-owl habitat from historical agricultural use and wood harvesting are still evident. The vegetation and soils of many valleys in the Sonoran Desert were shaped by the periodic flooding of dynamic wash systems, which partially recharged a shallow, fluctuating groundwater table. Because of agricultural development, these valleys no longer experience these defining processes and there has been a permanent loss of meso- and xero-riparian habitat (Jackson and Comus 1999, pp. 233, 249). These riparian areas are important pygmy-owl habitat, especially within drier upland vegetation communities like Sonoran desertscrub and semi-desert grasslands. In addition to these historical impacts, some mesquite control and removal currently occurs in the Altar Valley of southern Arizona. This occurs as ranchers remove mesquites to enhance grass cover and improve water infiltration. The Buenos Aires National Wildlife Refuge also implements mesquite control to benefit other species such as masked bobwhite quail, Pima pineapple cactus, and American pronghorn.

There is some evidence that historical agricultural practices by indigenous peoples and early settlers provided and potentially enhanced available pygmy-owl habitat in Arizona, primarily through the development of irrigation canals that promoted the presence of woody vegetation (BOR 1947, unpaginated; Johnson et al. 2004, p. 139). However, more recent agricultural developments typically remove areas of native vegetation resulting in pygmy-owl habitat loss and fragmentation over relatively large areas, causing reductions in ground and surface waters impacting riparian systems important to the pygmy-owl and pygmy-owl prey species, and resulting in habitat fragmentation and loss of habitat connectivity for the pygmy-owl. While the loss and fragmentation of habitat is more of an historical impact in Arizona and Texas, some agricultural development continues in these areas and some historical impacts are still evident. In Mexico, agricultural development is an ongoing threat to pygmy-owl habitat (Burquez 2022, pers. comm.).

In Arizona, although new agricultural development is limited, the effects to historical habitat are still evident. Jackson and Comus (1999, pp. 249–250) describe the long-term effects of agricultural development on native vegetation communities, “The groundwater has been mined, river flows have been relocated, tributaries have been channelized, and smaller waterways are blocked by roads or the canals of the Central Arizona Project. Soil-surface characteristics have been greatly altered by field leveling and irrigation ditches. Compounding these large-scale changes, soil in some areas has increased salinity, pesticide residues, or loss of physical structure due to repeated tillage, soil compaction, and irrigation.” There have been important biological losses and introductions as well. Seed sources of native plants in these old agricultural fields are now rare. Natural regeneration of many of the old agricultural fields is unlikely because they are no longer near to a native seed source (Jackson and Comus 1999, pp. 243–247, 250).

It is not known to what extent the loss of certain pollinators, predators, detritivores (organisms that obtain nutrients by consuming decomposing organic matter), cryptogamic crusts (soil with crusts formed by an association of algae, mosses, and fungi; such crusts stabilize desert soil, retain moisture, and protect germinating seeds), mycorrhizae (a fungus that grows in a symbiotic association with plant roots), etc., as well as the addition of exotic species, will have on recovery of habitat. Because of these profound changes, we believe that habitat recovery, either by natural succession or through various attempts at ecological restoration, will be very limited (Jackson and Comus 1999, p. 250). The significance of this lies in the fact that many acres of pygmy-owl habitat have been lost to agricultural development, especially along valley bottoms and drainages that were important for pygmy-owls as they supported higher quality meso- and xero-riparian habitats. A well-known example of this is the huge mesquite bosque (woodland) south of Tucson on the San Xavier District of the Tohono O'odham Nation that comprised old-growth mesquites and which was lost due to groundwater pumping and diversion for agriculture and urban growth (Stromberg 1993, pp. 117–119). Mesquite bosques provide important pygmy-owl habitat. These areas of large, dense trees can support cavities for pygmy-owl nests, provide adequate cover, and increase prey diversity. The viability of these bosques is dependent upon the ability of native trees, like mesquite, to reach the water table with their taproots. Only then can they grow to sizes that provide habitat for pygmy-owls. Even when abandoned and left to return to their natural state, there has been such extensive alteration of soils, drainage patterns, and contamination that these impacted bosques are unlikely to ever regain the historical habitat values. Restoration of old agricultural areas often meets with either limited success or failure.

Historically, agriculture in Sonora, Mexico, was restricted to small areas with shallow water tables, but it had, nonetheless, seriously affected riparian areas by the end of the nineteenth century. Large-scale agriculture was introduced in the 1940s, with the construction of dams in the Rio Yaqui and Rio Mayo watersheds. By the late 1970s, the delta regions and alluvial plains of these rivers were almost entirely converted to field crops. Huge expanses of natural vegetation had been cleared. The vast mesquite forests of the Llanos de San Juan Bautista in the plains of the Rio Sonora disappeared with the development of the Costa De Hermosillo irrigation district. In the Rio Mayo and Rio Yaqui coastal plains, nearly one million ha (2.5 million ac) of mesquite, cottonwood, and willow riparian forests and coastal thornscrub disappeared after dams upriver started to operate (Burquez and Martinez-Yrizar 2007, p. 543). In 1980, a national food system was initiated and the total area under cultivation in northern Mexico increased significantly (Stoleson *et al. 2*005, p. 59).

Based upon the number of acres currently in irrigated agriculture, Sonora, with 530,000 ha (1.3 million ac), ranks second among the States in Mexico to Sinaloa (747,800 ha (1.85 million ac)), a State which is also occupied by pygmy-owls. The area equipped for agricultural irrigation in Sonora is 668,900 ha (1.65 million ac), resulting in the potential future loss of approximately 139,000 ha (343,000 ac) of natural vegetation if these areas are developed for agriculture communities (FAO 2007, p. 2). Other Mexican States within the range of the pygmy-owl show similar potential for habitat loss. For example, in Tamaulipas, area under irrigation increased from 174,400 to 494,472 ha (431,000 to 1.22 million ac) between 1998 and 2004, with an area of 668,872 ha (1.65 million ac) equipped for irrigation. Michoacán supports 24,900 ha (61,500 ac) of irrigated lands with a potential infrastructure for 222,800 additional ha (550,600 ac). Although the amount of land converted to agriculture seems to be on the increase, we do not know where these areas are in relation to pygmy-owl habitat. Dry tropical forests on steeper slopes are not likely to be used for agricultural production. In addition, agricultural development in the States of Colima, Jalisco, Nayarit, and Nuevo Leon had substantial decreases in the amount of irrigated lands over the same period. Colima dropped from 64,100 ha (158,394 ac) to 37,800 ha (93,406 ac), Jalisco went from 161,600 ha (399,322 ac) to 95,600 ha (236,233 ac), Nayarit decreased from 55,400 ha (136,896 ac) to 43,200 ha (106,749 ac), and Nuevo Leon dropped from 143,000 ha (353,361 ac) to 32,484 ha (80,270 ac) (FAO 2007, p. 2). These numbers indicate that continuing destruction of habitat for agricultural production is not occurring with the same intensity throughout the range of the pygmy-owl, and may be declining in large parts of its southern range.

Agricultural development is declining in some parts of the pygmy-owl's range, but seems concentrated in the northern portion of the range. In certain localities in northwestern Mexico, especially Sonora, it has remained the same and even increased over the past few decades. In the Sonoyta Valley of Sonora flanking Organ Pipe Cactus National Monument across the United States–Mexico border, cropland quadrupled in extent between 1977 and 1987, due in part to government-supported agricultural development. Proximity to United States fruit and vegetable markets, inexpensive labor, good quality water, and government agency interest in increased fruit and vegetable crops in the area mean that agricultural production and the associated decline of groundwater levels will likely continue in the future (Nabhan and Holdsworth 1998, p. 36). Some scientists surveyed noted that clearing for agriculture was becoming more severe in portions of the Lower Colorado River Valley, Central Gulf Coast, and Viscaino. Current Sonoran Desert cropland is most extensive in the border municipality of Mexicali and the extreme southern end of the Sonoran Desert where most municipalities have from one-quarter to three quarters of their land surface as cropland. The central section around Hermosillo, Sonora, is 15 to 25 percent cropland, and the rest of the area is less than 15 percent (Nabhan and Holdsworth 1998, p. 36). However, these figures do not include the millions of hectares of abandoned agricultural land. While not all the area converted for agriculture was or could be suitable pygmy-owl habitat, agricultural development has typically occurred along river bottoms and other drainages that support important riparian vegetation for pygmy-owls (Flores-Villela and Fernandez 1989, p. 2). Additionally, associated habitat fragmentation exacerbates the actual impacts to available pygmy-owl habitat through loss of habitat connectivity (Stoleson *et al. 2*005, p. 60; Saunders *et al. 1*991, pp. 23 - 24). The effect of pesticide accumulation was previous unknown with regard to pygmy-owls. However, a recent study has documented pesticide accumulation in ferruginous pygmy-owls. This study collected blood and feathers from pygmy-owls near the Protected Natural Area Cerro Sonsonate, Chiapas, Mexico. In both tissues, pesticides belonging to seven organochlorine chemical families were detected. The results of this study confirm that pygmy-owls are being exposed to pesticides in their study area (Arrona-Rivera *et al. 2*016, entire).

Prescribed burning to reduce mesquite invasion into rangelands represents another potential threat to pygmy-owl habitat associated with agriculture. In general, improved grassland health adjacent to pygmy-owl habitat should benefit pygmy-owls through improved hydrology and enhance prey habitat. However, if woodlands providing important pygmy-owl habitat are not protected during prescribed burns, impacts to pygmy-owl habitat can be significant due to the loss of nest structures, predator and thermal cover, and prey habitat. For example, in Texas, two prescribed burns over the past 3 years have consumed 1,200 to 1,600 ha (3,000 to 4,000 ac) respectively, including areas that supported natural pygmy-owl nests, as well as pygmy-owl nest boxes (Proudfoot 2011b, pers. comm.). Other documented fires on the King Ranch consumed from several hundred up to 3,200 ha (8,000 ac) over this same time period (McFarland 2009; NOAA 2011; Baird 2011, Wilson and Kassabian 2008). While the loss of woodlands to fire is often a temporary impact, it can take many years for trees to reach adequate size to once again support cavities used for nesting by pygmy-owls.

Mesquite harvesting is also a potential threat. Mesquite wood is a valuable commodity. Historically in Arizona, mesquite trees have been harvested for decades. In the late 1800s through the early 1900s, Arizona saw large-scale harvesting for fuel and for mining. Fuelwood cutting once had a major impact on the riparian forests, mesquite thickets, and evergreen woodlands near most of southeastern Arizona's major cities and mining centers (Bahre 1991, p. 143). This whole-scale harvest may explain the scarcity of riparian trees in early (1890) photographs of southern rivers such as the San Pedro (Stromberg 1993, p. 119). In the Sonoran Desert of Mexico, the mesquite tree is being harvested in order to fulfill the demand for mesquite charcoal, and former mesquite forests have disappeared at an alarming rate (Burquez and Martinez Yrizar 2007, p. 545). Ironwood trees are also being harvested in Mexico where the wood is cherished for its hardness and carving potential for native artwork by groups such as the Seri Indians.

Mesquite and ironwood woodlands provide pygmy-owl habitat elements related to tree canopy cover and a diverse prey base. Unfortunately, woodcutters and charcoal makers do not use scrubby-type mesquite, but rather take advantage of large, mature mesquite and ironwood trees growing in riparian areas (Taylor 2006, p. 12), the exact tree class that is of most value as pygmy-owl habitat. From the time "mesquite charcoal" became popular in United States restaurants in the early 1980s, both mesquite and ironwood have been harvested from the same lands, with as much as 15 to 40 percent of each mesquite charcoal bag consisting of ironwood prior to 1991. As a result, both trees were locally overexploited in Sonora and Baja California Sur (Taylor 2006, p. 12).

Sonora supports 1,888,000 ha (4,665,000 ac), or 46 percent of total mesquite woodlands in Mexico; more than double that of any other State in Mexico. This also means that much of the mesquite harvested in Mexico comes from Sonora (Taylor 2006, p. 12). Current estimates suggest that ironwood is being rapidly depleted across an area roughly equivalent to twice the size of Massachusetts. In northern Mexico, over 202,000 ha (500,000 ac) of mesquite have been cleared to meet the growing demand for mesquite charcoal (Haller 1994, p. 1). Haller (1994, p. 3) projected that, if this trend continued, the entire ecosystem of the Sonoran Desert could crumble, and used the examples of the degraded ecosystem along the coast of Sonora near Kino Bay where most of the mesquite and ironwood had already been removed and virtually all plant and animal life has disappeared. Declining tree populations in the Sonoran Desert as a result of commercial uses and land conversion threatens other plant species, and may alter the structure and composition of the vertebrate and invertebrate communities as well (Bestelmeyer and Schooley 1999, p. 644). This has implications for pygmy-owl prey availability because pygmy-owls rely on a seasonal diversity of vertebrate and invertebrate prey species; loss of tree structure and diversity reduces prey diversity and availability.

In the Sonoyta region of Sonora, an area occupied by pygmy-owls, more than 193,000 ha (478,000 ac) have been affected by deforestation related to charcoal production, brick foundries, tourist crafts, and pasture conversion (Nabhan and Suzan 1994, p. 64). The accelerated rate of legume tree (trees belonging to the family Leguminosae whose characteristic fruit is a seed pod, including the mesquite and ironwood) depletion for charcoal and carvings in the Mexican States of Sonora and Baja California has clearly affected the health of ironwood populations and associated plant communities (Suzan *et al. 1*997, p. 955). This is evidenced by an increased number of damaged and dying trees, as well as generally small size classes for sampled areas (Suzan *et al. 1*997, pp. 950–955).

Pressure for fuelwood and crafts materials has been so intense in Mexico south of Organ Pipe Cactus National Monument that wood harvest, especially ironwood, has been detected more than 500 m (1600 ft) into the Monument as supplies have been depleted south of the border (Suzan *et al. 1*999, p. 1499). The structure of both wash and upland habitats in the Monument have been affected by this harvest (Suzan *et al. 1*999, p. 1499). Organ Pipe Cactus National Monument is one of four areas in Arizona that has been consistently occupied by pygmy-owls. In the arid environment of the Monument, tree canopy and structure are particularly important pygmy-owl habitat features.

Mesquite used as fuelwood is a thriving cross-border trade, although not on the same scale as charcoal. However, local impacts can be significant in the areas where the fuelwood is harvested. For example, Mexican trucks loaded with mesquite cross the border to Arizona at Sasabe. Interviews with these truck drivers indicated that most of the wood they haul comes from ejidos (communally owned lands) within a 20-km (12.4-mi) radius of the Town of Sasabe, an area occupied by nesting pygmy-owls (Taylor 2006, p. 5; Flesch 2008, p. 2).

In 2008, during field work in Sonora to gather pygmy-owl genetic samples, large areas of charcoal production were observed near Hermosillo. Impacts to vegetation were not limited to just the removal of the trees, but a significant area around the production sites was covered with fine, black charcoal dust covering all native vegetation (FWS 2009a, p. 1). The effects of these production areas are verified by reports of the complete removal of a dense mesquite bosque to the axe and charcoal pits just east of Hermosillo (Taylor 2006, p. 5). The immediate area around charcoal pits is often treeless. Walking transects away from charcoal pits revealed that all trees within a 1-km (0.6-mi) radius bear the scars of the chainsaw (Taylor 2006, p. 7).

Native woodlands in Sonora are additionally threatened as ranchers and charcoal producers team up to first clear the land of native trees for planting buffelgrass, and then use the dead trees to produce charcoal (Taylor 2006, pp. 6–7). The end result is the incentive to clear more native woodlands. Professional woodcutters are only permitted to harvest dead wood. However, dead wood to meet export demands is hard to come by. A simple solution practiced by many wood cutters is to ring trees and let them die; then the dead wood can be legally harvested (Taylor 2006, p. 7).

Impacts to pygmy-owl habitat in northwestern Mexico from these activities are resulting in the loss and fragmentation of habitat in this part of Mexico, and the inability to recover or restore habitats and habitat connectivity in Arizona. Impacts related to surface- and groundwater loss and channel diversions are long-term and are particularly significant as riparian vegetation, both meso- and xero-riparian, are crucial for maintaining viable pygmy-owl populations in the arid portions of their range in Arizona and Sonora, Mexico. Loss of leguminous trees results in long-term effects to the soil as they add organic matter, fix nitrogen, and add sulfur and soluble salts, affecting overall habitat quality and quantity (Rodriguez Franco and Aguirre 1996, p. 6-47). Ironwood and mesquite trees are important nurse species for saguaros, the primary nesting substrate for pygmy-owls in the northern portion of their range (Burquez and Quintana 1994, p. 11). Demand for mesquite charcoal and firewood contributes to the loss of extensive, mature mesquite forests in riparian areas of northern Mexico.

The harvest of mature mesquites in the Sonoran Desert for charcoal and firewood permanently alters desert ecosystems because leguminous trees like mesquite and ironwoods are such important anchors for these systems and their associated flora and fauna (Taylor 2006, p. 8). Thus, ongoing wood harvesting can reduce or eliminate pygmy-owl habitat in the Sonoran Desert region of Arizona and Mexico by perpetuating scrubby trees that are unsuitable for nest substrates, supporting increased fire frequency associated with nonnative grass invasion, eliminating important nurse trees for saguaro protection, reducing tall canopy coverage important for pygmy-owl cover, and altering prey availability through the reduction of structural diversity.

Once common in areas of the Rio Grande delta, significant habitat loss and fragmentation due to woodcutting have now caused the pygmy-owl to be a rare occurrence in this area of Texas. Oberholser (1974, p. 452) concluded that agricultural expansion and subsequent loss of native woodland and thornscrub habitat, begun in the 1920's, preceded the rapid demise of pygmy-owl populations in the Lower Rio Grande Valley of southern Texas. Because much of the suitable pygmy-owl habitat in Texas occurs on private ranches, habitat areas are subject to potential impacts that are associated with ongoing ranch activities such as grazing, herd management, fencing, pasture improvements, construction of cattle pens and waters, road construction, and development of hunting facilities. Brush clearing, in particular, has been identified as a potential factor in present and future declines in the pygmy-owl population in Texas (Oberholser 1974, p. 452). However, relatively speaking, the current loss of habitat is much reduced in comparison to the historical loss of habitat in Texas. Conversely, ranch practices that enhance or increase pygmy-owl habitat to support ecotourism can contribute to conservation of the pygmy-owl in Texas (Wauer *et al. 1*993, p. 1076). The best available information does not indicate that current ranching practices are significantly affecting pygmy-owl habitat in Texas.

Tamaulipan brushland is a unique habitat found in south Texas and northeastern Mexico. This vegetation community has historically supported occupancy by pygmy-owls. Brush clearing, pesticide use, and irrigation practices associated with agriculture have had detrimental effects on the Lower Rio Grande Valley (Jahrsdoerfer and Leslie 1988, p. 1). Since the 1920's, more than 95 percent of the original native brushland in the Lower Rio Grande Valley has been converted to agriculture or urban use. Along the Rio Grande below Falcon Dam, 99 percent of the land has been cleared for agriculture and development. Cook *et al.*(2001, p. 3) indicated that both banks of the Rio Grande are now completely developed with homes or farms, and that the only remaining natural areas south of the river are salt marshes and mudflats, both communities that are not used by pygmy-owls. A large percentage of similar area has been cleared in Mexico (Jahrsdoerfer and Leslie 1988, p. 17). This is supported by Tewes' (1993, p. 29) conclusion that most of the Rio Grande delta of Texas and Mexico has been developed over the past 60 years. Hunter (1988, p. 8) states, "Habitat removal in Mexico is widespread and nearly complete in northern Tamaulipas."

Habitat fragmentation in northeastern Mexico is extensive, with only about two percent of the ecoregion remaining intact, and no habitat blocks larger than 250 square km (96.5 square mi), and no significant protected areas (Cook *et al. 2*000, p. 4). This has the potential to limit pygmy-owl movements and dispersal, exacerbating the effects of small, isolated populations. Fire is often used to clear woodlands for agriculture in this area of Mexico, and many of these fires are not adequately controlled. There may be fire-extensive related effects to native plant communities (Cook *et al. 2*000, p. 4); however, there is no available information of how much area may be affected by this activity.

The best available scientific and commercial information indicates that historical land clearing, as a result of wood harvesting and agricultural development has caused the loss and alteration of substantial areas of pygmy-owl habitat in Arizona, Sonora, Texas, and northeastern Mexico. However, while past impacts continue to affect the extent of available pygmy-owl habitat in these areas, because of the extended time it takes for these lands to recover, even if negative actions cease, these impacts are expected to continue in many of these same areas into the future. However, based on our review of the best available scientific and commercial information, we conclude that these impacts are limited in magnitude, because they are significant only in the northern portion of the range (Arizona, Texas, northwestern and northeastern Mexico). Moreover, the best available scientific and commercial data indicate that habitat loss due to woodcutting or agriculture is primarily historical in Texas, and these activities are not currently impacting habitats occupied by pygmy-owls on the private ranches in Texas. Further, the impacts in the southern portion of the range are less extensive, both because woodcutting and agricultural development appear to be have less impact in the southern portion of the pygmy-owl's range, and because the pygmy-owl seems to be common throughout this area. Therefore, after reviewing and evaluating the best available scientific and commercial data, we conclude that woodcutting and agricultural development are not threats to the continued existence of the pygmy-owl rangewide, and are not likely to become so in the future, because many of these effects were historical and we do not expect further habitat loss due to this activity in some areas, and we do expect the habitat in some areas to slowly recover.

Improper Livestock Grazing

Probably no single land use has had a greater effect on the vegetation of southeastern Arizona or has led to more changes in the landscape than improper livestock grazing and range-management programs (Carothers 1977, p. 4). Undoubtedly, grazing since the 1870s has led to soil erosion, destruction of native plants most palatable to livestock, changes in the regional fire ecology, the spread of both native and alien plants, and changes in the age structure of evergreen woodlands and riparian forests (Bahre 1991, p. 123). Many areas of pygmy-owl habitat have recovered from these historical effects of grazing; however, other areas are slow to recover and may never recover due to the arid nature of the Sonoran Desert.

Livestock grazing in northwestern Mexico is probably the most widespread human use of Sonoran ecoregional landscapes. Grazing by cattle, goats, and other livestock has reduced vegetation cover and helped change grasslands to shrublands. Livestock grazing in the Sonoran Desert has fluctuated greatly in the last few centuries from being relatively confined and intensive to being extensive and intensive. In the 19th century, repeated Apache raids on ranchers and the paucity of water limited cattle production to relatively small areas (Bahre 1991, pp. 114–115). However, the late 19th century saw the largest stocking rates in history; extensive cattle production played a major role in the transformation of grasslands to scrublands, down-cutting of arroyos, the spread of nonnative plants, and degradation of riparian areas. Stocking rates are now much lower than in the 1890s because regulations such as those of the Taylor Grazing Act of 1934 helped improve rangeland quality in the United States. However, overstocking still continues in parts of northwestern Mexico, and Mexico's COTECOCA (Comisión Técnico Consultiva de Coeficientes de Agostadero) statistics confirm that 2 to 5 times the recommended stocking rates occur with regularity on the Sonoran side of the border (Walker and Pavlakovich Kochi 2003, p. 14; Nabhan and Holdsworth 1998, p. 2).

Available information on livestock grazing in Mexico that we evaluated was focused primarily on the border areas adjacent to the United States and in the arid areas of northwestern Mexico, such as Sonora. In Sonora, rangelands are often heavily grazed, with effects particularly apparent during drought (Rorabaugh 2008, p. 25). Sonora's higher stocking rate is likely due to its greater amounts of private and ejidal (communal) land, less regulation, and the greater dependence on ranching and farming in Mexico. Demand in North America drives the number of cattle in Sonora. The number of cattle in Sonora nearly doubled between 1950 and 1960. The Sonoran cattle population was 1,652,771 in 1990 according to official government statistics (Hawks 2003, p. 5). Other authors estimate the overstocking at 177 percent (Lopez 1992), with 60 to 400 percent overstocking in some areas (Burquez-Montijo *et al. 2*002, p. 134). Excessive grazing of vegetation by livestock, especially when combined with conversion of plant cover to exotic pasture grasses, ranked as number four on a list of threats to the Sonoran Desert Ecoregion (Nabhan and Holdsworth 1998, p. 1).

One study showed that overgrazing in Sonora leaves the Mexican landscape more exposed and, as a result, it dries out more rapidly following summer convective precipitation. After about 3 days, depletion of soil moisture evokes a period of higher surface and air temperatures in northwestern Mexico (Bryant *et al. 1*990, pp. 254–258). These drier soils and higher temperatures can result in impacts to vegetation survival and persistence. Effects of poorly managed livestock grazing in Sonora include changes in plant species composition and vegetation cover and structure, soil compaction, erosion, altered fire regimes, and nonnative plant species introductions and invasions (Stoleson *et al. 2*005, pp. 61–62). With regard to pygmy-owl habitat, improper stocking rates can result in reduced saguaro reproduction through trampling and alteration of microclimates (Abouhaidar 1989, pp. 40–48), reduced tree cover and reproduction through grazing of seedlings and seed pods, and impacts to prey availability from reduced vegetation structural diversity and species composition.

One of the most significant adverse impacts within western riparian systems has been the perpetuation of improper grazing practices. Belsky *et al.* (1999, p. 419) found that grazing by livestock has damaged 80 percent of the streams and riparian ecosystems in the arid regions of the western United States. The initial deterioration of western riparian systems began with the severe overgrazing in the late nineteenth century. Livestock grazing can affect four general components of riparian systems: (1) streamside vegetation; (2) stream channel morphology; (3) shape and quality of the water column; and (4) structure of streambank soil. Vegetation impacts include: (1) compaction of soil, which increases runoff and decreases water availability to plants; (2) herbage removal, which allows soil temperatures to rise, thereby increasing evaporation; (3) physical damage to vegetation by rubbing, trampling, and browsing; and (4) alteration of growth form of plants by removing terminal buds and stimulating lateral branching (Fleischner 1994, p. 635).

In a summary of studies investigating the impacts of livestock grazing on riparian areas, Belsky *et al.*(1999, p. 425) found that none of the studies showed positive impacts or ecological benefits that could be attributed to livestock activities when grazed areas were compared to protected areas. It was mostly negative effects that were reported, and there was little debate about those effects. Most of these studies tended to agree that improper livestock grazing can damage stream and riparian ecosystems. All types of riparian areas provide important pygmy-owl habitat elements due to the increased size, diversity, and structure associated with riparian communities and enhanced moisture availability. Larger trees provide substrates for nest cavities. Structure diversity provides important predator and thermoregulatory cover, as well as an increased number and diversity of prey species. A reduction of the extent or quality of riparian areas within the range of the pygmy-owl represents direct impacts on the availability and quality of pygmy-owl habitat.

Although proper management has greatly improved riparian communities in some areas, field data compiled in the last decade showed that riparian areas throughout much of the West were in the worst condition in history due mainly to the complications initiated by improper grazing techniques (Krueper 1993, p. 322). However, information submitted during the public comment period supports the idea that, in certain areas, riparian vegetation has returned and, perhaps, even increased in certain areas in Arizona, including areas that are being grazed by livestock. Parker (2008, p. 13) points out that Webb *et al.*(2007, pp. 388–389, 404–408) conclude that, in the drainages they studied, increases in riparian vegetation from 24 percent to 49 percent had occurred since the late 1800's and early 1900's, and that increases in the density of riparian plants appear to have accelerated in the 1970's. We are encouraged by this positive information indicating that riparian systems in some areas may become suitable for pygmy-owls. It is not our contention that grazing per se has a negative effect on riparian areas, but that improper or overgrazing can have detrimental effects. Parker (2008, p. 14) reiterates this by stating, "While there is little question that overgrazing can degrade riparian ecosystems, the question here is whether grazing has had long-term negative effects on woody riparian vegetation in Arizona." We acknowledge that, with proper management, riparian areas can recover and provide habitat for the pygmy-owl.

In Mexico, increasing human population numbers and the extent of subsistence agriculture threatens the future of Mexico's extensive riparian systems. Grazing impacts include contamination and an increasing demand for agricultural and forage production (Deloya 1985, pp. 9–11). Riparian destruction is evident throughout Mexico, but especially in areas of denser human population. Of particular relevance to the pygmy-owl has been the loss and destruction of virtually all of the dense woodlands within the Rio Grande valley. Despite the evident destruction of riparian systems, little information exists on the problem and there is apparently no strategy at a national level to solve the problem. The present trends pose serious concerns for the future of Mexico's riparian ecosystems (Deloya 1985, pp. 11–12).

In Texas, areas occupied by pygmy-owls are primarily on large, private ranches where livestock production is a primary objective. However, alternative sources of revenue for these ranches also include hunting and ecotourism. As a result, habitat management for the benefit of wildlife is also a high priority for these ranchers. Livestock management is often conducted with consideration of impacts to wildlife.

Pygmy-owls are known to exist in areas that are grazed. Grazing, itself, does not appear to negatively affect pygmy-owls. Properly managed grazing can enhance certain pygmy-owl habitat elements (Loeser *et al. 2*007, p. 96; Holechek *et al. 1*982, p. 208). Climatic variation is important in determining the ecological effects of grazing practices in arid rangelands (Loeser *et al. 2*007, pp. 93–96). However, improper grazing at inappropriate stocking rates or during seasons or years when drought and other conditions reduce forage availability can affect pygmy-owls directly through the loss of important habitat elements (e.g., saguaros, tree cover, riparian vegetation, vegetation reproduction) and prey availability. No studies specifically related to the effects of livestock grazing on pygmy-owls have been conducted; however, impacts to pygmy-owls can be determined indirectly from studies on related species or issues. For example, studies in Arizona and Sonora show that the number of lizard species and abundance of lizards declined significantly in heavily grazed areas (Jones 1981, p. 111); there is also a likely loss of lizard species in areas invaded by buffelgrass. Lizards are an important food resource for pygmy-owls; therefore, impacts to lizard abundance can affect pygmy-owls.

An additional concern related to grazing lands is that, faced with rising land prices, unstable markets, and unpredictable climate, many ranchers in the United States are choosing or are forced to sell their private lands to real estate developers or subdivide it themselves. This results in these lands being subject to the threats described above related to urbanization. There was no available information to determine if these same pressures apply to grazing lands in Mexico.

Improper livestock grazing is a documented threat that has a negative impact on pygmy-owl habitat under some circumstances in Arizona and Sonora. Within the Sonoran desert, over grazing can result in loss of structural habitat components important to pygmy-owls, as well as reducing prey availability and diversity. Additionally, improper grazing during droughts can affect the long-term viability of riparian areas, which are an important habitat type for pygmy-owls in Arizona and Sonora. However, there is no indication that livestock grazing precludes occupancy by pygmy-owls in any part of its range. While improper livestock grazing can have negative impacts to local pygmy-owl populations, we do not believe livestock grazing is significantly affecting pygmy-owl populations throughout its range. The best available scientific and commercial information does not appear to indicate that improper grazing is affecting pygmy-owl populations in Texas. We have no readily-available information to determine whether the effects of livestock grazing on pygmy-owl habitat in Mexico outside of Sonora are greater or more harmful than in Arizona and Sonora, but we suspect impacts are similar. Based on the best available scientific and commercial data, we conclude that improper livestock grazing is not a threat to the continued existence of the pygmy-owl rangewide, nor is it likely to become so.

Border Issues

One of the most pressing issues for the U.S.- Mexico border is the impact of illegal human and vehicular traffic through these unique and environmentally sensitive areas. Many of these locations now bear the scars of wildcat trails, abandoned refuse, and trampled vegetation (Marris 2006, p. 339; Walker and Pavlakovich-Kochi 2003, p. 15). Monitoring activities by the U.S. National Park Service (NPS) estimate that, annually, 300,000 individuals illegally cross through Organ Pipe Cactus National Monument in southwestern Arizona. Video surveillance equipment erected at Coronado National Memorial, in southeastern Arizona, indicates traffic volumes ranging from 100 to 150 immigrants per night (Walker and Pavlakovich-Kochi 2003, p. 15). In the Cabeza Prieta National Wildlife Refuge, located in southwestern Arizona, which has historically supported resident pygmy-owls, there are over 640 km (400 mi) of illegal roads plus another 1,280 km (800 mi) of unauthorized foot trails as a result of illegal border activities (Cohn 2007, p. 96). These activities result in direct impacts to pygmy-owl habitat.

Additional information from the NPS indicates a significant issue "…is the increasing drug smuggling, illegal immigrants, and law enforcement activity which results in much greater human disturbance of the birds." Further elaboration shows that the NPS believes "…that cactus ferruginous pygmy-owls within the Monument have been subject to repeated disturbance events and some critical habitat degraded as a result of long-term drought and impacts associated with illegal migration, drug smuggling, and law enforcement interdiction efforts" (Snyder 2005, pers. comm.). Trails and roadways remove pygmy-owl habitat features, noise and disturbance from people and vehicles disrupt important behaviors, and there is an increased risk of fire in important habitats resulting from cooking and warming fires, as well as signal fires used by cross-border immigrants and smugglers. Areas occupied by pygmy-owls in Organ Pipe Cactus National Monument have been abandoned by the owls, likely due, at least in part, to heavy illegal immigrant traffic and associated enforcement actions.

There is fear that efforts to curb illegal border activities through the construction of infrastructure such as fences and barrier will fragment the Sonoran Desert ecosystem, damage the desert's plant and animal communities, and prevent free movement of wildlife between the United States and Mexico (Cohn 2007, p. 96). During the time the pygmy-owl was listed under the Act, we consulted on the effects of Federal border infrastructure projects and identified a number of potential impacts (FWS 2003, pp. 66–85). The construction of new border infrastructure in the form of pedestrian fences, vehicle barriers, and patrol roads create impediments to pygmy-owl movement across the border due to pygmy-owl flight patterns and behavior (Tibbitts 2020, pers. comm.; Marris 2006, p. 239; Vacariu 2005, p. 354). The fences and vehicle barriers, when considered in conjunction with patrol roads, drag roads, and vegetation removal, result in a combination of unvegetated area with a raised structure in the middle causing an impediment to pygmy-owl movement, particularly given their normal flight patterns, where normal flights are generally less than 30 m (100 ft) and typically only 1.5 to 3.0 m (5 to 11 ft) above the ground (Flesch and Steidl 2007, p. 35; AGFD 2008b, pers. comm.). Flesch *et al.* (2009, pp. 7–9) show that the vegetation gaps, in association with the tall fences, may limit transboundary movements by pygmy-owls. In reality, no studies have specifically looked at how border infrastructure may affect pygmy-owl movements. We do not currently know if these structures will be a barrier, an impediment, or no issue at all for pygmy-owls. The above discussion lays out the factors that logically would result in some sort of impacts to pygmy-owl movements. On the other hand, pygmy-owls are capable flyers and easily navigate small openings in their normal day-to-day behaviors. Pygmy-owls are sometimes observed very high in trees, at or above the height of border infrastructure. So the border wall itself may not substantially affect all cross-border movements. However, the border wall in conjunction with lighting, patrol and interdiction activities, and vegetation clearing present more factors potentially deterring pygmy-owl movements. This is an issue that needs more research and monitoring to documents whether such border infrastructure affects pygmy-owl movements.

Raptors are often attracted to artificial hunting perches, especially in areas that lack tall trees (Oles 2007, p. 1; Heintzelman 2004, p. 35; Askham 1990, p. 147). Border fences can provide open hunting areas and improved hunting perches for a variety of raptors that are potential predators of pygmy-owls. This combination of perches, open area, and an impediment to movement may result in increased predation of pygmy-owls, particularly dispersing juvenile pygmy-owls. Because the overall population of pygmy-owls likely functions according to metapopulation dynamics, at least to an extent and especially in the more northern analysis units, the pygmy-owl depends on dispersal, emigration, and immigration to maintain the genetic and demographic fitness of regional populations. To the extent that border infrastructure and activities reduce or prevent such movements, and increase the likelihood of pygmy-owl predation, it follows that population-level impacts may result.

Off-highway Vehicle (OHV) Use

The information we have on impacts to the pygmy-owl from OHV use relates primarily to Arizona. Information was not readily available on any potential OHV impacts to pygmy-owls or pygmy-owl habitat in Texas and Mexico.

OHV use is widespread in Arizona and occurs on lands under a variety of management entities including the Forest Service, Bureau of Land Management, State Land Department, Tribes, and private individuals. The use of OHVs has grown considerably. For example, as of 2007, 385,000 OHVs were registered in Arizona (a 350 percent increase since 1998) and 1.7 million people (29 percent of Arizona’s population) engaged in off-road activity from 2005 to 2007 (AGFD 2007, pers. comm.). Over half of OHV users reported that merely driving off the paved road was their primary activity, versus using the OHV for the purpose of seeking a destination to hunt, fish, or hike (AGFD 2007, pers. comm.). Specific threats to the pygmy-owl or its habitat from OHV use when driving off road include disturbance from noise and human activity, vegetation damage, changes in plant abundance and species composition, reduced habitat connectivity, soil compaction, soil erosion, reduced water infiltration, higher soil temperatures, destruction of cryptogamic soils (soil with crusts formed by an association of algae, mosses, and fungi; such crusts stabilize desert soil, retain moisture, and protect germinating seeds), and increased fire-starts (Boarman 2002, pp. 46–47; Ouren *et al. 2*007, pp. 6–7, 11, 16).

Of specific concern is the regular use by OHV operators to utilize xero-riparian washes as travel ways. These washes provide important habitat elements for pygmy-owls due to the increased structure and productivity of vegetation resulting from the presence of increased moisture. Pygmy-owls use these wash areas for foraging, dispersal, thermal and predator cover, and for movements within their home range. Wash areas are often narrow and constrained, resulting in OHV impacts to vegetation and concentrated noise and disturbance, affecting the use and suitability of these areas as pygmy-owl habitat.

Pygmy-owls may be affected by OHV use in riparian areas. However, this effect is temporary and not continuous. Pygmy-owls may leave the area if disturbed by noise and return once the activity has ceased. Pygmy-owl habitat destruction in Arizona may result from OHV activity, but the magnitude and severity of this impact is relatively minor compared with other impacts, such as nonnative grass invasion and urbanization.

Summary of Habitat Loss and Fragmentation

In summary, pygmy-owls require habitat elements such as mature woodlands that include appropriate cavities for nest sites, adequate structural diversity and cover, and a diverse prey base. A number of negative impacts described above are affecting pygmy-owl habitat within portions of its range. In Arizona and Northern Sonoran, pygmy-owl habitat loss and fragmentation resulting from urbanization, changing fire regimes due to the invasion of buffelgrass, agricultural development and woodcutting, overgrazing, and border issues are significant threats have had negative impacts on pygmy-owl habitat in these areas. In Texas, historical loss of habitat has reduced the pygmy-owl range, but current impacts, such as livestock grazing and the invasion of nonnative plants, are reduced in their magnitude and severity. However, in Texas and other areas of the pygmy-owl's range, these past impacts continue to affect the current extent of available pygmy-owl habitat, because of the extended time it takes for these lands to recover. Therefore, even if habitat destruction ceases, the negative effects of past land use are expected to continue in many of these areas into the future, and this will be a cumulative impact with current impacts from invasive species, agricultural development, and other land use practices (Texas Land Trends 2019, entire; Wied et al. 2020, entire; DHS 2020, unpaginated; USGS 2022, unpaginated).

For the remaining larger part of the pygmy-owl's range and habitat in Mexico (south of Sonora), data available for our analysis is limited. The rate of growth in these southern Mexican States appears to be relatively slow compared with growth in Sonora and the Arizona border region. Historical loss of pygmy-owl habitat in northeastern Mexico has occurred, but the extent to which significant habitat destruction is currently taking place is not available.   In addition, pygmy-owls are still considered common in the southern portion of their range. This information indicates that the impacts to pygmy-owl habitat discussed herein may be having different levels of effects on the populations of pygmy-owls throughout their range, and habitat effects may not have the impacts to pygmy-owl population groups in the southern portion of the pygmy-owl's range due to increased pygmy-owl numbers. Nonetheless, Enríquez and Vazquez-Perez (2017, p. 546) indicate that during the last 50 years, Mexico has seen drastic changes in land uses due to rapid urbanization and industrialization, which has been poorly planned. The result has been impacts to the natural environment, including the degradation and loss of biological diversity in Mexico. There has been limited work in Mexico, however, to understand what the direct impacts of these threats are on owl population losses and changes in distribution and abundance of species in long term (Enríquez and Vazquez-Perez 2017, p. 546).

7.3 Human Activities and Disturbance

Birds, and other animals, are affected by human activities in a variety of ways. Among the most important are the activities associated with people acquiring resources needed for survival, such as agriculture, silviculture, ranching, and urbanization. Activities associated with these human endeavors substantially modify natural environments, often in ways that degrade, reduce, or eliminate the habitats of birds. Other human activities, such as ecotourism, outdoor recreation, and wildlife research, also have the potential to disturb birds, but do so in ways that are sometimes more subtle, including decreasing survival and productivity (e.g., Burger *et al.* 1995, Sekercioglu 2002, Müllner *et al.* 2004, Eason *et al.* 2006, Gibson *et al.* 2015, Herzog *et al.* 2020). Below we summarize existing information about how cactus ferruginous pygmy-owls are affected by human disturbance.

Ecotourism and Outdoor Recreation

Ecotourism and other outdoor activities focused on observing wildlife (e.g., bird watching and photography), have been helpful in preserving natural areas in developing countries and in fostering support for conservation worldwide (e.g., Burger *et al.* 1995, Müllner *et al.* 2004). People tend to support and appreciate things with which they have been able to directly interact, which is beneficial for conservation of the pygmy-owl. But activities associated with watching birds can also be detrimental to the species being observed. For example, bird watchers in coastal New Jersey negatively affected birds year-round by interrupting incubation and foraging patterns, scaring parents and fledglings from nests, preventing birds from using preferred areas, and playing tape-recorded bird calls (Burger *et al.* 1995). Because of their conservation status in the United States, cactus ferruginous pygmy-owls are a subspecies of interest to bird watchers and photographers, and tape-recorded calls are often used to attract them for easy viewing. Pygmy-owls are likely affected in the similar ways to all bird species, but there have been no specific studies or research completed on the effects of recreation, including birding or ecotourism, on pygmy-owls.

We do have some anecdotal observations in Arizona of how these activities may affect pygmy-owls. Because the pygmy-owls is rare, birders concentrate at several of the remaining known locations of pygmy-owls in the United States. For example, in 1996, a resident in Tucson reported a pygmy-owl sighting (a documented pair being monitored by AGFD) that subsequently was added to a local birding hotline, and the location was added to their website on the internet. Several carloads of birders were later observed in the area of the reported location (Abbate *et al.* 1999, p. 12). Additionally, in 2003, property owners in Tucson expressed concerns that birders and others have been documented trying to get photos or see pygmy-owls at occupied sites (AGFD 2003, pers. comm.). Most recently, in 2019 and 2020, locations of pygmy-owls were included on a number of birding list serves and social media pages. Subsequently, these sites have been regularly visited by birders and photographers, including during the nesting season. Some documentation related to this indicates that dozens of individuals and groups visited these sites over two nesting seasons (Flesch 2018b, pers. comm., Vaughan 2019, pers. comm.). We have coordinated with most birding list serves and other internet-based sites to restrict site specific location information for pygmy-owl territories, but some of this information is still available to the public. We are currently working with Tucson Audubon Society to develop a solution that allows the public to enjoy and appreciate pygmy-owls while reducing the potential negative effects of human disturbance.

In Texas, Tewes (1993, p. 28) states, "Frequent disruption by well-intentioned bird enthusiasts with call imitations may produce a local risk to the pygmy-owls, especially during breeding season." We believe this disturbance problem is most significant in southern Texas. Oberholser (1974, p. 452) made a similar observation: "They [pygmy-owls] are considerably disturbed by hordes of bird watchers, some of whom keep their portable tape recorders hot for hours at a time in hopes that one of these rare birds will answer." Recreational disturbance of pygmy-owls in Texas is particularly an issue in the side patches of mesquite, ebony, and cane in Starr and Hidalgo Counties (Oberholser 1974, p. 452). Oberholser (1974, p. 452) and Hunter (1988, p. 6) suggest that recreational birding may disturb pygmy-owls in highly visited areas, affecting their occurrence, behavior, and reproduction. Tewes (1993, p. 12) indicates that many amateur and professional ornithologists have strictly controlled or eliminated their use of taped calls to locate pygmy-owls because of the potential to affect the pygmy-owl's behavior.

Currently, a number of ranches in Texas offer the opportunity to view and photograph pygmy-owls. An internet search revealed invitations to birders to view pygmy-owls on the El Canelo, King, and San Miguelito ranches. Some Arizona bird guides have recently begun to advertise pygmy-owl sighting and photography opportunities on the internet. Additionally, both the AGFD and the FWS continue to get requests to view and photograph pygmy-owls in Arizona. The pygmy-owl remains a high interest target for birders and photographers.

With regard to recreation in general, we anticipate disturbance and human activities associated with recreation to increase as human populations increase within the range of the pygmy-owl. An example of this occurring in the Tucson area of Arizona comes from SNP. Stonum (2020, pers. comm.) showed that annual visitation to the park has increased steadily since the Park's establishment. He indicated that visitation at SNP exceeded one million for the first time in 2019 and they anticipated that visitation would continue to increase in the coming decades.

The Bureau of Land Management indicated that multiple outdoor recreational activities may occur on public lands managed under a multiple use philosophy, those activities could have locally significant impacts (see also OHV section above). The land management agencies should be encouraged to engage in conservation planning, as described in a later section of the SSA, to analyze the impacts of those activities, and address and manage those activities if the activities are found to have negative impacts to the pygmy-owl (Hughes 2021, pers. comm.).

In summary, impacts to pygmy-owls from over-zealous birdwatchers have been documented in some areas within the range of the pygmy-owl. While pygmy-owls continue to be a highly sought after subspecies by birders, there is some indication that compliance with etiquette related to use of tape-playback or call imitation has improved. We were unable to find any information on the effects of birding on pygmy-owls in Mexico, but we do not believe that it is a significant issue in Mexico, except perhaps on local ranches, or ejidos, where ecotourism and bird watching are promoted. While the above impacts may negatively affect individual pygmy-owls on a local basis, landowners in areas that promote ecotourism are also likely to implement actions that have positive effects for the pygmy-owl.

Wildlife Research

Information on productivity (e.g., nest success), rates of survival, habitat use, and movements (e.g., size of home range) often are critical to conservation efforts for birds, including cactus ferruginous pygmy-owls. But research activities designed to answer biological questions potentially can influence the information being acquired. For example, repeated visits to nests to estimate nest success potentially can reduce success by increasing rates of abandonment and predation (e.g., Piatt *et al. 1*990, Whelan *et al. 1*994, Gibson *et al. 2*015, but see Weidinger 2008, Reynolds and Schoech 2012 for opposing views), and attaching radio-transmitters to study movements can affect behavior, flight, adult survival and productivity, and nestling survival and growth (Herzog *et al. 2*020). In Texas, disturbance of nest sites to obtain information on nestling development did not affect nest productivity. Nest sites were inspected on alternating days; inspection time ranged from 5 to 10 min. When flushed from nest cavities during incubation and brooding, females usually returned within 20 min. (Proudfoot *et al.*, 2020). Beyond this observation in Texas, little information is available on the effects of research activities on pygmy-owls, but it is reasonable to assume that some effects to pygmy-owls may occur as a result of ongoing research and monitoring. Given the status of this subspecies, all research activities should be designed to minimize potential negative influences.

7.4 Human-caused Mortality

Direct and indirect human-caused mortalities (e.g., collisions with cars, glass windows, fences, power lines, introduced competitors and predators, etc.), while likely uncommon, are often underestimated, and probably increase as human interactions with pygmy-owls increase (Banks 1979, pp. 13–14; Klem 1979, pp. 1–2; Churcher and Lawton 1987, p. 439). This may be particularly important in areas of the pygmy-owl’s range where pygmy-owls are located in proximity to urban development. Documentation exists of pygmy-owls flying into windows and fences, resulting in serious injuries or death to the birds. In one incident, a pygmy-owl collided with a closed window of a parked vehicle; it eventually flew off, but had a dilated pupil in one eye, indicating neurological injury as a result of this encounter (Abbate *et al. 1*999, p. 58). In another incident, an adult pygmy-owl was found dead at a wire fence; apparently it flew into the fence and died (Abbate *et al.*, 2000, p. 18). AGFD also has documented an incident of individuals shooting BB guns at birds perched on a saguaro that contained an active pygmy-owl nest. The information we have related to human-caused mortality is limited to the United States and does not generally appear to be a significant effect on pygmy-owl populations. In Mexico the beliefs that owls are bad luck is culturally deeply rooted. Although the pygmy-owl is practically diurnal, it is not exempt from being affected by this belief. *Glaucidium* species are sometimes called brujas mochuelas (owl witches). Additionally, records from the illegal trafficking of species include records of ferruginous pygmy-owls in illegal wildlife markets (Enríquez 2021, pers. comm.).

7.5 Disease and Predation

Documentation of disease or predation as a significant mortality factor within a wildlife population requires extensive monitoring and the ability to observe individuals in hand. With regard to pygmy-owls, monitoring and capture has only occurred with any regularity in Arizona and Texas within the United States. This has included the capture of hundreds of individual pygmy-owls and subsequent monitoring using radio telemetry. Consequently, all of the available information on disease and predation is from Arizona and Texas. We are aware of only limited, anecdotal information related to predation for northwestern Mexico (Flesch 2011, pers. comm.). The following discussion outlines our evaluation of the information related to disease and predation that we have available from Arizona and Texas.

Little is known about the rate or causes of mortality in pygmy-owls; however, they are susceptible to predation from a wide variety of species. Recent research indicates that natural predation likely plays a key role in pygmy-owl population dynamics, particularly after fledging and during the post-breeding season (AGFD 2003, pers. comm.). AGFD telemetry monitoring in 2002 indicated at least three of the nine young produced that year were killed by predators prior to dispersal during a year when tree species failed to leaf out due to drought conditions (AGFD 2003, pers. comm.). Increased predation during a particularly harsh drought year (2004) in Arizona prompted a rescue effort by the AGFD and the Service during which two hatch-year pygmy-owls were temporarily brought into captivity to increase their chances of survival. They were subsequently released when habitat conditions improved (FWS 2004, pers. comm.).

Predators can have a significant impact on a local pygmy-owl population where each breeding pair is extremely important to species persistence when numbers are low, and especially in locations where pygmy-owls are already stressed by other environmental factors. AGFD has documented predation on pygmy-owl adults and their offspring during nest-site monitoring and radio-tracking when pygmy-owl remains and transmitters were found with sign such as plucked feathers that is consistent with avian predation. Although saguaro cavities appear to offer protection against most predators and there is little evidence of nest predation in Arizona, fledglings and dispersing young are particularly vulnerable as they negotiate unfamiliar landscapes. Reduction in vegetative cover especially in dry years may expose hatch-year pygmy-owls to greater risk. Potential predators include a variety of raptors such as Cooper's hawk, western screech owl, Harris's hawk, and great-horned owls.

Western screech owls are a particular concern as they occur in most areas where pygmy-owls reside (often using saguaro cavities for nests) and have been implicated by anecdotal observations as potential predators throughout southern Arizona (AGFD 2008b, pers. comm.). Screech owls readily respond to and approach broadcast callers during pygmy-owl surveys and have been observed pursuing pygmy-owls in OPCNM in Arizona. In Texas, observations of nesting Eastern screech owls (*Megascops asio*) in the same set of three nest boxes where pygmy-owls were found dead have also been documented (Proudfoot 2003, pers. comm.). It is not known if screech owls kill pygmy-owls for food, but we suspect where this occurs, kills are probably related to competition for cavities and territory defense. Proudfoot (2021, pers. comm.) indicated he had not observed eastern screech owls eating pygmy-owl, but they simply killed them and left them in the nest box. Other possible predators in Arizona include climbing snakes such as the coachwhip (*Masticophis flagellum*) and gopher snake (*Pituophis catenifer*) which have been observed climbing saguaros and have the ability to raid nests and take fledglings. A bullsnake (P. c. *Sayi*) in Texas regurgitated six nestling pygmy-owls shortly after being pulled from a nest box (Proudfoot 2003, pers. comm.).

Pygmy-owl predation by screech owls has been identified as a potential factor contributing to the decline of regional pygmy-owl population groups (AGFD 2008b, pers. comm.). However, there is not enough information to conclusively support this hypothesis. Predation is a significant pygmy-owl nest mortality factor associated with nest boxes and tree cavities in Texas. Proudfoot (2011a, p. 1) indicates that predation rates on natural cavities and unprotected nest boxes have been as high as 40 to 60 percent, with an average of 25 to 30 percent.

Domestic cat predation of pygmy-owls has been documented in both Texas and Arizona (AGFD 2003, pers. comm.; Proudfoot 1996, p. 79). Human population growth can increase the numbers of subsidized predators, such as household cats, that can affect pygmy-owl populations. As the number of potential predators increases, the chance of predation on pygmy-owls increases. In addition, domestic house cats consume considerable quantities of birds, reptiles, insects, and small mammals, reducing available pygmy-owl prey availability (Barratt 1995, p. 185; Coleman *et al. 1*997, p. 2; Evans 1995, p. 4). This introduction of additional potential predators and a reduction in prey availability negatively affects pygmy-owls.

Ectoparasites have recently been identified as a potential threat to pygmy-owl populations (Proudfoot *et al. 2*005, pp. 186–187; Proudfoot *et al.* 2006c, pp. 874–875). These recent investigations in Texas and Arizona have indicated the regular occurrence of avian parasites in the materials inside of pygmy-owl nest cavities. The numbers of parasites may be high enough to affect nestling pygmy-owl health and survival. Blood parasites have been implicated in reduced body condition and impacts to survival and dispersal in small raptors (Dawson and Bortolotti 2000, pp. 3–5). Proudfoot *et al.* (2005, pp. 186–187) could not rule out that blood loss from external parasites, in combination with other factors, may have contributed to the loss of an entire clutch of pygmy-owls in Arizona.

The West Nile virus has been identified as the cause of a number of raptor mortalities throughout the United States, including Arizona. A number of North American owl species have documented mortality from West Nile virus, including the northern pygmy-owl (Gancz *et al.* 2004, p. 2139). However, the West Nile virus has not been documented in cactus ferruginous pygmy-owls in either the United States or Mexico, and no pygmy-owl mortalities have been suspected to be the result of an infection with the West Nile virus.

The invasive fire ant is a substantial problem in Texas. They are known to depredate bird nests, even those fairly high in trees, including cavity nests. Boal (2021, pers. comm.) indicates he and others in Texas have found invasive fire ants in raptor nests. Additionally, they have been found to be associated with decreases in insectivorous (e.g., bluebirds; *Sialia sialis*) and smaller predatory birds (e.g. loggerhead shrikes; *Lanius ludovicianus*) (Ligon *et al.* 2011, entire).

In summary, our review of the best available information suggests that disease and predation clearly have the potential to affect pygmy-owl individuals and populations, and have done so in local populations. However, information related to these factors is limited to pygmy-owl populations in the United States. We have only limited, anecdotal information related to predation on pygmy-owls in Mexico. Even in the United States, where predation has been documented, we cannot conclusively say that it is not resulting in significant effects to the status of the pygmy-owl. No disease or predation effects have been identified as having population-level effects on pygmy-owls.

7.6 Small Population Size

An important principle of conservation genetics is that small, isolated populations will experience reductions in the health of the population due to the expression of negative population characteristics as a result of inbreeding. Loss of individual adaptation can also occur and may adversely affect population demography and increase the risk of population extinction (Caughley 1994, p. 217). Inbreeding in small, isolated populations often occurs because of a lack of mates to choose from, not from preferential mating among related individuals. This can lead to increased chances that both parents will contribute genes containing harmful traits, some of which may affect important adaptive and physiological characteristics, such as survival, fertility, and physiological vigor (Soule and Mills 1998, p. 1658).

Inbreeding has been documented within the small pygmy-owl population in Arizona (Abbate *et al. 2*000, p. 21). Lack of genetic diversity in Texas and Arizona has also been documented during recent genetics studies (Proudfoot and Slack 2001, pp. 5–7). Loss of isolated population groups has occurred in Arizona due to lack of productivity and inadequate dispersal (AGFD 2008, pers. comm.). In 2008, a possible genetic heart condition was diagnosed in the mortality of three related pygmy-owls in the captive breeding research project, a possible expression of the detrimental effects of the inbreeding of pygmy-owls in Arizona (AGFD 2009a, pers. comm.).

In addition to genetic factors, habitat degradation or human-caused mortality can cause shifts in population characteristics that drive population decline. Genetic factors may simply hasten the extinction process once a population is small (Miller and Waits 2003, p. 4334). In the face of ongoing loss and fragmentation of habitat, the potential for inbreeding increases as populations or groups of pygmy-owls are increasingly isolated. This increases the need for management that maintains, restores, or substitutes for historical patterns of between-population gene flow (Hogg *et al. 2*006, p. 1491). In addition to inbreeding, genetic drift (a change in the gene pool of a population that takes place strictly by chance) in small populations can depress population fitness and increase extinction risk (Tallmon *et al. 2*004, p. 489), as well as diminish future adaptations to a changing environment (Lande 1988, p. 1455). A significant loss in genetic variation within small populations may decrease population health or limit the long-term capacity of a population to respond to environmental challenges (Keller *et al. 1*994).

Similarly, chance environmental and demographic events may pose a more substantial threat to small populations than to large populations (Westemeier *et al. 1*998, p. 1695). Caughley and Gunn (1996, p. 166) noted that small populations can become extinct entirely by chance even when their members are healthy and the environment favorable. Demographic characteristics of small populations can be significant contributors in determining minimum viable population sizes. Viability of small populations is likely dependent on both demography and population genetics and should not be considered independently (Keller *et al.* 1994, p. 356; Lande 1988, p. 1459). Consequently, for those areas of the pygmy-owl's range where local small population size is an issue, if the result of any of the above factors negatively affects pygmy-owl demography or genetics, effects, at least at the local population scale, may be significant.

Genetic rescue within a metapopulation structure can occur through periodic immigration into small, inbred, at-risk populations and can alleviate inbreeding depression and boost fitness, but habitat connectivity and adequate dispersal opportunities must be present. However, immigration of genetically divergent individuals can lead to the opposite effect—a reduction in population fitness due to outbreeding depression (when crosses between individuals from different populations have lower fitness than progeny from crosses between individuals within the same population) (Tallmon *et al.* 2004, p. 489).

In conclusion, small population size and inadequate dispersal, as well as a reduced ability to adapt due to low genetic diversity, can result in increased vulnerability of extinction for pygmy-owls in small, isolated populations. The best information we have indicates that small, isolated population groups probably occur in Arizona, Texas, and northeastern Mexico. We know of no small, isolated populations in southern Mexico, and thus conclude that small population size is not likely to be a threat in that area.

Given the current pygmy-owl population status and the identified threats that are likely to result in additional habitat loss and fragmentation, the effects of small population size are likely to continue, especially in the northern portion of the range. Reduced population connectivity as a result of habitat impacts identified above will likely continue to increase the potential for inbreeding and the associated loss of genetic diversity. At least in Arizona, lack of dispersing juveniles and floating nonbreeding individuals in the population due to low numbers of breeding pygmy-owls will also affect long-term occupancy of breeding territories and further erode long-term demographic support (exchange of individuals and rescue effect) for population groups of pygmy-owls in Arizona and northern Sonora.

7.7 Inadequacy of Existing Regulatory Mechanisms

Federal Protections

Although the pygmy-owl in Arizona is considered nonmigratory, it is protected under the Migratory Bird Treaty Act (MBTA) (16 U.S.C. 703–712). The MBTA prohibits “take” of any migratory bird. However, unlike the Endangered Species Act, there are no provisions in the MBTA preventing habitat destruction unless direct mortality or destruction of an active nest occurs. Other Federal regulations and policies such as the Clean Water Act (33 U.S.C. 1251 et seq.), the military’s integrated natural resources management plans (INRMPs, such as the one for the Barry M. Goldwater Range) (Uken 2008, pers. comm.), and National Park Service policy provide varying levels of protection, but they have not been effective in protecting the pygmy-owl from further decline. As a result of the implementation of the 2005 Real ID Act (Division B of Pub. L. 109–13), the U.S. Department of Homeland Security (DHS) has waived application of the Act and other environmental laws in the construction of border infrastructure, including areas occupied by the pygmy-owl (73 FR 5272; January 29, 2008). As recently as 2020, DHS waived environmental compliance for the construction of border walls along the U.S. –Mexico border in Arizona and Texas (Fischer 2019, entire; USCBP 2020, entire).

Court actions and changes in regulations have decreased the potential for evaluation under section 7 of the Act for Federal actions that may affect the pygmy-owl. The 2006 *Rapanos* Supreme Court decision restricts the linear extent of jurisdiction to watercourses having a “significant nexus” with a Traditionally Navigable Water. This means that after the Court’s decision was implemented starting in 2008, fewer watercourses were deemed jurisdictional. This ruling has had the effect of further reducing the Federal nexus needed to trigger the section 7 consultation process and its associated evaluation and minimization of effects to the pygmy-owl and its habitat that occurred back in the late 1990s when the pygmy-owl was listed as endangered under the Act. This limitation in the extent of jurisdiction particularly affected ephemeral streams in the pygmy-owl’s Arizona habitat. Based on the individual approved jurisdictional determinations in Pima County by the U.S. Army Corps of Engineers, it is likely that most of the Avra-Altar system, which supports pygmy-owl occupancy, will be found to lack significant nexus to the Colorado River system, which means that a primary Federal nexus that historically triggered section 7 consultation on Clean Water Act activities will be much reduced in this part of the pygmy-owl’s range (Meltz and Copeland 2007, entire; Keith 2007, entire; PCOSC 2022, pers. comm.).

State Protections

Although the pygmy-owl is included on the State of Arizona's list of species of concern (AGFD 2021a, p. 16), there are currently no provisions under Arizona statute addressing the destruction or alteration of pygmy-owl habitat. The State of Texas lists the pygmy-owl as threatened (Texas Administrative Code, title 31, part 2, chapter 65, subchapter G, rule 65.175; TPWD 2009, unpaginated; TPWD 2022, unpaginated). This designation allows permits to be issued for the taking, possession, propagation, transportation, sale, importation, or exportation of pygmy-owls if necessary to properly manage that species, but does not provide any habitat protections (Texas Park and Wildlife Code, chapter 67, section 67.0041). There are no provisions for habitat protection. The pygmy-owl is also on the Texas Organization for Endangered Species (TOES) "watch list", but this list provides no regulatory support (TOES 1995, p. 1).

Some local conservation mechanisms, such as habitat conservation plans, are in development in southern Arizona. These plans include conservation measures for pygmy-owls, but are at least a year from completion, and as drafts, do not afford the pygmy-owl any level of protection or conservation (although some pygmy-owl habitat has been conserved through acquisitions related to these plans). There are currently no provisions under Arizona statute addressing the destruction or alteration of pygmy-owl habitat.

Some have expressed the opinion that, because the current distribution of pygmy-owls occurs primarily on lands under Federal, State, or Tribal control, these lands are not at risk for the primary threats that have been identified (James 2008, pers. comm.). However, activities occur on all these lands that can result in all of the stressors and threats to pygmy-owls identified in this document. None of these types of lands are immune or restricted from impacts of facilities development, non-native invasive species, changing fire regimes, drought/climate change, wood harvesting, bird watching, avian disease and predation, border issues, or any of the other threats discussed above. In fact, it is on these very lands that many of these threats, such as border issues, non-native species invasions, fire, and recreation are concentrated. As discussed above, existing regulations governing these lands do not specifically protect pygmy-owls or their habitats, particularly absent protection under the Act.

Protections in Mexico

The conservation of pygmy-owls is complicated in Mexico by the fact that the distribution of owls is so large and includes multiple States in Mexico. The administration of land use in Mexico depends not only on the national government, which implements Natural Protected Areas and other Federal programs, but also the policies of each State and even municipal governments (Enríquez 2021, pers. comm.). This system represents a wide range of management, conservation, and natural resource use approaches that affect pygmy-owl conservation, resulting in inconsistent policies and implementation of conservation activities. There are currently no laws or regulations that specifically protect pygmy-owls and pygmy-owl habitat, and, with so many entities involved in how lands in Mexico are used and managed, there is unlikely to be a widespread, consistent application of regulations that promote the conservation of pygmy-owls in Mexico. Enríquez (2021, pers. comm.) also states that it is important to study the pygmy-owl across its range in Mexico to determine the variables and local, state, and regional threat factors that contribute to the current condition of the pygmy-owl population in Mexico.

Mexico's wildlife historically has been impacted by human-use patterns influenced by socioeconomic and political factors that have resulted in the mismanagement of its wildlife resources and decreased biodiversity (Valdez *et al.* 2006, p. 270). Goals and objectives of wildlife management in Mexico have primarily focused on huntable or harvestable species. Unless there is some sort of monetary incentive, very few of the private landowners in Mexico (which constitutes most of the wildlife habitat in Mexico) are motivated to specifically manage their lands in a way that maintains habitat for pygmy-owls and other wildlife. Federal and State wildlife agencies essentially have no authority on these private lands. This situation leaves pygmy-owl vulnerable throughout their range in Mexico (Mesta 2020, p. 1).

A program set up in Mexico to protect sensitive habitats and species is the National Natural Protected Areas (NPAs), where designation would protect areas that have not been significantly altered by human activities and which provide diverse ecosystem services. However, prior to 1994, most NPAs lacked sound and comprehensive management plans. By 2000, approximately 30 percent of new and existing NPA's had developed management plans. However, under the NPA model, these lacked detailed information, and in many cases could be considered obsolete. NPA goals to promote sustainable natural resources were often unattainable because of conflicting land ownership interests (Valdez *et al.* 2006, p. 272). The allocation of funds for management of natural reserve areas in Sonora is precarious and some reserves have not received protection other than that given by government edicts or their natural isolation (Burquez and Martinez-Yrizar 1997, p. 378). Urban development has taken its toll on Sonora's natural reserves. Three of the reserves have already disappeared, which reflects the tenuous state of many nature reserves in Mexico during the 1990's (Burquez and Martinez-Yrizar 2007, p. 546).

Another program set up to promote wildlife management on private property in Mexico is the development of wildlife management units, or UMAs. The UMA program in Mexico has not been effective in promoting wildlife management or biodiversity conservation. It has increased the introduction of exotic species. There is a lack of technical capabilities on private lands to conduct proper wildlife monitoring and management (Weber *et al.* 2006, p. 1482). In the United States, resources and funding for wildlife management have typically been a low priority for Federal and State agencies apart from wildlife agencies (LeFranc and Millsap 1984, p. 276). Even for wildlife agencies, funding and resources have been declining. Wildlife management in both countries is often the result of political or social priorities, rather than biological realities. For example, in the United States, species which are not federally listed as threatened or endangered, but which are in danger of extirpation, received little attention from State and Federal agencies (LeFranc and Millsap 1984, p. 281). In Mexico, the exploitation of minerals and industrial development has not been matched by strong measures to protect the environment (Burquez and Martinez-Yrizar 2007, p. 547). Riparian management in particular seems to lack sufficient efforts (Kusler 1985, p.6).

Summary

The Migratory Bird Treaty Act and Arizona and Texas state laws do address direct take of pygmy-owls within the United States. Mexico has no specific regulations in place to protect or conserve pygmy-owls. None of the areas within the range of the pygmy-owl are adequately protected by regulation with regard to loss of or impacts to pygmy-owl habitat. Specifically, there are no regulatory mechanisms in place that adequately protect pygmy-owls or their habitat, particularly in the face of significant habitat threats as identified in this SSA.

7.8 Conservation Activities Influencing Pygmy-owl Viability

Survey and Monitoring

The AGFD initiated surveys to determine the extent of pygmy-owl occurrence in Arizona in 1992 and were continued with the addition of limited surveys in other areas from 1993 through 1995, primarily in response to a petition to list the pygmy-owls under the Endangered Species Act (Felly and Corman 1993; Collins and Corman 1994; Lesh and Corman 1995). From 1996 to 2006, AGFD increased its monitoring and research efforts focusing on Pima and Pinal counties to document the more recent distributions. Partly in response to the Federal listing of the pygmy-owl as endangered in 1997, this work attempted to answer basic questions on the ecology of this subspecies in Arizona to help guide potential management decisions. AGFD's effort to assess population distribution at that time was complemented by surveys of historical locations outside of the greater Tucson area (Harris Environmental Group, Inc. 1998; 1999), and also benefited from numerous project clearance surveys. During this period a standardized survey protocol was updated and refined from earlier survey methods and jointly approved by the FWS and AGFD after a public comment period (FWS 2000). Survey requirements under section 7 of the ESA resulted in a number of private consultants conducting surveys in numerous areas on private and public lands which helped to confirm previous estimates of low numbers, limited distribution and the apparent occurrence of pygmy-owls in small disjunct populations (FWS unpublished data; Flesch 1999, entire; Harris Environmental Group, Inc. 1998, entire; 1999, entire; and others). AGFD's field efforts at the time focused on wild population surveys in areas of previous pygmy-owl activity as well as new locations with appropriate habitat characteristics. Researchers also monitored breeding areas, documented observations of behavior and movements, and conducted diet and habitat studies (AGFD 2000, unpublished data; Abbate *et al.* 1996; 1999; 2000). Despite funding limitations and prohibited access to some areas, this effort detected localized population fluctuations and raised concerns about further population decline. In addition, municipalities and other agencies conducted their own monitoring and clearance surveys associated with a variety of development projects providing additional records indicating the limited distribution of pygmy-owls in the state.

Once the pygmy-owl was delisted in 2006, a small number of monitoring surveys were conducted from 2007 to 2019 by the FWS and AGFD biologists, but due to lack of funds, these were restricted to a few sites with potential to provide captive breeding stock for the captive breeding pilot project described below, and therefore were insufficient to address larger population parameters. The absence of formal monitoring and surveys over a number of years resulted in a data gap that did not allow complete assessment of the wild population status within the area of historical distribution.

In 2020, a comprehensive survey effort was coordinated by AGFD in order to give us a better idea of the current numbers and distribution of the pygmy-owl to inform the development of this SSA report. Specifically, this effort included surveys to document distribution, territory occupancy monitoring, and some nest searches. Biologists from AGFD, FWS, Phoenix Zoo, Pima County, University of Arizona SNRE, Tucson Audubon, and BLM conducted perhaps the most exhaustive assessment of the wild pygmy-owl population in Arizona, covering in one breeding season the largest area of potential habitat and the greatest number of historical activity areas ever completed in the state during one breeding season. This work resulted in confirmation of 57 pygmy-owl nesting pairs (the highest number since formal surveys were initiated in the early 1990's) and an additional nine sites with unpaired territorial males. Biologists verified a minimum of 110 adult pygmy-owls in the state during this effort. All detections were in Pima County and most were found in the Altar Valley.

Renewed territory monitoring and survey efforts are not only considered essential for current assessment of conservation needs but would be integral to determining abundance and distribution of pygmy-owls to inform management actions.

Nest Box Trials

Research in Texas had demonstrated successful use of artificial nest structures by pygmy-owls (Proudfoot *et al.* 1999). Pygmy-owl researchers in Arizona suspected that nest cavity availability and interspecific competition for cavities might be some of the factors influencing pygmy-owl abundance and distribution in Arizona. In response to concerns about cavity availability, two nest box trials were conducted in Arizona. In 1998, a preliminary nest box trial was conducted when 15 nest boxes were installed on native deciduous trees along three segments of the Cienega Creek Preserve and in Catalina State Park where mature riparian vegetation offered cover and plentiful prey. This location represented historical pygmy-owl habitat, however there were no recent records of pygmy-owl activity in this area. No pygmy-owls were detected during nest box inspections over the 1998 and 1999 breeding seasons and the trial was terminated.

In 2006, an expanded nest box pilot study was initiated with the identification of 20 sites and the installation of 60 nest boxes (three boxes per site) on the Buenos Aires National Wildlife Refuge (BANWR) in the Altar Valley, Pima County. Sites were selected based on where pygmy-owl activity was documented in recent years (Richardson 2007). The launch of this project was a cooperative effort by the FWS Arizona Ecological Services Office and research biologist Dr. Glenn Proudfoot. The project was funded by AGFD’s Arizona Bird Conservation Initiative Grant. Field assistance during installation and monitoring was provided by the University of Arizona student chapter of the Wildlife Society, BANWR volunteers and the Phoenix Zoo. Nest boxes were installed near historical pygmy-owl activity areas, near saguaros or in areas with larger trees and more extensive canopy cover. After monitoring over three breeding seasons (2007–2009), no evidence of nest box use by pygmy-owls was found. Although some of the boxes were occupied by Africanized bees, more than 50 percent were used for nesting by several bird species including Western screech-owls (*Megascops kennecottii,*), suggesting natural cavity availability for small owls and other birds in this area was limited. Since screech-owls are considered potential pygmy-owl predators, some boxes were later modified to exclude them. Even so, use of these boxes by a small owl is instructive regarding size, design and protective cover within semi-desert grassland habitat where pygmy-owls are known to occur. Though pygmy-owl use was not detected during this trial, it should be noted that nest box placements were limited to a relatively small area. The expansion of artificial nest structures over a larger portion of the Altar Valley remains promising especially where there are few nest saguaros or where vegetative structure is optimal, but cavity limited. This strategy may be a way to increase nesting pairs in the valley and adjacent canyons where pygmy-owl nesting has been documented in recent years but may be at risk due to loss of mature saguaros or other landscape changes. Additionally, installation of nest boxes near new release sites for captive-bred individuals that are learning how to navigate their environment will also provide nesting substrate and predator escape cover where cavity availability is restricted.

Captive Breeding and Population Augmentation

A cactus ferruginous pygmy-owl captive breeding pilot program was established in 2006. The goal of this managed breeding program for cactus ferruginous pygmy-owls is to provide individuals to augment existing population groups or establish new population groups in areas where pygmy-owl habitat exists (AGFD 2015, entire). To date, these efforts have demonstrated: a) successful capture and transport of wild cactus ferruginous pygmy-owls, b) safe, healthful and stress-free captive facilities, c) the development of appropriate care, feeding and maintenance protocols, d) successful breeding, and e) appropriate care and development of young-of-the-year birds. Three pilot releases of captive-bred pygmy-owls have been implemented since the inception of this program. This effort establishes the first formal captive-breeding for the species and provides the groundwork for evaluation of this strategy in wild cactus ferruginous pygmy-owl population augmentation.

Investigations into the feasibility of breeding cactus ferruginous pygmy-owls in captivity have occurred at Wild at Heart, a raptor care facility in Cave Creek, Arizona, from 2006 to the present. These investigations provided the following information and successes in consideration of potential augmentation actions:

- Formation of the pygmy-owl working group to address issues related to captive breeding and potential augmentation actions.
- Completed construction of state-of-the-art breeding aviary facilities with capacity to care for up to 12 breeding pairs.
- Installation of video monitoring systems in all aviaries covering internal nest box and wide-angle aviary views allowing remote monitoring, observational research, and record storage.
- Established successful capture and transport strategies without any injuries or mortalities.
- Confirmed utility and protective features of transport and holding containers.
- Established methods of health screening and quarantine on intake of wild birds into captivity.
- Established successful monitoring, feeding and general care routines resulting in the health and longevity of captives.
- Developed appropriate nutrition program for captives resulting in healthy weights with flexibility to mimic seasonal changes in wild food sources through opportunistic harvest of lizards and other prey groups.
- Documented pygmy-owl longevity in captivity with the oldest known pygmy-owl at 11 years.
- Demonstrated pygmy-owl tolerance of captive conditions and associated maintenance activities through documentation of appropriate behaviors and longevity.
- Demonstrated successful aviary and nest box designs supporting favorable breeding environments.
- Documented egg production by all paired females and some unpaired females during each trial breeding season.
- Successful reproduction documented with fledging of young by one or more pairs during each breeding season except for 2007.
- Demonstrated successful technique for increased egg production through removal of some eggs prior to clutch completion.
- Demonstrated successful hatching of eggs through artificial incubation.

- Initiation of experiments with techniques for increasing egg viability using humidifier apparatus and nest box design changes.

The Phoenix Zoo became the second captive breeding site for pygmy-owls in Arizona when it entered into partnership with the FWS and the AGFD in 2017. Wild-At-Heart provided two pygmy-owls to the Zoo’s Conservation and Science Department from their captive program in January 2018 to start the second captive population. After intensive monitoring of several nests in Pima County, AGFD and FWS biologists captured seven fledgling pygmy-owls and transferred these to the Zoo’s captive population in June 2018. Two of these perished, but the remaining five were used to establish potential breeding pairs and the Zoo recorded egg-laying and new hatchlings in May 2019. An additional nine chicks were hatched and fledged in 2020.

Figure 7.1 Pygmy-owls and nestlings in nest box at Phoenix Zoo (Photo courtesy of Phoenix Zoo)

Figure 7.2. Pygmy-owl in nest box at Phoenix Zoo (Photo courtesy of Phoenix Zoo).

Figure 7.3. Nestling pygmy-owl at Phoenix Zoo (Photo courtesy of Phoenix Zoo).

In 2016, the Wild-At-Heart breeding facility had reached its capacity for housing breeding pygmy-owl pairs and potentially releasable offspring. Since this site was the only approved breeding location at that time, the options for removal of excess captives to maintain healthy captive conditions were limited. Members of the pygmy-owl working group agreed that nothing would be learned by euthanizing excess pygmy-owls and a trial release was needed before proceeding further with any expanded captive breeding and release program. A trial release option would allow the assessment of this soft-release hacking technique as a workable conservation tool for pygmy-owls, examination of logistics and identification of potential problems for future releases (see Figure 7.6). Sixteen owls were identified for release. Pima County authorized the use of a county-owned parcel for hack-box installations and releases. This parcel is surrounded by the Ironwood Forest National Monument and provided pygmy-owl habitat with good access for monitoring and feeding during the week of acclimation and the transition to independent prey acquisition. All pygmy-owls to be released were marked with color bands and FWS bands and eight individuals were outfitted with radio-transmitters to enable tracking of movements and assessment of survivorship (see Figure 7.4 and 7.5). Frozen mice were provided to each box during the acclimation week and feeding continued after captives were released from the boxes for a total of 56 days. Those individuals with radio-transmitters provided the opportunity to track movements and to locate mortalities. After release, the radio-tracked owls either died or signals were lost and unable to be relocated. By day 14 post-release, only two of the eight transmittered owls' radio signals were detected despite ground searches throughout the area for the remaining four. Ground searches were ended on 17 November 2016 when no signals were detected and all transmittered owls were presumed dead or lost. The six pygmy-owls without transmitters were no longer observed after seven days post-release and their survival status was unknown for the remainder of the monitoring period. It should be noted that unbanded pygmy-owls were located at the release site the fall of 2017 following the 2016 release and in the fall of 2020, providing evidence that the release site selected could support pygmy-owls.

Figure 7.4 Captive-bred pygmy-owl being banded prior to release. (Photo credit: George Andrejko, AGFD)

Figure 7.5 Radio transmitter being placed on a captive-bred pygmy-owl prior to release. (Photo credit: George Andrejko, AGFD)

Figure 7.6 Captive-bred pygmy-owls being placed in hack box prior to releasing as part of the captive breeding/population augmentation pilot project. (Photo credit: George Andrejko, AGFD)

Conservation Planning

Several municipalities located in the vicinity of current or historical pygmy-owl activity areas have explored or implemented Habitat Conservation Plans (HCP) under the ESA as an approach to address potential conflicts between development projects and requirements of the ESA.

The HCP plans included the Sonoran Desert Conservation Plan (Multi-Species Conservation Plan) developed by Pima County (Pima County 2016, entire), the Town of Marana Habitat Conservation Plan and the City of Tucson's Avra Valley and Southlands Habitat Conservation

Plans. Each of these four HCP efforts identified the pygmy-owl as one of the covered species under their prospective plans. The planning areas for three of the four plans include locations where pygmy-owls are currently active or were historically documented during surveys and monitoring since 1993. Since the initiation of these planning efforts, Pima County has completed their Multi-Species Conservation plan and was issued a FWS permit in 2016. Implementation is ongoing and includes conservation measures for the pygmy-owls such as ongoing survey and monitoring and habitat acquisition and protection. These actions occur throughout Pima County and significantly contribute to the conservation of the pygmy-owl, especially in the Altar Valley which is one of the last stronghold for breeding pygmy-owls in Arizona. The City of Tucson has focused conservation planning for the Avra Valley and this HCP remains in progress and should be finalized soon. Progress on the Southlands HCP has been put on hold, as has the Town of Marana HCP. Currently, substantial habitat for pygmy-owls remains within the City of Tucson and Town of Marana jurisdictions and together with federally-managed natural preserves in adjacent areas such as Saguaro National Park and Ironwood Forest National Monument, may present further opportunities for pygmy-owl conservation associated with augmentation, should these municipalities offer cooperation on actions within their jurisdictions.

Another conservation planning effort that is ongoing and has the potential to support pygmy-owl conservation in the Altar Valley of southern Arizona is the Altar Valley Watershed Management Plan being developed by the Altar Valley Conservation Alliance with numerous partners and participants. The plan will describe stewardship practices and tools and a series of high-priority projects that maximize positive impacts on the land and in the community. It is expected that most projects will address two major themes: 1) Hydrology issues including channel incision of the Altar Wash main stem and upland tributaries; and 2) Vegetation issues related to brush encroachment from mesquite and other woody species. The Altar Valley Watershed Plan was completed in 2022 and will contribute to the enhancement of pygmy-owl habitat in Altar Valley, Arizona (Altar Valley Watershed Working Group 2022, entire).

The purpose of the restoration plan is to: clarify shared goals, determine the best stewardship practices to achieve those goals, describe where and how to deploy these practices, and build a strong foundation from which to seek appropriate project partners and funding. The plan will be an accessible resource that supports efforts by those living and working in the valley. More specifically, the plan will:

- Provide a clear, unified source of guidance to collaborative parties, focused on shared goals
- Devise solutions to complex problems in the Altar Valley, and promote continuance of effective practices
- Create a “toolbox” of information and resources on stewardship practices, permitting, monitoring, and other topics

- Identify and prioritize restoration projects important to accomplish across the valley over the next 25 years
- Prepare conceptual plans for 15-20 potential projects

Recommended stewardship practices are likely to include: brush removal using various methods, prescribed fire, managed grazing, erosion control and floodplain enhancement structures, water harvesting from ranch roads, and more. Restoring and maintaining a healthy watershed in Altar Valley will enhance conservation of the pygmy-owl with respect to habitat quality, connectivity, and long-term retention of open space resources.

In Mexico there are federal, state, or municipal protected Natural Areas. These areas can work well as conservation strategies for the pygmy-owl. There is now a new option for protected areas called Voluntary Conservation Areas (Áreas Destinadas Voluntariamente a la Conservación; ADVA) which are areas for conservation and can be a good conservation strategy(https://www.gob.mx/conanp/articulos/areas-destinadas-voluntariamente-a-la-conservacionparticipacion-social-por-el-ambiente-193042) (Enríquez 2021, pers. comm.).

7.9 Summary

Our analysis of the past, current, and future influences on what the pygmy-owl needs for long-term viability revealed that the primary influence that poses the largest risk to future viability of the pygmy-owl is habitat loss and fragmentation. This is complex issue that is driven by a number of factors, primarily climate change, drought, and change in fire regime. However, permanent loss of habitat and habitat connectivity because of urbanization and other land uses is a significant concern in both pygmy-owl populations and in all analysis units. While some aspects of issues related to climate change can be addressed to enhance conservation of the pygmy-owl, such as non-native invasive plant management and fire management, many of the effects of climate change have no short-term or local resolutions. They will require a global approach over the long term. Finding support for and adequate resources to implement ongoing and new conservation activities is crucial in being able to offset some of the effects of circumstances we cannot control. Large scale land-use planning to maintain habitat and habitat connectivity across the range of the pygmy-owl is needed to maintain pygmy-owl population viability.

CHAPTER 8. VIABILITY AND FUTURE CONDITIONS

This report has considered what pygmy-owl needs for viability and the current condition of those needs (Chapters 2-5), and we reviewed the risk factors that are driving the historical, current, and future conditions of the subspecies (Chapter 7). In this Chapter, we consider what the subspecies' future conditions are likely to be. We apply our future projections to the concepts of resiliency, redundancy, and representation to assess the future viability of pygmy-owl.

8.1 Introduction

In the absence of human influences, most owl or raptor populations are limited by either food supply, particularly in the winter, or availability of nest sites (Exo 1992, p. 64). In the case of the pygmy-owl, both human influences on the landscape (urbanization, infrastructure, land management, etc.) and natural stressors, such as climate change, drought, extreme weather events, and fluctuations in prey populations, affect the future viability of pygmy-owl populations. To assess the future viability of the pygmy-owl, we must consider the future effects of stressors and threats on habitat intactness, prey availability, and the health and condition of vegetation and cover. Cactus ferruginous pygmy-owls appear to have spatially structured population groups and, particularly in the northern portion of the geographic range, function similarly to metapopulations. Pygmy-owl movements among the population groups and analysis units are affected by roads, openings in vegetation, aggregations of suitable vegetation, urbanization, agricultural development, etc. Land uses and landscape patterns can affect pygmy-owl occupancy patterns within its range, particularly if habitat is fragmented (Flesch *et al*. 2009, pp. 7 – 9; Flesch and Steidl 2010, pp. 1033 – 1037; Flesch 2017, entire).

For example, the rate of future urbanization and infrastructure development needs to be considered as we project the future intactness of suitable vegetation within the range of the pygmy-owl. Additionally, changes in future climate patterns and their influence on vegetation condition, increasing occurrence of non-native plant species, and prey availability will likely reduce the resiliency of pygmy-owls, exacerbating effects of nearly all threats and stressors and create varying levels of risk to pygmy-owls into the future. Both the eastern and western populations of the pygmy-owl face risks from anthropogenic sources, however, the smaller population groups in Arizona, Texas, and Northern Sonora (one of which is currently in low condition) are more vulnerable to a single stochastic event, such as a severe drought or hurricane, which could eliminate an entire population group.

The current lack of habitat connectivity in some analysis units decreases the potential for natural recolonization and other aspects of demographic support (interchange of individuals among population groups), therefore, extirpation of one population group or analysis unit would result in the permanent loss of representation and redundancy in that pygmy-owl population. Historically, the pygmy-owl was probably able to maintain population resiliency through interconnected population groups. However, analysis units are currently limited in some areas of the pygmy-owl's range due to lack of vegetation intactness. Thus, these historical population groups would have been more resilient to stochastic events because even if some population groups were extirpated by such events, they could be recolonized over time by dispersal from nearby surviving population group, similar to what has been observed in some area of Arizona and northern Sonora. This connectivity would have made for more highly resilient pygmy-owl populations overall. Under current conditions, restoring that connectivity on a large scale may not be feasible due to the permanent loss and alteration of habitat resulting in reduced habitat intactness; however, improving the redundancy of populations within at least some of the areas of representation is feasible through the implementation of conservation activities.

In summary, as a consequence of the current conditions of the pygmy-owl discussed above, the viability of pygmy-owl populations in the future now primarily depends on maintaining representation and redundancy in those analysis units that currently have moderate resiliency, and improving the resiliency of the three analysis units that are rated has having low resiliency. Improving resiliency in these analysis units will also improve the representation and redundancy in the analysis units and the population within which they occur. To assess whether resiliency can be maintained or improved in the future, we consider the effects of the primary threats and stressors discussed in Chapter 7 on the same demographic and habitat factors used to assess the current condition of the analysis units (Table 6.1).

8.2 Future Scenarios and Considerations

Because climate change models generally present a range of possible outcomes, there is some uncertainty regarding: 1) how climate will change in the future, which in turn will have an effect on the severity of future periods of drought and warming; 2) the extent and location of land use activities that lead to pygmy-owl habitat loss and fragmentation in the future; and 3) whether and where conservation actions which improve demographic and habitat factors will be implemented and be effective in improving the viability of pygmy-owl populations. We have projected what pygmy-owls may have in terms of resiliency, redundancy, and representation under four plausible future scenarios (Scenario 1: Continuation; Scenario 2: Increased Effects; Scenario 3: Reduced Effects, and Scenario 4: Conservation Planning; Table 8.1) which project the viability of pygmy-owls over the next 30 years. We chose this timeframe based on the subspecies' life span and observed cycles in population abundance. The average lifespan of a pygmy-owl is 3 to 5 years. Thus over a 30-year timeframe, we would expect eight to ten generations of pygmy-owls to be produced which should be adequate to assess the effects of both threats and conservation actions. Because the primary avenue through which pygmy-owls move across the landscape is through the dispersal of juveniles, it can take multiple generations to provide adequate exchange of individuals to illicit detectable change at the population group and analysis unit scale. Including multiple generations of pygmy-owls also allows adequate time to account for lags in demographic factors resulting from changes in environmental conditions. Therefore, this number of generations is sufficient to assess the effective levels of resiliency, redundancy and representation. Monitoring of pygmy-owl occupancy and productivity also indicates that, at least in Arizona and northern Sonora, 30 years was an adequate time period to document abundance cycles driven by climate conditions. Monitoring in both Arizona and northern Sonora from the mid-1990’s to present showed a period of decline in occupancy and productivity, primarily due to drought, followed by an increase in productivity and occupancy during years of better precipitation such that abundance and occupancy recovered to nearly the original levels (Flesch et al. 2017, p. 12; Service 2021, entire). Additionally, 30 years was the maximum horizon where we could also reasonably project certain land use changes, urbanization, and climate patterns relevant to the pygmy-owl and its habitat. For more information on the models and their projections, please see the SSA report (Service 2021, entire).

For each future scenario, we describe the effects from the identified source/stressors that would be expected to occur in each population (Table 8.1). All of the scenarios involve some degree of uncertainty; however, they present a range of realistic and plausible future conditions. Each scenario is described in further detail below (Table 8.1), but in summary, Scenario 1, or the Continuation scenario, evaluates the condition of pygmy-owls if there is no increase in risks to the populations from what exists today. In other words, those factors that are having an influence on populations of pygmy-owls continue at current rates. Scenario 2, or the Increased Effects scenario, evaluates the response of the subspecies to changes in risks, including the application of Representative Concentration Pathways (RCP) 8.5 projections (note that RCP is explained in the following section), increased habitat loss and fragmentation, and limited efficacy of conservation efforts. Scenario 3, or the Reduced Effects scenario, evaluates the response of the species to a reduction in threats, including a reduction in the rate of habitat fragmentation and loss as well as effective conservation actions. The Conservation Planning scenario (Appendix 4), explores possible conservation strategies that if implemented, could improve current conditions, by slowing or halting declines in habitat and population conditions over the next 30 years.

Table 8.1 Future Scenario Descriptions by Source/Stressor and Conservation.

Source/Stressor	Climate Change	Habitat Fragmentation and Loss	Conservation
Scenario 1 **Continuation**	RCP[1] 4.5	Fragmentation and loss continue at the same rate.	Captive rearing, conservation planning efforts – Limited efficacy/implementation
Scenario 2 **Increased Effects**	RCP 8.5	The rate of fragmentation and loss increase.	Captive rearing, conservation planning efforts – Not effective/not implemented
Scenario 3 **Reduced Effects**	RCP 4.5	Fragmentation and loss continue at a reduced rate.	Captive rearing, conservation planning efforts – Effective and implemented at current levels
Scenario 4 **Conservation Planning (Appendix 4)**	RCP 4.5	Fragmentation and loss continues at the same rate.	Captive rearing, conservation planning efforts; additional conservation activities developed – High efficacy/implementation

[1] Representative Concentration Pathway (RCP) is a measure of carbon dioxide emissions

We examine the resiliency, representation, and redundancy of the pygmy-owl under each of these four plausible scenarios for a 30-year time period. Resiliency of pygmy-owl populations depends on future availability of intact habitat, prey availability, and vegetation health and cover (discussed in Chapter 3), and how these habitat factors influence subspecies abundance, recruitment, and the amount of habitat occupied. For the climate-related factors we considered in these future scenarios, we compare these factors from a baseline time period (1981 – 2010) and compared it to a future time period (2041 – 2070). The data sets available for our use had defined time periods by which the data were presented. We selected the time periods that best fit our needs for a baseline condition (1981 – 2010), for the current condition (2011 – 2040), and for our future condition of 30 years (2041 – 2070). While these time periods do not exactly match the time frames of this SSA, they are the best approximation of those time frames encompassed by the available data. This allowed us to consider the changes in climate factors that are projected into the future by the models we selected and how those factors may affect future resiliency. In particular, the use of RCP 8.5 in a future scenario captures the time period where this increased RCP results in the greatest effects. We expect the five pygmy-owl analysis units to experience changes to these aspects of their habitat in different ways under the different scenarios. We projected the expected future resiliency of each analysis unit based on the events that would occur under each scenario. We then project an overall condition for each population based on these habitat and population factors. Classification of the overall condition score for each analysis unit follows the same break down as applied for the current condition table: High (a score of 22 - 28), Moderate (a score of 15 – 21), or Low (a score of 8 - 14). For these projections, populations in high (healthy) condition are expected to have high resiliency in 30-years (i.e., abundance is increasing, the majority of available habitat is occupied, and populations are successfully reproducing, habitats are intact with adequate prey availability, and vegetation cover is adequate and healthy). Populations in high condition are expected to persist into the future (>85 % chance of persistence beyond 30 years) and have the ability to withstand stochastic events that may occur. Populations in moderate condition have less resiliency than those in high condition, but these populations have a good likelihood of persistence (>60 – 85%) beyond 30 years. Populations in moderate condition have lower rates of abundance and occupancy or reduced vegetation intactness or greenness or higher aridity than those in high condition. Populations in low (unhealthy) condition have low resiliency and are not necessarily able to withstand stochastic events. As a result, they are less likely to persist beyond 30 years ($\leq$60%).

8.2.1 Climate considerations

In section 7.1, we discussed the potential effects of drought and warming caused by climate change on pygmy-owl. We have analyzed drought and the risk of future drought in a limited way using the data available to us (NDVI and Hargreaves Climate Moisture Deficit). We did not look at every possible measure of drought and did not comprehensively look at the different aspects associated with the severity of future droughts. We focused on the modeled projects related to climate change associated with changes in emissions over time. In general, however, climate change scenarios project that drought will occur more frequently and increase in severity, with a decrease in the frequency and increase in severity of precipitation events (Seager *et al.* 2007, p. 9; Cook *et al.* 2015, p. 6; Pascale *et al.* 2017, p. 806; Williams *et al.* 2020, p. 317). In this section, we briefly explain the two different climate change trajectories considered in the future scenarios for the subspecies. The future scenarios include the effects of future climate change using emissions projected at 4.5 and 8.5 RCP scenarios contributed by the Working Group III to the Fifth Assessment Report and described in the most recent Synthesis Report of the Intergovernmental Panel on Climate Change (IPCC 2014a, pp. 9, 22, 57). The IPCC Report describes four alternative trajectories for carbon dioxide emissions (RCPs) and the resulting atmospheric concentrations from the year 2000 to 2100 (van Vuuren *et al.* 2011, p. 5). For the purposes of our analysis, we chose one intermediate scenario (RCP4.5) and scenario with very high greenhouse gas emission (RCP8.5) (IPCC 2014a, p. 8).

Pygmy-owl future Scenarios 1 and 3, the Continuation and Reduced Effects scenarios, assume RCP4.5, a medium stabilization scenario where CO_2 emissions continue to increase through mid-

21st century, but then decline and atmospheric carbon dioxide concentrations are between 580 and 720 ppm CO_2 from 2050 to 2100, representing an approximate +2.5 ºC in global mean temperature change relative to 1861-80 (IPCC 2014a, p. 9, Figure SPM.5). Future scenario 2, Increased Effects scenario, assumes RCP8.5 where atmospheric carbon dioxide concentrations are above 1000 ppm CO_2 between 2050 and 2100, representing an approximate +4.5 ºC in global mean temperature change relative to 1861-80 (IPCC 2014a, p. 9, Figure SPM.5). The 2014 IPCC Synthesis Report projects global temperature change to 2100 (IPCC 2014a, p. 8). A recent study suggests that, because of uncertainty in long-run economic growth rates, there is "a greater than 35% probability that emissions concentrations will exceed those assumed in the most severe of the available climate change scenarios (RCP8.5)" by 2100 (Christensen *et al.* 2018, p. 5409).

For both RCP4.5 and RCP8.5, global mean surface temperature change for the end of the 21st century (2081-2100) is projected to likely exceed 1.5 ºC, relative to 1850-1900 (IPCC 2014a, p. 60). Under RCP8.5, global mean surface temperature change is projected likely to exceed 2.0 ºC by 2100, perhaps as high as 4.8 ºC, relative to 1850-1900 (IPCC 2014a, p. 60). Global mean surface temperature for the mid-century (2046-2065) is projected to increase under RCP4.5 and 8.5, but projections are lower than those for the end of the century (IPCC 2014a, p. 60). It is virtually certain that there will be more frequent hot and fewer cold temperature extremes over most land areas on daily and seasonal timescales, as global mean surface temperature increases (IPCC 2014a, p. 58).

Annual precipitation in the United States has decreased in much of the West, Southwest, and Southeast, including areas occupied by the pygmy-owl. However, extreme precipitation events will increase. Future changes in climate patterns will impact climate across the range of the pygmy-owl. For example, change in the Hadley circulation will causes the subtropics, the region between the northern and southern edges of the tropics and the midlatitudes (about 35° of latitude), to be drier in warmer climates as well as moving the mean storm track northward and away from the subtropics, decreasing the frequency of precipitation-producing systems. The combination of these two factors results in precipitation decreases in the southwestern United States and Mexico, resulting in increasing drought and reduced vegetation health (Easterling et al. 2017, entire).

8.3 Viability (Resiliency, Redundancy, and Representation)

This section reviews the viability of the pygmy-owl under three scenarios. The output of the Continuation, Increased Effects, and Reduced Effects scenarios at 30 years and synopses of the effects to the populations over time are included below. The fourth scenario, the Conservation Planning scenario, is presented in Appendix 4. We developed and analyzed these scenarios through a combination of expert elicitation and GIS modeling. The outcomes of these analyses are generally qualitative in nature, but the habitat variables are quantified to the extent the modeling efforts allowed. The fourth scenario, the Conservation Planning scenario, is presented in Appendix 4.

8.3.1. Scenario 1 – Continuation

Under Scenario 1 (continuation of current trends), we projected there would be no significant changes to the rate of habitat loss and fragmentation within the subspecies' range over the next 30 years. For this scenario, we considered that climate change would track Representative Concentration Pathway (RCP) 4.5, which is one of four alternative trajectories for carbon dioxide emissions set forth by the International Panel on Climate Change. Specifically, RCP 4.5 is an intermediate scenario where carbon dioxide emissions continue to increase through the mid-21st century, but then decline. This scenario would result in atmospheric carbon dioxide levels between 580 and 720 parts per million (ppm) between 2050 and 2100 and would represent an approximately 2.5 oC increase in global mean temperature relative to the period 1861–1880 (IPCC 2014, p. 9). We also considered that conservation efforts that are currently underway, such as captive rearing, would continue to be limited in their efficacy, due to limited resources and the continued efforts to identify appropriate and effective methodologies and protocols. Additionally, climate change will continue to affect the suitability of conditions at release sites for captive-reared pygmy-owls, potentially limiting the effectiveness of pygmy-owl releases.

We consider the effects of the continuation of these factors on pygmy-owls over the next 30 years and project that population numbers will remain low and that occupancy of population groups will continue to vary based on local environmental conditions. Habitat fragmentation and loss continue to reduce pygmy-owl habitat at current rates. Climate change, which is already occurring, follows a RCP4.5 emissions scenario and results in an increasing Climate Moisture Deficit and reduced vegetation greenness. Conservation efforts that are underway (e.g., captive rearing and release in Arizona) will continue with limited efficacy.

8.3.1.1. Resiliency (see Table 8.3)

Arizona

Of the eleven factors affecting pygmy-owl viability that we summarized (see Appendix 5), the effects of eight are increasing (invasive species, climate change, urbanization, agriculture/wood harvesting, border issues, human activity and disturbance, small population size, and inadequacy of existing regulations), three are stable (conservation actions, improper livestock grazing, and disease and predation), and none are decreasing. We do not anticipate that any of the factors used to evaluate resiliency will improve and, in fact, we anticipate that vegetation intactness will be reduced because of the rate of development and infrastructure. International border infrastructure will impede the cross border movements of pygmy-owls into this analysis unit. Vegetation greenness will remain low and climate moisture deficit will not improve. The number of pygmy-owls will remain low and occupancy will continue to vary based on local conditions. Although substantial amounts of pygmy-owl habitat occur on federal lands in Arizona, effects from climate change, recreation, and border issues are unlikely to be mitigated by the federal status of these lands. The low resiliency rating will continue for this analysis unit.

Northern Sonora

Of the eleven factors affecting pygmy-owl viability that we summarized (see Appendix 5), the effects of eight are increasing (invasive species, climate change, urbanization, agriculture/wood harvesting, improper livestock grazing, border issues, small population size, and inadequacy of existing regulations), three are stable (conservation actions, human activity and disturbance, and human caused mortality), and none are decreasing. Under the Continuation scenario, we anticipate that changes to some of the factors affecting resiliency will maintain their current levels in the Northern Sonora analysis unit. However, even with changes occurring at the current rate, it is likely that increased habitat loss and fragmentation will occur around the cities and along major travel routes such as Route 2 and Route 15. Urbanization will continue in these areas. International border infrastructure will impede the cross border movements of pygmy-owls into this analysis unit. Agricultural development will also continue to expand and water use in agricultural and urban areas will continue to result in water being pumped from aquifers and rivers, drying some surface waters that provide habitat for pygmy-owls. Vegetation greenness will continue to be in low condition. Rates of occupancy for population groups will continue to vary due to local conditions. Although some protected areas occur within this analysis unit, they make up only approximately 6 percent of suitable vegetation for the pygmy-owl within this analysis unit (see Table 8.2) and the protected status of these lands is variable (see Section 7.7 above). We project an overall rating of low resiliency for this analysis unit under the Continuation Scenario.

Western Mexico

Of the nine factors affecting pygmy-owl viability that we summarized (see Appendix 5), four are increasing (climate change, urbanization, agriculture/wood harvesting, and inadequacy of existing regulations), three are stable (conservation actions, human activities and disturbance, and human caused mortality), and none are decreasing. However, the trend of the effects of two of these factors (invasive species and improper livestock grazing) is unknown. We anticipate that vegetative greenness will decrease to a moderate condition in the Western Mexico analysis unit under the Continuation scenario due to the continued effects of climate change on habitat factors, particularly drought. Additionally, we project that there will be a continued increase in habitat loss and fragmentation, particularly in the coastal plain, as well as deforestation and habitat loss associated with urban growth, resource extraction, grazing, and agriculture such that vegetation intactness will drop to a low condition. There are no laws, regulations, or policies in place that would conserve or protect pygmy-owl habitat within this analysis unit. Although some protected areas occur within this analysis unit, they only make up approximately 6.9 percent of suitable vegetation for the pygmy-owl within this analysis unit (see Table 8.2) and the protected status of these lands is variable (see Section 7.7 above). We project the overall rating of moderate condition in this analysis unit under the Continuation Scenario, with some reduction in long-term viability for pygmy-owls.

Table 8.2 Areas (in square miles) of protected areas in Mexico and percentage of total suitable vegetation each accounts for by analysis unit. Information is from World Database of Protected Areas (https://www.protectedplanet.net/country/MEX), version 1.5 – 2015.

Analysis Unit	Suitable landcover (square miles)	Landownership										
		Federal or national ministry or agency			Sub-national ministry or agency			Individual Landowners			Not Re	
		Total Area (sq. miles)	Protected Suitable Vegetation (sq. miles)	% of Total Suitable Vegetation	Total Area (sq. miles)	Protected Suitable Vegetation (sq. miles)	% of Total Suitable Vegetation	Total Area (sq. miles)	Protected Suitable Vegetation (sq. miles)	% of Total Suitable Vegetation	Total Area (sq. miles)	Protec Suital Vegeta (sq. mi
Northeastern Mexico	42075.98	4921.53	1535.42	3.65%	1313.65	722.76	1.72%	129.00	6.96	0.02%	136.25	7
Northern Sonora	25951.95	1754.32	1473.03	5.68%	107.47	82.73	0.32%	72.66	11.31	0.04%	470.01	1
Western Mexico	70229.57	10039.79	4487.68	6.39%	1097.77	316.86	0.45%	13.65	5.18	0.01%	2432.20	120

Texas

Of the eleven factors affecting pygmy-owl viability that we summarized (see Appendix 5), six are increasing (invasive species, climate change, urbanization, border issues, small population size, and inadequacy of existing regulations), five are stable (conservation actions, agriculture/wood harvesting, improper livestock grazing, human activities and disturbance, and disease and predation), and none are decreasing. The effects of climate change are anticipated to reduce the rating for Climate Moisture Deficit to moderate for the Texas analysis unit. Factors such as invasive species, hurricanes, urbanization, and lack of existing regulations to conserve pygmy-owl habitat will result in continued habitat loss and fragmentation. Models project drier annual Heat Moisture Index, decreased annual precipitation, and increased annual temperatures for Texas (See Appendix 1). Extended drought will reduce vegetation greenness. Factors along the international border with Mexico such as border activity and infrastructure and agricultural development are projected to inhibit movements of pygmy-owls across the border and may result in a reduced number of pygmy-owls and reduce occupancy. Additionally, the majority of lands in Texas are private and do not have the same likelihood of conservation as federal lands would have. All of this, in combination, lead us to project a low resiliency rating for the Texas analysis unit under the Continuation scenario.

Northeast Mexico

Of the ten factors affecting pygmy-owl viability that we summarized (see Appendix 5), five are increasing (climate change, urbanization, agriculture/wood harvesting, border issues, and inadequacy of existing regulations), three are stable (conservation actions, human activity and disturbance, and human caused mortality), and none are decreasing. However, the trend in effects of two of the factors (invasive species and improper livestock grazing) are unknown. We project a continued increase in habitat loss and fragmentation, particularly associated with urban growth, resource extraction, grazing, and agriculture. Models project a drier annual Heat Moisture Index and hotter mean annual temperatures for northeastern Mexico which may reduce vegetation greenness, however, the Climate Moisture Deficit is projected to remain moderate. There are no laws, regulations, or policies in place that would conserve or protect pygmy-owl habitat within this analysis unit. Although some protected areas occur within this analysis unit, they only make up approximately 5.4 percent of suitable vegetation for the pygmy-owl within this analysis unit (see Table 8.2) and the protected status of these lands is variable (see Section 7.7 above). Factors along the border with Texas such as border activity, infrastructure, and agricultural development are projected to inhibit movements of pygmy-owls across the border and may result in a reduced number of pygmy-owls and affect occupancy due to lack of rescue effect. We project the overall rating of moderate condition will be maintained in this analysis unit under the Continuation Scenario.

Table 8.3 Resiliency of pygmy-owl populations under Scenario 1, Continuation over the next 30 years.

	Analysis Unit	Demographic Factors			Habitat Factors			Future Condition
		Abundance	**Occupancy**	**Evidence of reproduction**	**Vegetation intactness**	**Climate Moisture Deficit**	**Vegetative greenness**	
Western Population	**Arizona**	**Low**[1]	**Moderate**	**Yes**	**Low**	**Moderate**	**Low**	**Low**
	Northern Sonora	**Moderate**	**Moderate**	**Yes**	**Low**	**Moderate**	**Low**	**Low**
	Western Mexico	**High**	**Unknown**[2]	**Yes**	**Moderate**	**Moderate**	**Moderate**	**Moderate**
Eastern Population	**Texas**	**Moderate**	**Moderate**	**Yes**	**Low**	**Moderate**	**Low**	**Low**
	Northeast Mexico	**High**	**Unknown**[2]	**Yes**	**Low**	**Moderate**	**Moderate**	**Moderate**

[1] No comprehensive survey effort has been completed on the Tohono O'odham Nation.

[2] Presumed common due to anecdotal evidence; will assume Moderate condition for this category for analysis purposes

8.3.1.2 Representation

In the Continuation scenario, the current level of representation for pygmy-owl populations are projected to be maintained for the next 30 years in all five analysis units. However, resiliency will decrease in three of the five analysis units and remain low in Arizona under this scenario, which may affect the representation within some analysis units. For example, pygmy-owls have not been detected in two population groups in Arizona in recent years and low habitat intactness in Northern Sonora, Texas, and Northeastern Mexico may result in lost or reduced occupancy of some population groups. Although the level of representation within analysis units may be reduced, the overall representation within the populations will be maintained over this 30-year time period.

8.3.1.3 Redundancy

Because pygmy-owls will continue to occupy all analysis units under the Continuation scenario, redundancy will still occur across the range of the pygmy-owl for the next 30 years. However, under the Continuation scenario, resiliency will decrease in some population groups and may not provide the same level of redundancy within analysis units even though redundancy is maintained at the population level. For example, the number of pygmy-owls will likely decline under this scenario and some pygmy-owl population groups may become extirpated, reducing redundancy within that analysis unit. Vegetation intactness is projected to decline in the Northern Sonora analysis unit and the overall condition classification is projected to drop to low. Vegetation greenness is projected to decrease in the Western Mexico and Texas analysis units and Climate Moisture Deficit to increase in the Texas analysis unit. These reductions in habitat conditions are expected to lead to a decrease in redundancy within analysis units, even though at the broader population scale overall redundancy will be maintained at some level. Therefore, because viability is tied to the level of resiliency, we anticipate that long-term viability of the subspecies will be reduced.

8.3.1.4 Scenario 1 Summary

Under Scenario 1, we do not anticipate that any of the factors used to evaluate resiliency would improve and, in fact, vegetation intactness would be reduced due to continued development. Northeastern Mexico is projected to maintain its current level of high pygmy-owl abundance since significant changes to habitat conditions are not expected. Because of this, the northeastern Mexico analysis unit is expected to maintain a moderate level of population resiliency under this scenario. Conditions in the Arizona analysis unit would continue to decline due to continued habitat fragmentation and climate change, and resiliency would remain low. Resiliency in the remaining three analysis units, northern Sonora, western Mexico, and Texas, would decline due to continued loss of cactus ferruginous pygmy-owl habitat, reduced habitat intactness, and a reduction in cover and prey availability for cactus ferruginous pygmy-owls. Overall, current levels of population redundancy and representation would be maintained rangewide because all analysis units would remain occupied; however, representation within each analysis unit would likely decline at the population-group scale.

Figure 8.1 Resiliency of pygmy-owl populations under Scenario 1, Continuation scenario.

8.3.2 Scenario 2 – Increased Effects

Under Scenario 2 (worsening or increased effects scenario), we projected increased rates of habitat loss and fragmentation leading to a decline in pygmy-owl habitat conditions. For this scenario, we considered that climate change would track RCP 8.5, which is the highest greenhouse gas emission scenario. Under this scenario, atmospheric carbon dioxide concentrations are projected to exceed 1,000 ppm between 2050 and 2100 and would represent a 4.5 oC increase in global mean temperature (IPCC 2014, p. 9). Scenario 2 thus examines increased risks to pygmy-owl populations as a result of increased effects from climate change.

We also project that there will be additional increases in habitat fragmentation and loss. This may include habitat loss from catastrophic hurricanes or wildfire, as well as ongoing effects such as climate change, urbanization, and human activities on the landscape. All factors influencing the viability of the pygmy-owl as outlined in Chapter 7 will continue at an increased rate than is occurring under the current conditions described in Chapter 6. We also considered that conservation efforts that are currently underway would not be effective or not be implemented.

8.3.2.1 Resiliency (see Table 8.4)

Arizona

Under the Increased Effects scenario, the eight factors with an increasing trend of effect (see Appendix 5) will continue at an increased rate and will result in substantial reduction in resiliency in all five analysis units. In Arizona, under the Increased Effects scenario, we project a reduction in the condition of demographic factors, including a reduction in abundance and occupancy, and a decrease into a low condition for the vegetation greenness habitat factor. Increased habitat loss and fragmentation will result in the greatest affect to overall condition through a reduction in abundance and occupancy of pygmy-owls. Increased development and urbanization will result in a permanent loss of habitat. Indirect effects to vegetation and prey availability as a result of climate change are also expected. These factors are projected to result in a continued low overall condition rating and substantially reduce the continued long-term viability of the analysis unit resulting from decreased resiliency.

Northern Sonora

Under the Increased Effects scenario, the Northern Sonora analysis unit is projected to experience a reduction in the condition of demographic factors (abundance and occupancy) affecting resiliency. Habitat loss and fragmentation are expected to accelerate due to increase land use impacts such as urbanization, agriculture, and improper grazing, which results in a low condition score for vegetation intactness. Climate change is projected to exacerbate these effects through a decrease in woody vegetation cover as well as in saguaro recruitment and replacement, resulting in a decrease in nesting habitat and nest cavity availability. With low condition for abundance and occupancy, as well as in vegetation intactness and vegetation greenness, the overall resiliency will be in low condition under this scenario for the Northern Sonora analysis unit.

Western Mexico

Under the Increased Effects scenario, we project that the demographic factors will be reduced to moderate condition in the Western Mexico analysis unit. Accelerated development and other land use conversion will increase habitat loss and fragmentation. Climate change will exacerbate effects to habitat and will decrease vegetation greenness to moderate condition. Vegetation intactness will drop to low condition. Increased threats combined with lack of regulations and conservation protecting pygmy-owl habitat reduce the potential future viability of this analysis unit. However, after 30 years, we expect this analysis unit to be in moderate condition, primarily because of the demographic factors in this analysis unit.

Texas

Because the six factors influencing pygmy-owl viability that we found to be increasing (see Appendix 5) will continue to increase at a more rapid rate under the Increased Effects scenario, we anticipate reduced resiliency in this analysis unit beyond that experienced in the Continuation Scenario. We project that abundance and occupancy will be reduced in the Texas analysis unit due to lack of rescue potential among population groups and the increased effects of climate change on habitat quality. This will result in a low condition for overall resiliency within this analysis unit and substantially reduce the continued long-term viability.

Northeast Mexico

Under the Increased Effects scenario, the primary effects to the Northeastern Mexico analysis unit will be the reduction of the demographic factor of abundance, which will drop from high to moderate due to habitat fragmentation and the increased effects of climate change on habitat quality. Effects from climate change, including expanded distribution of invasive species, increases in frequency of hurricanes and tropical storms, as well as increases in habitat fragmentation and loss from urbanization and agricultural development will cause vegetation intactness to remain low and lead to a decline in vegetation greenness. Therefore, the overall condition rating for this analysis unit will continue to be low under the Increased Effects scenario, with a continued downward trend.

Table 8.4 Resiliency of pygmy-owl populations under Scenario 2, Increased Effects over the next 30 years.

		Demographic Factors			**Habitat Factors**			
	Analysis Unit	**Abundance**	**Occupancy**	**Evidence of reproduction**	**Vegetation intactness**	**Climate Moisture Deficit**	**Vegetative greenness**	**Future Condition**
Western Population	**Arizona**	**Low[1]**	**Low**	**Yes**	**Low**	**Moderate**	**Low**	**Low**
	Northern Sonora	**Low**	**Low**	**Yes**	**Low**	**Moderate**	**Low**	**Low**
	Western Mexico	**Moderate**	**Unknown[2]**	**Yes**	**Low**	**Moderate**	**Moderate**	**Moderate**
Eastern Population	**Texas**	**Low**	**Low**	**Yes**	**Low**	**Moderate**	**Low**	**Low**
	Northeast Mexico	**Moderate**	**Unknown[2]**	**Yes**	**Low**	**Moderate**	**Low**	**Low**

[1] No comprehensive survey effort has been completed on the Tohono O'odham Nation.

[2] Presumed common due to anecdotal evidence; but will assume Moderate condition for this category for analysis purposes within the Increased Effects Scenario

8.3.2.2 Representation

In the Increased Effects scenario, representation will continue to occur within each of the five analysis units over the next 30 years, although the Arizona, Texas, and Northern Sonora analysis units will become more vulnerable to extirpation due to low abundance and there is a possibility that those areas of representation would be lost. The extirpation of these three analysis units would cause the loss of occupancy in two unique habitat types, Sonoran desertscrub and oak motte habitats. Thus, representation would be reduced in both the eastern and western pygmy-owl populations. The current level of representation, overall, in Mexico would also decrease within 30 years because of low resiliency and the likely loss of some population groups within those analysis units. Genetic representation would be reduced by loss of either population groups or analysis units. Additionally, under this scenario, there would be a subsequent reduction of gene flow and genetic rescue due to reduced numbers of pygmy-owls and reduction of pygmy-owl movement due to habitat fragmentation. Ecological representation is decreased by the loss of population groups, and, potentially, the loss of analysis units within unique ecological sites. Therefore, while representation will still occur within both pygmy-owl populations, it will be reduced and there will be a loss of representation within most analysis units. Therefore, the likelihood of maintaining long-term viability is considerably reduced.

8.3.2.3 Redundancy

The two pygmy-owl populations (western and eastern) have three and two analysis units each for redundancy, respectively. Under this scenario, population groups within analysis units will be lost and there is the potential for two or more analysis units to be lost because four out of the five analysis units are in low condition. Therefore, similar to representation, redundancy within the analysis units that make up the two populations will be reduced within 30 years under the Increased Effects scenario. Population groups within each analysis units will likely be lost and, potentially, even entire analysis units could be extirpated. Redundancy will be reduced at all three levels (population group, analysis unit, and population) and there will be the loss of demographic support (exchange of individuals and rescue effect) within both the eastern and western pygmy-owl populations. The greatest potential for loss of redundancy will be from the Arizona, Northern Sonora, and Texas analysis units.

8.3.2.4 Scenario 2 Summary

Under Scenario 2, increased habitat loss and fragmentation would result in the greatest effect to overall resiliency through a reduction in abundance and occupancy of pygmy-owls. Increased development and urbanization would result in a permanent loss of habitat. Indirect effects to vegetation and prey availability as a result of climate change would also be expected. Due to increased habitat fragmentation, such as agricultural development, as well as a reduction in vegetation health from drought, resiliency in the western Mexico analysis unit is projected to decline. Under this scenario, climate change and increased habitat fragmentation from urbanization and agricultural development lead to the loss of some population groups within the Texas, Arizona, and northern Sonora analysis units. The resultant decline would decrease representation and redundancy within these analysis units. In particular, the Texas and Arizona analysis units would become more vulnerable to extirpation because of low pygmy-owl abundance and occupancy driven by reduced habitat quality as a result of drought and high levels of habitat fragmentation from ongoing urbanization and agricultural development. Genetic representation would be reduced through the loss of population groups or analysis units and the subsequent reduction of gene flow. Overall, there would be a reduction in resiliency, representation, and redundancy within most analysis units and the likelihood of maintaining long-term viability would be considerably reduced.

National Geographic, Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

Figure 8.2 Resiliency of pygmy-owl populations under Scenario 2, Increased Effects scenario.

8.3.3 Scenario 3 – Reduced Effects

Under Scenario 3 (improving or reduced effects scenario), we project that habitat loss and fragmentation would continue, but at a reduced rate over the next 30 years. For this scenario, we considered that climate change would track RCP 4.5. A key factor under this scenario is that conservation efforts that are underway (e.g., captive rearing and release in Arizona) will continue, but will effective. We acknowledge that, in reality, there is much work to be done to understand how conservation actions can be implemented in such a way that these efforts improve the status of the pygmy-owl, but this scenario is based on an over ten year captive breeding and release pilot project. Much has been learned over this time and, under this scenario these efforts are effective. We expect that captive rearing will produce a sufficient number of cactus ferruginous pygmy-owls to augment population groups in Arizona. We also anticipate that releases of captive-bred owls will result in augment abundance and occupancy of cactus ferruginous pygmy-owls on the landscape in Arizona and, potentially, in northern Sonora. However, it is important to note that while rates of threats on the viability of pygmy-owls are reduced under this scenario, conditions within the analysis units will not improve over the current condition under the Reduced Effects Scenario. This scenario simply projects what will happen over the next 30 years with the current condition as the baseline. All of the effects to pygmy-owl viability from the eleven factors affecting pygmy-owl viability that we summarized (see Appendix 5) will continue under the Reduced Effects scenario and, with the exception of conservation actions, all will continue to reduce the viability of pygmy-owls across its geographic range.

8.3.3.1 Resiliency (see Table 8.5)

Arizona

Under the Reduced Effects scenario, we project that the Arizona analysis unit will see an increase in abundance of pygmy-owls and improved occupancy due to effective conservation actions such as captive breeding and population augmentation. This will increase the demographic factors of abundance and occupancy to a moderate level, although vegetation intactness will be reduced to low due to ongoing effects of urbanization, invasive species, mesquite control, and border issues. Climate change will result in an increased Climate Moisture Deficit and a reduction in vegetation greenness. As a result, the overall resiliency of the Arizona analysis unit will remain in low condition for the Reduced Effects scenario, but demographic factors affecting resiliency at the population group scale would likely increase.

Northern Sonora

Under the Reduced Effects scenario, we project that occupancy and abundance will remain stable for the Northern Sonora analysis unit, possibly benefitting from effective conservation actions in Arizona and subsequent movements of owls into northern Sonora. Habitat factors will also remain the same as under current conditions with the exception of vegetation intactness, which will drop to low condition, similar to the Continuation Scenario. We project that, while rates of impacts will be reduced under this scenario, pygmy-owl habitat loss and fragmentation will continue to add to the habitat loss and fragmentation found under the current condition and reduce vegetation intactness to low condition in this scenario. Therefore, the overall resiliency rating will be low for the Northern Sonora analysis unit under the Reduced Effects scenario.

Western Mexico

Because no real improvement in the habitat factors are likely to occur, even under the Reduced Effects scenario, we anticipate that ongoing climate change will result in the reduction of the vegetative greenness factor to a moderate level under this scenario. Ongoing urbanization, deforestation, and agricultural development will continue to reduce vegetation intactness, but we project that vegetation intactness will remain in moderate condition for this analysis unit. We project that numbers of owls and occupancy will remain in high condition condition. The overall resiliency rating will be moderate for this analysis unit under the Reduced Effects scenario.

Texas

Because no real improvement in the habitat factors is likely to occur, even under the Reduced Effects scenario, we anticipate that ongoing climate change will result in the reduction of the climate moisture deficit factor to a moderate level under this scenario. Under the Reduced Effects scenario, a low level of vegetation intactness for this analysis unit will continue because we project that vegetation intactness will not improve. We anticipate that demographic factors within the Texas analysis unit will remain the same as the current condition under this scenario. Therefore, we project that the Texas analysis unit will be in moderate condition under the Reduced Effect scenario.

Northeast Mexico

Under the Reduced Effects scenario, both the demographic and the habitat resiliency factors will remain the same as the ratings for the current condition for the Northeastern Mexico analysis unit. Climate change effects and ongoing habitat loss and fragmentation will reduce resiliency in this analysis unit, however, we are uncertain as to the extent of those effects on pygmy-owls for this analysis unit. Therefore, we project that those reductions will not occur to such an extent that a reduction in resiliency from the current condition will result under this scenario. Therefore, the overall resiliency rating will be moderate for this analysis unit under the Reduced Effects scenario.

Table 8.5 Resiliency of pygmy-owl populations under Scenario 3, Reduced Effects over the next 30 years.

		Demographic Factors			**Habitat Factors**			**Future Condition**
	Analysis Unit	**Abundance**	**Occupancy**	**Evidence of reproduction**	**Vegetation intactness**	**Climate Moisture Deficit**	**Vegetative greenness**	
Western Population	**Arizona**	Moderate	Moderate	Yes	Low	Moderate	Low	Low
	Northern Sonora	Moderate	Moderate	Yes	Low	Moderate	Low	Low
	Western Mexico	High	Unknown[2]	Yes	Moderate	Moderate	Moderate	Moderate
Eastern Population	**Texas**	Moderate	Moderate	Yes	Low	Moderate	Low	Moderate
	Northeast Mexico	High	Unknown[2]	Yes	Low	Moderate	Moderate	Moderate

[1] No comprehensive survey effort has been completed on the Tohono O'odham Nation.

[2] Presumed common due to anecdotal evidence; will assume Moderate condition for these categories for analysis purposes

8.3.3.2 Representation

In the Reduced Effects scenario, the current level of representation for pygmy-owl populations will be maintained because all of the analysis units will remain occupied by pygmy-owls. Current levels of resiliency drop in two of the five analysis units and will be maintained under this scenario in the remaining three analysis units and we anticipate that representation, at least at the analysis unit level, will continue for the next 30 years. However, habitat factors will still experience a reduction in condition in three out of the five analysis units affecting the overall likelihood of maintaining viability over this 30-year time period.

8.3.3.3 Redundancy

Because pygmy-owls will continue to occupy all analysis units under the Reduced Effect scenario, redundancy will still occur across the range of the pygmy-owl for the next 30 years. However, under the Reduced Effects scenario, the Arizona analysis unit will increase to a moderate condition rating for pygmy-owl abundance, but will also drop to low condition for vegetation intactness. Vegetation intactness will continue in low condition for the Eastern population of pygmy-owls and climate change will reduce the condition rating in the Western Mexico analysis unit within 30 years. We anticipate that because of these reductions in a number of condition categories in a number of analysis units, redundancy within analysis units will likely decrease in most analysis units, but will see some improvement in the Arizona analysis unit due to effective conservation measures. Overall redundancy will be maintained at some level in both pygmy-owl populations. However, we anticipate that the likelihood of long-term viability will be reduced due to reductions in habitat factors, primarily vegetation intactness.

8.3.3.4 Scenario 3 Summary

Despite effective conservation actions in portions of the range, the viability of pygmy-owl populations would continue to decline within all five analysis units due to the ongoing effects of habitat loss and fragmentation and climate change. Resiliency would remain low in the Arizona analysis unit and would decline in both the northern Sonora and western Mexico analysis units due to a reduction in habitat quality as a result of climate change. Pygmy-owl habitat fragmentation from urbanization, deforestation, and agricultural development are expected to continue under this scenario, though at a slower rate. Resiliency would remain in moderate condition for the Texas and northeastern Mexico analysis units. Although habitat conditions are expected to continue to decline, due to drought and climate change, we do not expect a large decline in pygmy-owl occupancy and abundance in Texas and northeastern Mexico. Under this scenario, each analysis unit remains occupied and contributes to the representation and redundancy across the range of the pygmy-owl. However, within each analysis unit, threats continue, albeit at a reduced rate, and the resiliency of population groups would decline in three of the five analysis units. Thus, within analysis units, representation and redundancy is likely to decrease at the population-group scale.

Figure 8.3 Resiliency of pygmy-owl populations under Scenario 3, Reduced Effects scenario.

8.4 Status Assessment Summary

Under all future scenarios, we project a continued reduction in species viability throughout the range of the subspecies due to climate change, habitat loss, and habitat fragmentation. Over the next 30 years, four of the five analysis units will become increasingly vulnerable to extirpation through the degradation of habitat conditions. Continued loss and degradation of pygmy-owl habitat will reduce overall species resiliency, impeding the ability of the subspecies to withstand stochastic events and increasing the risk of extirpation following such events. The loss of population groups will lead to a reduction in representation, reducing the subspecies' ability to adapt over time to changes in the environment, such as climate changes. This expected reduction in both the number and distribution of resilient population groups will reduce redundancy and impede the ability of the subspecies to recolonize following catastrophic disturbance.

We used the best available information to describe the current conditions, and project the likely future conditions, of the eastern and western pygmy-owl populations. Our goal was to describe the viability of the subspecies by examining how the subspecies' needs, and threats to those needs, influence the resiliency, representation, and redundancy of the subspecies. The pygmy-owl faces a variety of risks from climate change and habitat loss and fragmentation. These risks play a large role in the future viability of pygmy-owls. If populations lose resiliency, they are more vulnerable to extirpation, with resulting losses in representation and redundancy. Our results describe a range of possible future conditions in terms of the overall resiliency of the populations and analysis units (Table 8.6).

In 30 years, under Scenario 1 – Continuation, we would expect viability of both pygmy-owl populations to decrease. Analysis units would generally be characterized by similar levels of resiliency, representation, and redundancy to what it has currently, but this means that no analysis unit is in high condition. Two of the five analysis units would be in moderate condition, but would have likely lost some potential to remain viable because of the reduction in condition of habitat factors. Three analysis units would be in low condition with ongoing reductions in demographic factors and habitat factors. Therefore, overall resiliency would be reduced from the current condition and all analysis units would be experiencing the reduction of some factors under this scenario. Also, while representation and redundancy would remain present in both populations, three analysis units would see some reductions in representation and redundancy within analysis units. Overall viability of both populations would be reduced from the current condition.

In 30 years, under Scenario 2 – Increased Effects, we would expect viability of the pygmy-owl to be characterized by lower levels of resiliency, representation, and redundancy than it has currently. Every analysis unit but Western Mexico would be rated as being in low condition under this scenario. This means that there are even greater reductions in resiliency for all analysis units and, thus, levels of representation and redundancy are further reduced. Overall viability is reduced substantially for both populations. Four of the five analysis units have a 40 – 90 % probability of extirpation in the next 30 years.

Table 8.6. Pygmy-owl population and analysis unit conditions under each scenario at the 30-year time period.

	Population Condition			
Population/Analysis Unit	**Current Condition**	**Scenario 1- Continuation**	**Scenario 2- Increased Effects**	**Scenario 3– Reduced Effects**
Western/Arizona	**Low**	**Low**	**Low**	**Low**
Western/Northern Sonora	**Moderate**	**Low**	**Low**	**Low**
Western/Western Mexico	**High**	**Moderate**	**Moderate**	**Moderate**
Eastern/Texas	**Moderate**	**Low**	**Low**	**Moderate**
Eastern/Northeastern Mexico	**Moderate**	**Moderate**	**Low**	**Moderate**

In 30 years, under Scenario 3 – Reduced Effects, we would expect viability of both pygmy-owl populations to decrease, but not to the degree as would occur under Scenario 1, Continuation. Analysis units would generally be characterized by similar levels of resiliency, representation, and redundancy to what it has currently, but this also means that no analysis unit is in high condition. Two of the five analysis units would be in moderate condition, but would have likely lost some potential to remain viable because of the reduction in condition of habitat factors. Three analysis units would remain in low condition with ongoing reductions in habitat factors. However, under this scenario, we would anticipate some increases in demographic factors as a result of effective conservation measures. Therefore, although overall resiliency would be reduced from current condition and experiencing reduction of some factors under this scenario, there is also an increase in demographic factors. Representation and redundancy would remain similar to current conditions with a bit of an increase in these factors in the Arizona and possibly Texas analysis units. As a result, both pygmy-owl populations would likely see similar levels of representation and redundancy as with the current condition. Overall viability of both populations would be similar to the current condition, with some demographic gains under this scenario.

In summary, our analysis of the cactus ferruginous pygmy-owl’s future conditions show that the population and habitat factors used to determine resiliency, representation, and redundancy will continue to decline. The primary threats are currently acting on the species, and are likely to continue into the future. The range of plausible future scenarios for the pygmy-owl all indicate a reduction in species viability into the future. Under the current trend scenario, resiliency is low for three of the analysis units and moderate for two analysis units. Under the increased effects, or worsening scenario, resiliency is low in four of the analysis units and moderate in one analysis unit. Under the reduced effects, or improving, scenario, resiliency is low in two analysis units and moderate in three analysis units. Over the next 30 years, pygmy-owls in up to four of the five analysis units will become increasingly vulnerable to extirpation and there is a possibility that those areas of representation would be lost, resulting in a reduction in species redundancy. Additionally, species representation and redundancy within analysis units will likely be reduced through the loss of population groups, genetic representation, and the reduction of movements between population groups. This expected reduction in both the number and distribution of resilient populations is likely to make the species vulnerable to catastrophic disturbance.

APPENDIX 1. MODELING LAND COVER SUITABILITY

Background

Characterizing the current condition of the landscape a species depends upon is required to conduct a Species Status Assessment (SSA). For the Cactus Ferruginous Pygmy-Owl (pygmy-owl) SSA we characterized landscape conditions spatially to analyze the ability of those landscapes to support the biological needs of the pygmy-owl. Previous work has demonstrated that the primary concern for the pygmy-owl is habitat loss and fragmentation (Oberholser 1974, Johnsgard 1988, Millsap and Johnson 1988, Wauer *et al. 1*993, Tewes 1993, Abbate *et al. 1*999, p. 59; Abbate *et al. 2*000, p. 29; Flesch *et al. 2*010, Flesch 2017). We conducted a GIS analysis to analyze the extent of suitable vegetation types and vegetation intactness within the range of the pygmy-owl.

Purpose

1. Create a current condition land cover layer which identifies and ranks land cover classes and landscape features as they relate to pygmy-owl activities. The layer consists of three components (each component is discussed in greater detail later in this document), derived from a variety of spatial data inputs:

a. Land Cover

b. Woody Canopy Density

c. Developed Areas (roads and urban areas)

d. Elevation

e. Protected Areas/Land Ownership

2. Develop an “intactness” land cover model which analyzes relative disturbance on the landscape. This will use the same data layers as the suitable land cover analysis, and provide a general assessment of fragmentation.

All of these processes will be described in detail in this document.

General Limitations

The remotely sensed data products and large national datasets used in this analysis may contain inherent temporal discrepancies and errors of omission and commission. We did not conduct any independent accuracy assessments for any of the datasets. Actual, on-the-ground, condition of mapped cover types is not addressed. All land cover data has a minimum spatial resolution of 30-meters. No field verification or reviews of ancillary datasets/aerial imagery were done to verify the accuracy of the original data used. These data, and all maps/products created from it, are subject to change.

Models and associated data developed from these analyses are general representations of land cover condition at a large landscape scale. These data cannot be used to assess/identify specific habitat location or value.

Analysis Area

All data, results and analysis information are reported by the five analysis units which cover areas in the southern United States and eastern/western Mexico. Figure A.1 shows the locations of the five areas.

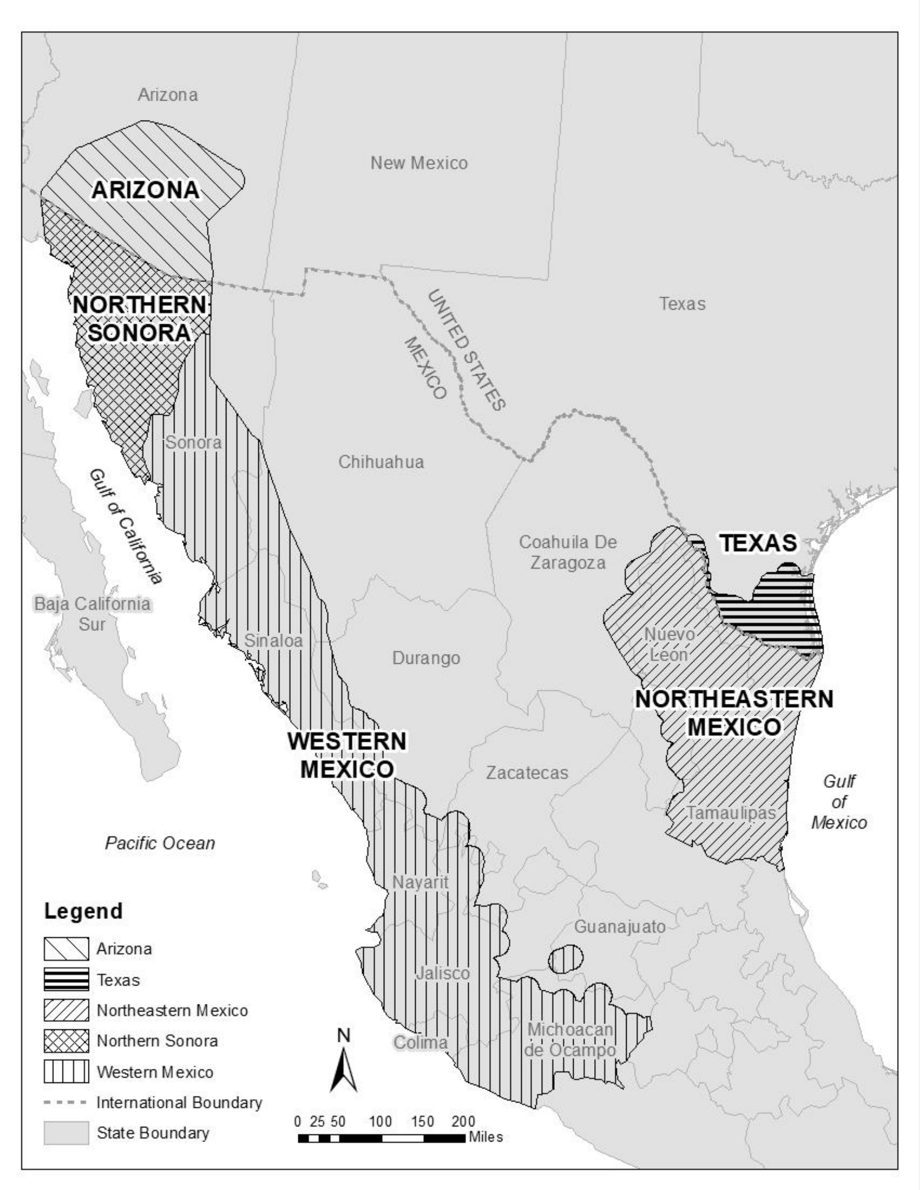


Figure A1-1. Cactus ferruginous pygmy-owl analysis units.

Spatial Data Sources

Land Cover Data:

Land cover data is useful for examining the vegetation condition of a landscape. It can provide information on vegetation types and structure.

The primary data of the U.S. were the Geological Survey (USGS) LANDFIRE Existing Vegetation Type (EVT) and Existing Vegetation Cover (EVC) 2016 land cover data (LANDFIRE 2016, unpaginated).

These was chosen because of its temporal currency and relationship with other spatial datasets used in this study. It should be stated that LANDIFE data is updated from satellite imagery as well as on-the-ground observations, often at regional or ecoregional scales, resulting in minor inconsistencies across larger landscape scales. The limited accuracy of all land cover data, including LANDFIRE data, is acknowledged and accepted. Land cover classes with ill-defined or unclear definitions (LANDFIRE/GAP Land Cover Map Unit Descriptions, 2016) were closely examined with aerial imagery (ESRI, Inc. ArcMap on-line data) to determine inclusion/exclusion as a suitable class.

For Mexico, the primary data used for the land cover suitability was 2015 30 meter land cover data from the North American Environmental Atlas (NAEA-Commission for Environmental Cooperation website).

These data were used because of their temporal currency and consistent coverage across the vast analysis area (described earlier). Though this dataset also covers the U.S. portions of the analysis units, the more-detailed LANDFIRE data was chosen since its vegetation classification is more detailed (tables below for U.S. and Mexico classification application). All land cover data used (U.S. & Mexico) is publicly available and downloadable.

Roads and Developed Areas Data:

Roads data is a helpful dataset to use for examining to scope of fragmentation on a landscape.

For the U.S., TIGER 2017 (U.S. Census Bureau) was downloaded and used. Roads data for Mexico were created by extracting the developed land cover layer from the Mexico land cover dataset, then converted to polygons and buffered. This helped to connect road networks which can sometimes be identified inconsistently with 30 meter satellite-based data.

Elevation Data:

Elevation data will help confine the analysis to elevations the pygmy-owl is known to utilize, or remove areas the subspecies will not use. For the U.S. and Mexico, USGS 1 arc-second Digital Elevation Models (DEM) were used. This dataset has a 30 meter resolution and provides seamless coverage for all of North America. The data were downloaded from the USGS National Map application (nationalmap.gov).

Protected Areas and Land Ownership Data:

Land Ownership/Protected Areas data layers are useful for identifying areas that may or may not be protected from development based on available ownership status.

For the U.S. areas, the Bureau of Land Management (BLM) provides a detailed national, publicly available, land ownership data layer (BLM National Surface Management Agency), downloadable from “Data.gov”. For Mexico, the protected areas data came from the World Database on Protected Areas (WDPA). This data is also publicly available and downloadable.

Projections and Transformations

All data were projected in NAD 1983 Albers. This was the USGS LANFIRE data source projection. All non-Albers data were projected into this system. This projection maintains a perfect 30m x 30m pixel size and allows all of the raster layers to overlay exactly. Projection details can be found in the properties of the spatial data layers.

Basic GIS & Geoprocessing Methods

Since this study area covers a vast geographical landscape, most of the geoprocessing will be performed in the raster data format. This is an image-based format with data comprised of pixels, each containing a value. The ArcGIS software accesses the raster data according to its cell value(s) providing a cell count for each value, so there may be millions of pixels in a layer but only a few values to deal with. This makes the geoprocessing run much faster than the vector (point/line) data. Raster data also neatly "stacks" on top of one and other (as long as the pixel size is the same or a multiple of the source pixel size), making the layers easy to combine (cell statistics function) and reclassify. Source data that is acquired in vector format may have some processing done in the vector environment (like buffering), but then will be converted to raster to be combined with the other layers for the analysis.

For this study, all raster data will have a 30 meter by 30 meter pixel size. This is a standard size for large landscape datesets (such as LANDFIRE, NLCD, etc.). All layers will be "snapped" to the LANDFIRE source layer. This will assure proper alignment of all data layers avoiding the slivers and gaps that occur in vector data. With proper classification and attribution each layer can maintain its unique cell value identifying the spatial relationship between different overlaying/intersecting layers (described later in this section).

For the final part of the spatial analysis, some of the data layers were converted into a vector format to aid with multiple intersections of data layers and acreage calculations.

Current Condition: Identifying Suitable Vegetation Types

The Current Condition landscape model was basically created the same way for the U.S. and Mexico areas, even though the data layers are slightly different. The differences will be discussed at the end of this section. The current condition GIS analysis consists of five primary layers (as mentioned above). Through geoprocessing, these layers were overlaid and mathematically overlayed/intersected (cell statistics), providing a direct spatial relationship between the cell values in all of the layers.

1. Reclassified Land Cover Layer

For the U.S., LANDFIRE EVT 2016 Remap data, this layer was reclassified and resampled to identify suitable, and non-usable areas as it relates to the pygmy-owl (previous definitions). This served as the primary input layer for the current condition and the future scenario modeling.

Original data source: 2016 USGS LANDFIRE Existing Vegetation Type (EVT)

a. Data is downloaded from USGS LANDFIRE website (https://www.landfire.gov/)

b. Data is extracted/clipped to analysis unit boundaries

c. All original LANDFIRE individual land cover types/classes (93 in AX, 72 in TX) are reclassified by giving them a pygmy-owl-related value (this is done by expert elicitation by FWS Biologists);

- ***Suitable Vegetation Types (woody tree and shrub classes, some herbaceous classes)***
- ***Unusable Areas (other veg. classes non-veg/developed areas)***

Pygmy-owl Reclassifications (as defined above) for all LANDFIRE EVT land cover classes are described in Table A.3.

To aid in the decision process and to attempt to compensate for inherent classification errors, many aspects of each LANDFIRE classification were scrutinized to provide context beyond just the class name. Factors used during expert elicitation as considerations for reclassifying land cover classes:

- Review of aerial photography
- Geographic location/landscape position
- Pixel count
- Proximity to (buffered) pygmy-owl siting locations
- Multiple attribute fields within the dataset, and their associated descriptions (LANDFIRE/GAP Land Cover Map Units Description, 2016)

For Mexico, the same basic process was used with the NAEA land cover data. This data fewer vegetative classes that the LANDFIRE data, but the process yielded similar results at a much less detailed level.

Pygmy-owl Reclassifications (as defined above) for all NAEA land cover classes are described in Table A.3.

2. Reclassified Vegetation Cover data

To help define suitable vegetation types that may hold a higher suitability value Canopy density 20% or greater), the LANDFIRE vegetation cover layer (EVC) (https://www.landfire.gov/) was reclassified as follows (Table A.2);

Table A1-1. EVC woody vegetation canopy densities used. Note the variations in the maximum of the EVC classes. This is due to the fact that densities did not go above stated values for the specific areas

	EVC Class	FWS Designation
TX	Tree Cover = 10%-19%	Canopy Cover <20%
	Tree Cover = 20%-76%	Canopy Cover >20%
	Shrub Cover = 10%-19%	Canopy Cover <20%
	Shrub Cover = 20%-63%	Canopy Cover >20%
AZ	Tree Cover = 10%-19%	Canopy Cover <20%
	Tree Cover = 20%-81%	Canopy Cover >20%
	Shrub Cover = 10%-19%	Canopy Cover <20%
	Shrub Cover = 20%-74%	Canopy Cover >20%

Classes outside of what is listed above were not used in the analysis.

There was no canopy cover/density data available for Mexico.

3. Reclassified Elevation Data Layer

For the U.S. and Mexico, elevation data were used to eliminate areas above 4000 ft. (1220 m). For modeling purposes, these areas were considered biologically unusable by the pygmy-owl.

Elevation data were acquired from USGS Digital Elevation Data Model (DEM) 1 arc-second 30 meter North American dataset (nationalmap.gov). This resolution was used because of its seamless coverage across the U.S. Mexican border. DEM data were reclassified basically into an “in/out” system. Pixels with a value less than 1220 m (approx. 4000 ft.) were considered “in”, pixels 1220 m or greater were considered “out”.

4. Data Processing: Combining and Upscaling into the Initial Suitable Vegetation Model

To best utilize the needed information from the EVT, EVC, and DEM data the Cell Statistics tool (ArcMap, Spatial Analyst) was used to “combine” the three raster layers together.

Each of these layers is first reclassified (AcrMap, Spatial Analyst) with a unique numeric code:

EVT Data;

Suitable Vegetation Types = 1

Unusable/Developed Types = 0

DEM Data;

0-1219 m = 0

1220 & greater m = 100

EVC Data;

Shrub/Tree canopy Cover 20% or greater = 1000

Shrub/Tree canopy Cover less than 20% = 0

Cell Statistics Tool;

This Spatial Analyst tool calculates the per-cell statistic from multiple rasters. For this process, the SUM overlay statistic is used. This adds up the values from the three rasters to create one output using the above numeric values.

The model results appear as follows;

0 (Unusable/below 1220/<20% Canopy) = Out

1 (Suitable veg/below 1220/<20% Canopy) = In

100 (Unusable/above 1220/<20% Canopy) = Out

101 (Suitable veg/above 1220/<20% Canopy) =Out

1000 (Unusable/below 1220/>20% Canopy) = Out

1001 (Suitable veg/below 1220/>20% Canopy) = In

1100 (Unusable/above 1220/>20% Canopy) =Out

1101 (Suitable veg/above 1220/>20% Canopy) = Out

The new raster values of 1 and 1001 meet the criteria for overall Suitable Vegetation;

a. Suitable Vegetation Types

b. Below 1220 meters

c. Both (<20% & >20%) Canopy Cover Type

5. Aggregating the New Suitable Vegetation Raster Layer

With the size of the work areas and the combination of many data layers, the number of pixels/features is extremely high. This slows upcoming geoprocessing actions and creates a very digitally "noisy" data layer. Also at the large landscape scale of this project, this extreme detail is not needed. To help, the data were Aggregated (ArcMap, Spatial Analyst) to provide a more reasonable and easier-to-use dataset, while still maintaining the overall structure and distribution of the data features.

The first step was reclassifying the above data layer (1, 1001 features) to a simpler system;

1 = Suitable Vegetation <20% Canopy cover

2 = Suitable Vegetation >20% Canopy cover

Next, the Aggregation Tool was used to simplify the data layer. This was done by selecting a new pixel size, in this case 90 meter pixel (Cell Factor 3x) and an Aggregation Technique = Median. This tool then created a new 90 m cell grid, and took the median value of the previous 30 m cells within, and gave it a new 1 or 2 value (Note: this one operation took the data layer from 54 million pixels to 6 million pixels, with an overall acreage difference of around 4%).

6. Adding back in Major Highways and Roads

In order to maintain a representative land cover model, after aggregation, larger roads and highways were "added" back into the new Suitable Vegetation layer. This was done to provide some separation between features in areas that were "lumped" back together by aggregation. Only Interstate Highways and U.S. & State Highways were used. The linear features were extracted from the TIGER dataset (U.S. Census Bureau, 2016), and rasterized to a 30 m pixel size. They were integrated into the New Suitable Vegetation layer using the Cell Statistic tool, then the overlap pixels were removed with reclassification, leaving only the "1 & 2" features, but now with the major roads now cut out.

7. Converting Raster features to Polygon (vector) Features

The new Suitable Vegetation layer was then converted from its image-based raster format to a vector or polygon format. Converting to vector allows for easier acreage calculations and the ability to analyze features as individual units instead of all being grouped by their classification (most raster layers have multi-part features meaning all pixels/features with the same attribute are grouped into one features that may have many parts across the work area). With all of the features now being presented as individual features, the number of features is once again at very high. To further clean up the digital "noise", all polygon features under 10 acres are removed from the dataset. In this large landscape, this helps to focus attention on the more substantial areas of suitable vegetation. This is a common practice for landscape models of this scale.

8. Land Ownership Analysis

The final step for this part of the land cover analysis was to overlay the new Suitable Vegetation polygons with land ownership data (U.S. - BLM NSMA). Because it is difficult to fully derive the level or amount of protection from any given property, this data was reclassified into 3 categories, with some general assumptions;

> **a. Federal -** May provide protection & FWS could have some influence.
>
> **b. Tribal -** May provide protection, but FWS may have some/limited influence.
>
> **c. Other -** (local gov't/state gov't/private/undetermined) – Limited to no protection/unknown influence.

This can help provide information on amounts of suitable vegetation that could be protected, and areas for future surveys.

After reclassification, the ownership data were converted to polygon (vector) features, dissolved using the above designations, and "unioned" (GIS process combining multiple layers and maintaining attribution from each layer) together. This provided acreages of the 2 Suitable Vegetation categories for each ownership designation.

Mexico Analysis: Differences from U.S. Analysis

The data processing for Mexico followed the same basic methods used for the U.S. analysis units, with a few minor differences.

The land cover data used to identify suitable vegetation (downloaded from NAEA) had only 15 to 18 different classes, Table A.3 (the LANDFIRE data had up to 93 classes in Arizona). This class system was designed to be used at a hemispheric scale, it does not provide the same detail in the vegetated classes as the LANDFIRE data.

There was no canopy cover/density data available for Mexico. This part of the analysis was not done for Mexico.

There was some "protected lands" data available from the World Database of Protected Areas (WDPA). Though this data provided spatially explicit polygons, there was no information on the actual ownership of these areas or the levels of protection they may provide, limiting its use in the analysis.

To The road network layer for Mexico was created from the land cover data (no usable vector data available). The "Urban/Built-up" classification was extracted from the land cover data, vectorized and buffered by 30 meters (this creates a more uniform data layer). It was then added back into the analysis as its own layer, to be integrated with the land cover data (like with the U.S. areas).

Developing a Terrestrial Intactness Model

To try and address the issue of fragmentation and impact of development, this model was developed to analyze the landscape by reclassifying the LANDFIRE land cover data in a different context, by examining the relative frequency of human development within a defined spatial resolution on that landscape. The land cover types or classes were reclassified/ranked as follows;

1. **Natural/Intact vegetation classes:** These classes were mostly intact woody and herbaceous vegetation classes that have importance to the pygmy-owl.

2. **Natural/Intact vegetation classes, less value:** These classes are intact vegetated classes that have less importance to pygmy-owl.

3. **Disturbed/Introduced/Sparse vegetation classes:** These classes are described as being disturbed, introduced or sparsely vegetated. They represent classes more affected by human intervention.

4. **Developed/Urban vegetated classes:** These are identified as vegetation within or directly associated with human development.

5. **Developed/Urban/Agriculture:** All non-vegetated human development.

100. Vegetation classes unusable by pygmy-owl, but may have an intact condition.

The tables below will list all of the classes and their intactness ranking. These rankings were developed by the pygmy-owl team biologists.

After the land cover classes are reclassified, the road raster layer used in the Suitable Vegetation Layer is added back into this dataset (Cell Statistics, SUM function). This is done to assure the road and developed areas are properly captured providing a more continuous layer. This data is attributed with a “10”. The new intactness layer with the roads data, are now aggregated (ArcMap, Spatial Analyst).

Result and reclassification after Cell Statistics;

Cell Statistics Result	Reclassification (relative: best to worst)
1. Natural/Intact vegetation	1.
2. Natural/Intact vegetation classes, less value	2.
3. Disturbed/Introduced/Sparse vegetation	3.
4. Developed/Urban vegetated classes	4.
5. Developed/Urban/Agriculture	10.
10. Roads	10.
11. Natural/Intact vegetation classes with roads	5.

12. Natural/Intact vegetation classes, less value with roads	6.
13. Disturbed/Introduced/Sparse vegetation with roads	7.
14. Developed/Urban vegetated classes with roads	8.
15. Developed/Urban/Agriculture with roads	10.
100. Unusable	9.
110. Unusable with roads	10.

This reclassification (1-10) creates a relative best (least impact) to worst (most impact/unusable) type of classification. This classification was then aggregated to get an “average” ranking.

The aggregation tool resampled the 30 m x 30 m data to 900 m x 900 m (Factor 30x), with an aggregation technique applying a MEAN function. This new cell size creates a pixel that is now approximately 200 acres in size. This is significant for the pygmy-owl as this approximates the home range size. What this does is looks at the landscape with a “larger window”, averaging the 30m pixels within the new 900m pixels by the 1-10 classification.

For the Mexico analysis units, the same basic principle was applied. The more generalized Mexico land cover classification did not include any kind of disturbed or impacted vegetation classes. So, a slightly different model was applied;

1. Intact/Usable: Vegetation class more important to the pygmy-owl.

2. Intact/Other: Vegetation class less important to the pygmy-owl.

3. Sparse: Barren areas

4. Unusable: Vegetation not used by the pygmy-owl

5. Developed: Developed areas including agriculture.

10. Roads

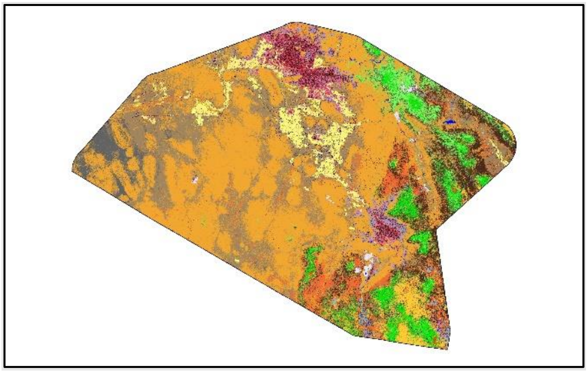
Cell Statistics Result	Reclassification (relative: best to worst)
1. Intact/Usable	1.
2. Intact/Other	2.
3. Sparse	3.
4. Unusable	4.
5. Developed	10.
10. Roads	9.

11. Intact/Usable with roads	5.
12. Intact/Other with roads	6.
13. Sparse with roads	7.
14. Unusable with roads	8.
15. Developed with roads	10.

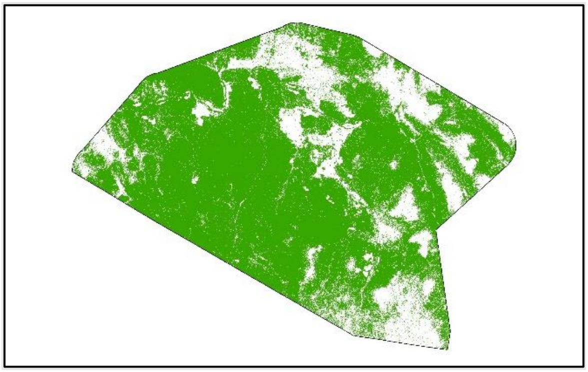
Though this model does not have the detail of the U.S. areas, it still yielded usable result that works with the Suitable Vegetation data,

Analyzing the Suitable Vegetation Layer with the Intactness layer

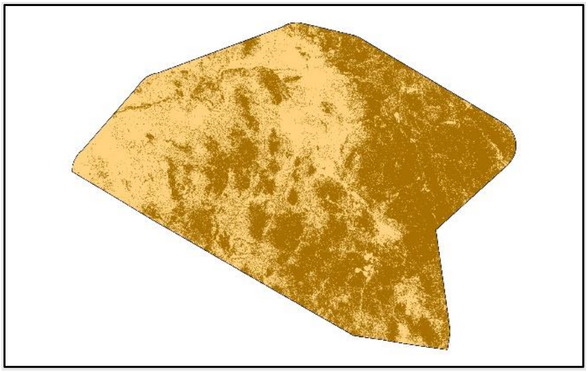
To get a sense of where the least impacted areas of suitable vegetation fell within the analysis units, the new Suitable Vegetation layer and the intactness layer were analyzed together using the Cell Statistics tool. This can be used as a general representation of where the most intact, or least impacted areas of suitable vegetation may be within the analysis units, and provide a landscape-scale representation of development impact or fragmentation.



USGS LANDFIRE EVT Data (93 Classes)

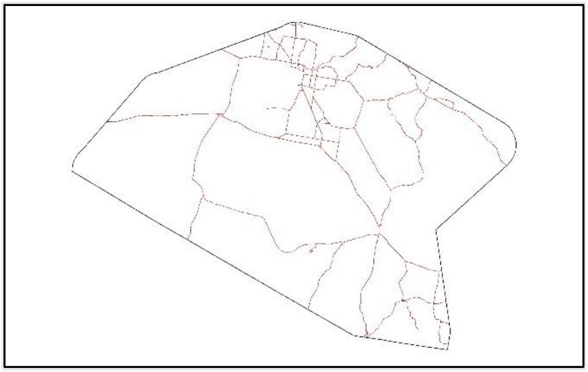


Reclassified LANDFIRE EVT data. Green are all Suitable Vegetation Types.

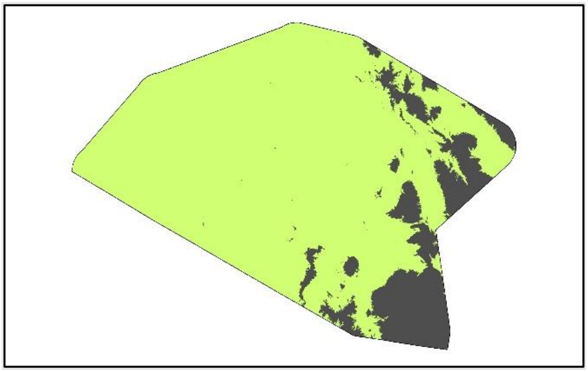


Reclassified LANDFIRE EVC Data. Dark color is canopy cover 20% and greater, light color is canopy cover less that 20%.

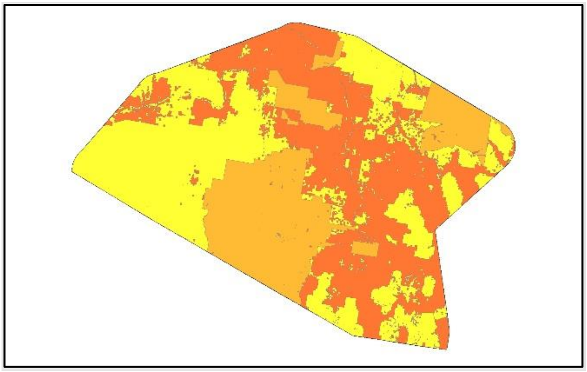
Figure A1-2. Visual Summary of Suitable Vegetation Model



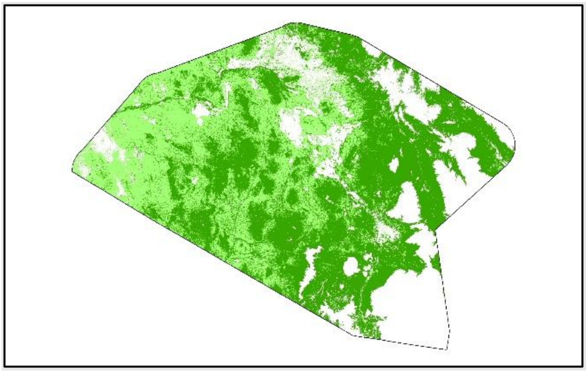
TIGER data primary and secondary road data.



Reclassified USGS DEM Data, Dark color are areas 1220 meters (4000 ft.) or greater, light color are areas under 1220 meters.

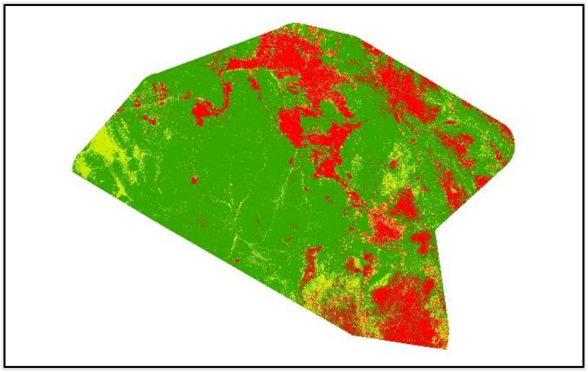


Reclassified BLM Land Ownership data. Light colored areas are Federal, medium color are Tribal, darker are other.



Final result after geoprocessing, darker colored areas are Suitable Vegetation with canopy cover 20% or greater, light color are Suitable Vegetation with canopy cover under 20%.

Figure A1-2. Visual Summary of Suitable Vegetation Model (continued)

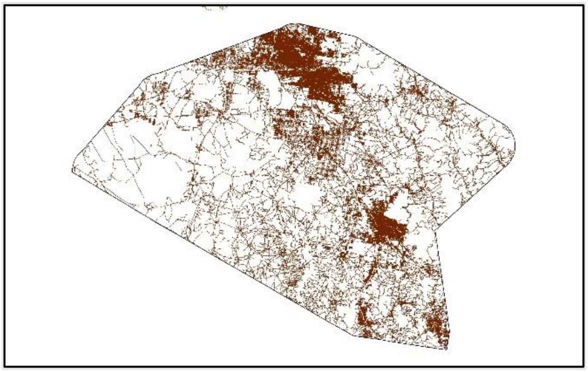


Reclassified LANDFIRE EVT data for intactness model;

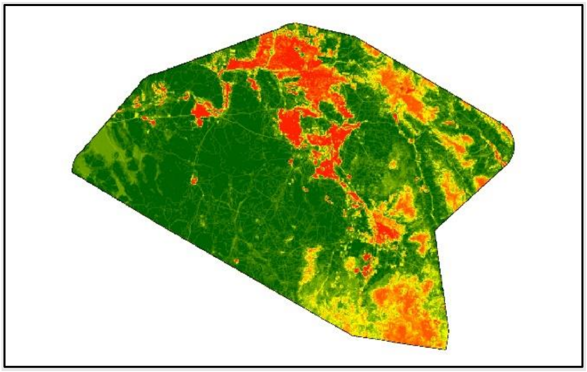
🟩 Intact Vegetation

⇩

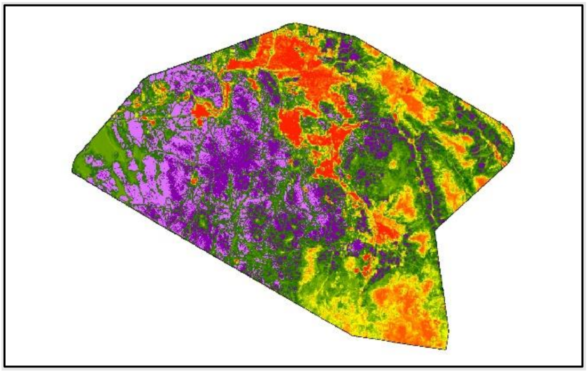
🟥 Developed Areas



TIGER data complete road network.

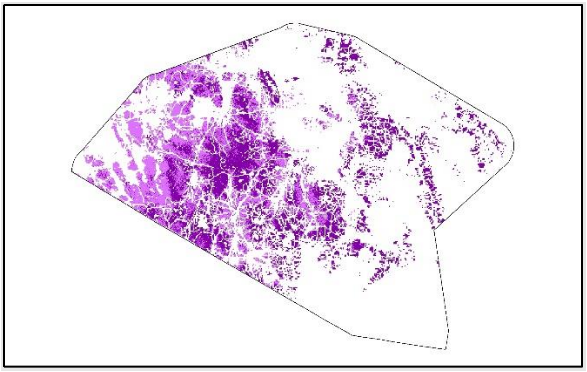


Final Intactness model; LANDFIRE and roads layer combined with Cell Statistics. Data aggregated to 900 sq. m pixel size.



Purple areas represent Suitable Vegetation that intersects intact classification. Darker purple is canopy density 20% or greater, lighter purple is canopy density less than 20%.

Figure A1-3. Visual Summary of Intactness Model



Intact Suitable Vegetation.

Figure A1-3. Visual Summary of Intactness Model (continued)

Table A1-2. Suitable vegetation/protected land cover analysis, by analysis unit, in the United States

	Arizona		Texas	
	Acres	% of WA	Acres	% of WA
Work Area (WA)	17,710,315		5,852,068	
Suitable Veg (<20% canopy cover)	5,279,815	30%	1,495,959	26%
Suitable Veg (>20% canopy cover)	7,879,830	44%	2,186,396	37%
Total Suitable Veg.	13,159,645	74%	3,682,355	63%
Suitable Veg (<20% canopy cover)-Federal	2,605,436	49%	42,456	2%
Suitable Veg (<20% canopy cover)-Tribal	1,308,801	25%	0	0%
Suitable Veg (<20% canopy cover)-Other*	1,359,367	26%	2,103,521	96%
Suitable Veg (<20% canopy cover)-Out**	6,211	0%	40,419	2%
	5,279,815	100%	2,186,396	100%
Suitable Veg (>20% canopy cover)-Federal	2,502,482	32%	23,120	2%
Suitable Veg (>20% canopy cover)-Tribal	2,315,741	29%	0	0%
Suitable Veg (>20% canopy cover)-Other*	3,053,912	39%	1,417,419	95%
Suitable Veg (>20% canopy cover)-Out**	7,695	0%	55,420	4%
	7,879,830	100%	1,495,959	100%

*** Other Ownership = Local Govt/State/Private/Undertermined**

*****The resolution of the Land Ownership data layer is not as detailed as the veg. layer and does not cover the entire veg. layer.***

General Ownership Assumptions:

Federal = May provide more protection, and FWS could have some influence.
Tribal = Probably provide protection, but FWS may have limited influence.
Other = Limited to no protection/influence.

Table A1-3. Suitable vegetation/protected land cover analysis, by analysis unit, in Mexico.

	Northeast Mexico		**Northern Sonora**		**Western Mexico**	
	Acres	% of WA	Acres	% of WA	Acres	% of WA
Work Area (WA)	35,410,630		19,807,496		76,799,819	
Total Suitable Veg.	26,928,630	76%	16,609,246	84%	44,946,927	59%
Suitable Veg.-Protected	1,499,359	4%	1,011,622	5%	3,813,523	5%
Suitable Veg.-Not Protected	25,429,271	72%	15,597,624	79%	41,133,404	54%
Total Suitable Veg.		76%		84%		59%

Table A1-4. Summary of suitable vegetation and intactness analysis for each analysis unit.

Analysis Area	Total Analysis Area Acreage	Total Suitable Vegetation	Suitable Veg. Percent of Analysis Area	Suitable Intact Vegetation	Suitable Intact Veg. Percent of Total Suit. Veg.	Suitable Intact Veg. Percent of Analysis Area
Arizona	17,710,315	13,159,645	74%	4,766,953	36%	27%
Texas	5,852,068	3,682,355	63%	273,344	7%	5%
U.S. Total	23,562,383	16,842,000	71%	5,040,297	30%	21%
Northeast Mexico	35,410,630	26,928,630	76%	6,784,363	25%	19%
Northern Sonora	19,807,496	16,609,246	84%	10,676,153	64%	54%
Western Mexico	76,799,819	44,946,927	59%	19,598,994	44%	26%
Mexico Total	132,017,945	88,484,803	67%	37,059,510	42%	28%
Combined Total	155,580,328	105,326,803	68%	42,099,807	40%	27%

Table A1-5. LANDFIRE Existing Vegetation Types (EVT) within the Arizona analysis unit. Habitat types considered suitable for pygmy-owl are shown in green.

VALUE	EVT_NAME	FWS Designation
7087	Sonora-Mojave Creosotebush-White Bursage Desert Scrub	Suitable Vegetation
7091	Sonoran Mid-Elevation Desert Scrub	Suitable Vegetation
7100	Chihuahuan Mixed Desert and Thornscrub	Suitable Vegetation
7104	Mogollon Chaparral	Suitable Vegetation
7109	Sonoran Paloverde-Mixed Cacti Desert Scrub	Suitable Vegetation
7910	Western Warm Temperate Urban Deciduous Forest	Suitable Vegetation
7914	Western Warm Temperate Urban Shrubland	Suitable Vegetation
7928	Western Warm Temperate Developed Ruderal Shrubland	Suitable Vegetation
9034	North American Warm Desert Riparian Woodland	Suitable Vegetation
9035	North American Warm Desert Lower Montane Riparian Woodland	Suitable Vegetation
9148	North American Warm Desert Cienega	Suitable Vegetation
9152	North American Warm Desert Riparian Mesquite Bosque Woodland	Suitable Vegetation
9310	North American Warm Desert Ruderal & Planted Scrub	Suitable Vegetation
9327	Interior West Ruderal Riparian Forest	Suitable Vegetation
9533	North American Warm Desert Riparian Herbaceous	Suitable Vegetation
9534	North American Warm Desert Riparian Shrubland	Suitable Vegetation
9535	North American Warm Desert Lower Montane Riparian Shrubland	Suitable Vegetation
9652	North American Warm Desert Riparian Mesquite Bosque Shrubland	Suitable Vegetation
9654	North American Warm Desert Wash Shrubland	Suitable Vegetation
9827	Interior West Ruderal Riparian Scrub	Suitable Vegetation
7011	Rocky Mountain Aspen Forest and Woodland	Not Suitable/Developed
7023	Madrean Encinal	Not Suitable/Developed
7024	Madrean Lower Montane Pine-Oak Forest and Woodland	Not Suitable/Developed
7025	Madrean Pinyon-Juniper Woodland	Not Suitable/Developed
7026	Madrean Upper Montane Conifer-Oak Forest and Woodland	Not Suitable/Developed
7051	Southern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest and Woodland	Not Suitable/Developed
7052	Southern Rocky Mountain Mesic Montane Mixed Conifer Forest and Woodland	Not Suitable/Developed
7054	Southern Rocky Mountain Ponderosa Pine Woodland	Not Suitable/Developed
7055	Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	Not Suitable/Developed
7075	Chihuahuan Mixed Salt Desert Scrub	Not Suitable/Developed
7076	Chihuahuan Stabilized Coppice Dune and Sand Flat Scrub	Not Suitable/Developed
7077	Chihuahuan Succulent Desert Scrub	Not Suitable/Developed
7088	Sonora-Mojave Mixed Salt Desert Scrub	Not Suitable/Developed
7090	Sonoran Granite Outcrop Desert Scrub	Not Suitable/Developed
7107	Rocky Mountain Gambel Oak-Mixed Montane Shrubland	Not Suitable/Developed
7108	Sonora-Mojave Semi-Desert Chaparral	Not Suitable/Developed
7116	Madrean Juniper Savanna	Not Suitable/Developed
7117	Southern Rocky Mountain Ponderosa Pine Savanna	Not Suitable/Developed
7121	Apacherian-Chihuahuan Semi-Desert Shrub-Steppe	Not Suitable/Developed

7133	Chihuahuan Sandy Plains Semi-Desert Grassland	Not Suitable/Developed
7145	Rocky Mountain Subalpine-Montane Mesic Meadow	Not Suitable/Developed
7191	Recently Logged-Herb and Grass Cover	Not Suitable/Developed
7192	Recently Logged-Shrub Cover	Not Suitable/Developed
7193	Recently Logged-Tree Cover	Not Suitable/Developed
7195	Recently Burned-Herb and Grass Cover	Not Suitable/Developed
7196	Recently Burned-Shrub Cover	Not Suitable/Developed
7197	Recently Burned-Tree Cover	Not Suitable/Developed
7198	Recently Disturbed Other-Herb and Grass Cover	Not Suitable/Developed
7199	Recently Disturbed Other-Shrub Cover	Not Suitable/Developed
7200	Recently Disturbed Other-Tree Cover	Not Suitable/Developed
7256	Apacherian-Chihuahuan Semi-Desert Grassland	Not Suitable/Developed
7292	Open Water	Not Suitable/Developed
7295	Quarries-Strip Mines-Gravel Pits-Well and Wind Pads	Not Suitable/Developed
7296	Developed-Low Intensity	Not Suitable/Developed
7297	Developed-Medium Intensity	Not Suitable/Developed
7298	Developed-High Intensity	Not Suitable/Developed
7299	Developed-Roads	Not Suitable/Developed
7503	Chihuahuan Loamy Plains Desert Grassland	Not Suitable/Developed
7504	Chihuahuan-Sonoran Desert Bottomland and Swale Grassland	Not Suitable/Developed
7911	Western Warm Temperate Urban Evergreen Forest	Not Suitable/Developed
7912	Western Warm Temperate Urban Mixed Forest	Not Suitable/Developed
7913	Western Warm Temperate Urban Herbaceous	Not Suitable/Developed
7925	Western Warm Temperate Developed Ruderal Deciduous Forest	Not Suitable/Developed
7926	Western Warm Temperate Developed Ruderal Evergreen Forest	Not Suitable/Developed
7927	Western Warm Temperate Developed Ruderal Mixed Forest	Not Suitable/Developed
7929	Western Warm Temperate Developed Ruderal Grassland	Not Suitable/Developed
7945	Western Warm Temperate Developed Ruderal Deciduous Forested Wetland	Not Suitable/Developed
7947	Western Warm Temperate Developed Ruderal Mixed Forested Wetland	Not Suitable/Developed
7948	Western Warm Temperate Developed Ruderal Shrub Wetland	Not Suitable/Developed
7949	Western Warm Temperate Developed Ruderal Herbaceous Wetland	Not Suitable/Developed
7980	Western Warm Temperate Orchard	Not Suitable/Developed
7981	Western Warm Temperate Vineyard	Not Suitable/Developed
7983	Western Warm Temperate Row Crop - Close Grown Crop	Not Suitable/Developed
7984	Western Warm Temperate Row Crop	Not Suitable/Developed
7985	Western Warm Temperate Close Grown Crop	Not Suitable/Developed
7986	Western Warm Temperate Fallow/Idle Cropland	Not Suitable/Developed
7987	Western Warm Temperate Pasture and Hayland	Not Suitable/Developed
7988	Western Warm Temperate Wheat	Not Suitable/Developed
9011	North American Arid West Emergent Marsh	Not Suitable/Developed
9018	Rocky Mountain Cliff Canyon and Massive Bedrock	Not Suitable/Developed

9019	Rocky Mountain Lower Montane-Foothill Riparian Woodland	Not Suitable/Developed
9145	North American Warm Desert Active and Stabilized Dune	Not Suitable/Developed
9146	North American Warm Desert Badland	Not Suitable/Developed
9147	North American Warm Desert Bedrock Cliff and Outcrop	Not Suitable/Developed
9150	North American Warm Desert Pavement	Not Suitable/Developed
9151	North American Warm Desert Playa	Not Suitable/Developed
9153	North American Warm Desert Volcanic Rockland	Not Suitable/Developed
9154	North American Warm Desert Wash Woodland	Not Suitable/Developed
9329	Western North American Ruderal Wet Shrubland	Not Suitable/Developed
9519	Rocky Mountain Lower Montane-Foothill Riparian Shrubland	Not Suitable/Developed
9810	North American Warm Desert Ruderal & Planted Grassland	Not Suitable/Developed
9828	Interior Western North American Temperate Ruderal Grassland	Not Suitable/Developed
9829	Western North American Ruderal Wet Meadow & Marsh	Not Suitable/Developed

Table A1-6. LANDFIRE Existing Vegetation Types (EVT) within the Texas analysis unit. Habitat types considered suitable for pygmy-owl are shown in green.

VALUE	EVT_NAME	FWS Designation
7192	Recently Logged-Shrub Cover	Suitable Vegetation
7196	Recently Burned-Shrub Cover	Suitable Vegetation
7338	Central and South Texas Coastal Fringe Forest and Woodland	Suitable Vegetation
7390	Tamaulipan Mixed Deciduous Thornscrub	Suitable Vegetation
7391	Tamaulipan Mesquite Upland Woodland	Suitable Vegetation
7392	Tamaulipan Calcareous Thornscrub	Suitable Vegetation
7438	Tamaulipan Savanna Grassland	Suitable Vegetation
7467	Tamaulipan Floodplain Woodland	Suitable Vegetation
7474	Tamaulipan Floodplain Shrubland	Suitable Vegetation
7475	Tamaulipan Floodplain Herbaceous	Suitable Vegetation
7476	Tamaulipan Riparian Woodland	Suitable Vegetation
7560	Tamaulipan Mesquite Upland Scrub	Suitable Vegetation
7562	Tamaulipan Riparian Shrubland	Suitable Vegetation
7573	Tamaulipan Riparian Herbaceous	Suitable Vegetation
7911	Western Warm Temperate Urban Evergreen Forest	Suitable Vegetation
7912	Western Warm Temperate Urban Mixed Forest	Suitable Vegetation
7914	Western Warm Temperate Urban Shrubland	Suitable Vegetation
7925	Western Warm Temperate Developed Ruderal Deciduous Forest	Suitable Vegetation
7927	Western Warm Temperate Developed Ruderal Mixed Forest	Suitable Vegetation
7928	Western Warm Temperate Developed Ruderal Shrubland	Suitable Vegetation
7929	Western Warm Temperate Developed Ruderal Grassland	Suitable Vegetation
7987	Western Warm Temperate Pasture and Hayland	Suitable Vegetation
9266	Tamaulipan Closed Depression Wetland Woodland	Suitable Vegetation
9268	Tamaulipan Ramadero	Suitable Vegetation
9270	Tamaulipan Saline Thornscrub	Suitable Vegetation
9323	Southeastern Ruderal Shrubland	Suitable Vegetation
9325	Great Plains Comanchian Ruderal Shrubland	Suitable Vegetation
9766	Tamaulipan Closed Depression Wetland Shrubland	Suitable Vegetation
9823	Southeastern Ruderal Grassland	Suitable Vegetation
9825	Great Plains Comanchian Ruderal Grassland	Suitable Vegetation
7191	Recently Logged-Herb and Grass Cover	Not Suitable/Developed
7193	Recently Logged-Tree Cover	Not Suitable/Developed
7195	Recently Burned-Herb and Grass Cover	Not Suitable/Developed
7197	Recently Burned-Tree Cover	Not Suitable/Developed
7198	Recently Disturbed Other-Herb and Grass Cover	Not Suitable/Developed
7199	Recently Disturbed Other-Shrub Cover	Not Suitable/Developed
7292	Open Water	Not Suitable/Developed
7295	Quarries-Strip Mines-Gravel Pits-Well and Wind Pads	Not Suitable/Developed
7296	Developed-Low Intensity	Not Suitable/Developed

7297	Developed-Medium Intensity	Not Suitable/Developed
7298	Developed-High Intensity	Not Suitable/Developed
7299	Developed-Roads	Not Suitable/Developed
7434	Texas-Louisiana Coastal Prairie	Not Suitable/Developed
7437	Texas Coast Dune and Coastal Grassland	Not Suitable/Developed
7439	Tamaulipan Lomas	Not Suitable/Developed
7486	Texas Saline Coastal Prairie	Not Suitable/Developed
7487	Texas-Louisiana Coastal Prairie Pondshore	Not Suitable/Developed
7500	South Texas Salt and Brackish Tidal Flat	Not Suitable/Developed
7910	Western Warm Temperate Urban Deciduous Forest	Not Suitable/Developed
7913	Western Warm Temperate Urban Herbaceous	Not Suitable/Developed
7945	Western Warm Temperate Developed Ruderal Deciduous Forested Wetland	Not Suitable/Developed
7947	Western Warm Temperate Developed Ruderal Mixed Forested Wetland	Not Suitable/Developed
7948	Western Warm Temperate Developed Ruderal Shrub Wetland	Not Suitable/Developed
7949	Western Warm Temperate Developed Ruderal Herbaceous Wetland	Not Suitable/Developed
7980	Western Warm Temperate Orchard	Not Suitable/Developed
7983	Western Warm Temperate Row Crop - Close Grown Crop	Not Suitable/Developed
7984	Western Warm Temperate Row Crop	Not Suitable/Developed
7985	Western Warm Temperate Close Grown Crop	Not Suitable/Developed
7986	Western Warm Temperate Fallow/Idle Cropland	Not Suitable/Developed
7988	Western Warm Temperate Wheat	Not Suitable/Developed
7989	Western Warm Temperate Aquaculture	Not Suitable/Developed
9068	Central Texas Coastal Prairie Riparian Forest	Not Suitable/Developed
9227	Southeastern Coastal Plain Cliff	Not Suitable/Developed
9228	Southeastern Coastal Plain Interdunal Wetland	Not Suitable/Developed
9273	Texas Coast Beach	Not Suitable/Developed
9274	Texas Coast Fresh and Oligohaline Tidal Marsh	Not Suitable/Developed
9275	Texas Coast Salt and Brackish Tidal Marsh	Not Suitable/Developed
9290	Southeastern Great Plains Cliff	Not Suitable/Developed
9324	Southeastern Ruderal Wet Meadow & Marsh	Not Suitable/Developed
9332	Southeastern Exotic Ruderal Flooded & Swamp Forest	Not Suitable/Developed
9774	Texas Coast Fresh and Oligohaline Tidal Marsh Shrubland	Not Suitable/Developed
9775	Texas Coast Salt and Brackish Tidal Marsh Shrubland	Not Suitable/Developed

Table A1-7. North American Environmental Atlas (NAEA) vegetation types within the Mexico analysis units. Habitat types considered potentially suitable for pygmy-owl are shown in green.

Region	Value	LC Class	FWS Designation
MX NE	1	Temperate or sub-polar needleleaf forest	Not Usable
MX NE	3	Tropical or sub-tropical broadleaf evergreen forest	Suitable Veg.
MX NE	4	Tropical or sub-tropical broadleaf deciduous forest	Suitable Veg.
MX NE	5	Temperate or sub-polar broadleaf deciduous forest	Not Usable
MX NE	6	Mixed Forest	Suitable Veg.
MX NE	7	Tropical or sub-tropical shrubland	Suitable Veg.
MX NE	8	Temperate or sub-polar shrubland	Not Usable
MX NE	9	Tropical or sub-tropical grassland	Suitable Veg.
MX NE	10	Temperate or sub-polar grassland	Not Usable
MX NE	14	Wetland	Not Usable
MX NE	15	Cropland	Suitable Veg.
MX NE	16	Barren Lands	Not Usable
MX NE	17	Urban and Built-up	Suitable Veg.
MX NE	18	Water	Not Usable
N. Son.	1	Temperate or sub-polar needleleaf forest	Not Usable
N. Son.	3	Tropical or sub-tropical broadleaf evergreen forest	Not Usable
N. Son.	4	Tropical or sub-tropical broadleaf deciduous forest	Not Usable
N. Son.	5	Temperate or sub-polar broadleaf deciduous forest	Not Usable
N. Son.	7	Tropical or sub-tropical shrubland	Suitable Veg.
N. Son.	8	Temperate or sub-polar shrubland	Not Usable
N. Son.	9	Tropical or sub-tropical grassland	Suitable Veg.
N. Son.	10	Temperate or sub-polar grassland	Not Usable
N. Son.	14	Wetland	Not Usable
N. Son.	15	Cropland	Suitable Veg.
N. Son.	16	Barren Lands	Not Usable
N. Son.	17	Urban and Built-up	Not Usable
N. Son.	18	Water	Not Usable
MX W	1	Temperate or sub-polar needleleaf forest	Suitable Veg.
MX W	3	Tropical or sub-tropical broadleaf evergreen forest	Suitable Veg.
MX W	4	Tropical or sub-tropical broadleaf deciduous forest	Suitable Veg.
MX W	5	Temperate or sub-polar broadleaf deciduous forest	Suitable Veg.
MX W	6	Mixed Forest	Suitable Veg.
MX W	7	Tropical or sub-tropical shrubland	Suitable Veg.
MX W	8	Temperate or sub-polar shrubland	Not Usable
MX W	9	Tropical or sub-tropical grassland	Suitable Veg.
MX W	10	Temperate or sub-polar grassland	Not Usable
MX W	14	Wetland	Not Usable

MX W	15	Cropland	Suitable Veg.
MX W	16	Barren Lands	Not Usable
MX W	17	Urban and Built-up	Suitable Veg.
MX W	18	Water	Not Usable

Table A1-8. LANDFIRE Existing Vegetation Types (EVT) in the Arizona analysis unit showing habitat value rankings assigned to each vegetation type.

VALUE	EVT_NAME	Rank	Description
7076	Chihuahuan Stabilized Coppice Dune and Sand Flat Scrub	1	Natural/Intact Veg.
7087	Sonora-Mojave Creosotebush-White Bursage Desert Scrub	1	Natural/Intact Veg.
7090	Sonoran Granite Outcrop Desert Scrub	1	Natural/Intact Veg.
7091	Sonoran Mid-Elevation Desert Scrub	1	Natural/Intact Veg.
7100	Chihuahuan Mixed Desert and Thornscrub	1	Natural/Intact Veg.
7104	Mogollon Chaparral	1	Natural/Intact Veg.
7108	Sonora-Mojave Semi-Desert Chaparral	1	Natural/Intact Veg.
7109	Sonoran Paloverde-Mixed Cacti Desert Scrub	1	Natural/Intact Veg.
9019	Rocky Mountain Lower Montane-Foothill Riparian Woodland	1	Natural/Intact Veg.
9034	North American Warm Desert Riparian Woodland	1	Natural/Intact Veg.
9035	North American Warm Desert Lower Montane Riparian Woodland	1	Natural/Intact Veg.
9152	North American Warm Desert Riparian Mesquite Bosque Woodland	1	Natural/Intact Veg.
9154	North American Warm Desert Wash Woodland	1	Natural/Intact Veg.
9519	Rocky Mountain Lower Montane-Foothill Riparian Shrubland	1	Natural/Intact Veg.
9534	North American Warm Desert Riparian Shrubland	1	Natural/Intact Veg.
9535	North American Warm Desert Lower Montane Riparian Shrubland	1	Natural/Intact Veg.
9652	North American Warm Desert Riparian Mesquite Bosque Shrubland	1	Natural/Intact Veg.
9654	North American Warm Desert Wash Shrubland	1	Natural/Intact Veg.
9148	North American Warm Desert Cienega	2	Natural/Intact Veg., less value
9533	North American Warm Desert Riparian Herbaceous	2	Natural/Intact Veg., less value
7195	Recently Burned-Herb and Grass Cover	3	Disturbed/Introduced/Sparse Veg.
7196	Recently Burned-Shrub Cover	3	Disturbed/Introduced/Sparse Veg.
7197	Recently Burned-Tree Cover	3	Disturbed/Introduced/Sparse Veg.
7198	Recently Disturbed Other-Herb and Grass Cover	3	Disturbed/Introduced/Sparse Veg.
7199	Recently Disturbed Other-Shrub Cover	3	Disturbed/Introduced/Sparse Veg.
7200	Recently Disturbed Other-Tree Cover	3	Disturbed/Introduced/Sparse Veg.
9018	Rocky Mountain Cliff Canyon and Massive Bedrock	3	Disturbed/Introduced/Sparse Veg.
9145	North American Warm Desert Active and Stabilized Dune	3	Disturbed/Introduced/Sparse Veg.
9146	North American Warm Desert Badland	3	Disturbed/Introduced/Sparse Veg.
9147	North American Warm Desert Bedrock Cliff and Outcrop	3	Disturbed/Introduced/Sparse Veg.
9150	North American Warm Desert Pavement	3	Disturbed/Introduced/Sparse Veg.
9151	North American Warm Desert Playa	3	Disturbed/Introduced/Sparse Veg.
9153	North American Warm Desert Volcanic Rockland	3	Disturbed/Introduced/Sparse Veg.
9310	North American Warm Desert Ruderal & Planted Scrub	3	Disturbed/Introduced/Sparse Veg.
9327	Interior West Ruderal Riparian Forest	3	Disturbed/Introduced/Sparse Veg.
9329	Western North American Ruderal Wet Shrubland	3	Disturbed/Introduced/Sparse Veg.
9810	North American Warm Desert Ruderal & Planted Grassland	3	Disturbed/Introduced/Sparse Veg.
9827	Interior West Ruderal Riparian Scrub	3	Disturbed/Introduced/Sparse Veg.
9828	Interior Western North American Temperate Ruderal Grassland	3	Disturbed/Introduced/Sparse Veg.

9829	Western North American Ruderal Wet Meadow & Marsh	3	Disturbed/Introduced/Sparse Veg.
7910	Western Warm Temperate Urban Deciduous Forest	4	Developed/Urban Veg.
7911	Western Warm Temperate Urban Evergreen Forest	4	Developed/Urban Veg.
7912	Western Warm Temperate Urban Mixed Forest	4	Developed/Urban Veg.
7913	Western Warm Temperate Urban Herbaceous	4	Developed/Urban Veg.
7914	Western Warm Temperate Urban Shrubland	4	Developed/Urban Veg.
7925	Western Warm Temperate Developed Ruderal Deciduous Forest	4	Developed/Urban Veg.
7926	Western Warm Temperate Developed Ruderal Evergreen Forest	4	Developed/Urban Veg.
7927	Western Warm Temperate Developed Ruderal Mixed Forest	4	Developed/Urban Veg.
7928	Western Warm Temperate Developed Ruderal Shrubland	4	Developed/Urban Veg.
7929	Western Warm Temperate Developed Ruderal Grassland	4	Developed/Urban Veg.
7945	Western Warm Temperate Developed Ruderal Deciduous Forested Wetland	4	Developed/Urban Veg.
7947	Western Warm Temperate Developed Ruderal Mixed Forested Wetland	4	Developed/Urban Veg.
7948	Western Warm Temperate Developed Ruderal Shrub Wetland	4	Developed/Urban Veg.
7949	Western Warm Temperate Developed Ruderal Herbaceous Wetland	4	Developed/Urban Veg.
7295	Quarries-Strip Mines-Gravel Pits-Well and Wind Pads	5	Developed/Urban/Agriculture
7296	Developed-Low Intensity	5	Developed/Urban/Agriculture
7297	Developed-Medium Intensity	5	Developed/Urban/Agriculture
7298	Developed-High Intensity	5	Developed/Urban/Agriculture
7299	Developed-Roads	5	Developed/Urban/Agriculture
7980	Western Warm Temperate Orchard	5	Developed/Urban/Agriculture
7981	Western Warm Temperate Vineyard	5	Developed/Urban/Agriculture
7983	Western Warm Temperate Row Crop - Close Grown Crop	5	Developed/Urban/Agriculture
7984	Western Warm Temperate Row Crop	5	Developed/Urban/Agriculture
7985	Western Warm Temperate Close Grown Crop	5	Developed/Urban/Agriculture
7986	Western Warm Temperate Fallow/Idle Cropland	5	Developed/Urban/Agriculture
7987	Western Warm Temperate Pasture and Hayland	5	Developed/Urban/Agriculture
7988	Western Warm Temperate Wheat	5	Developed/Urban/Agriculture
7011	Rocky Mountain Aspen Forest and Woodland	100	Veg. Class Unusable by pygmy-owl
7023	Madrean Encinal	100	Veg. Class Unusable by pygmy-owl
7024	Madrean Lower Montane Pine-Oak Forest and Woodland	100	Veg. Class Unusable by pygmy-owl
7025	Madrean Pinyon-Juniper Woodland	100	Veg. Class Unusable by pygmy-owl
7026	Madrean Upper Montane Conifer-Oak Forest and Woodland	100	Veg. Class Unusable by pygmy-owl
7051	Southern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest and Woodland	100	Veg. Class Unusable by pygmy-owl
7052	Southern Rocky Mountain Mesic Montane Mixed Conifer Forest and Woodland	100	Veg. Class Unusable by pygmy-owl
7054	Southern Rocky Mountain Ponderosa Pine Woodland	100	Veg. Class Unusable by pygmy-owl
7055	Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	100	Veg. Class Unusable by pygmy-owl
7075	Chihuahuan Mixed Salt Desert Scrub	100	Veg. Class Unusable by pygmy-owl
7077	Chihuahuan Succulent Desert Scrub	100	Veg. Class Unusable by pygmy-owl
7088	Sonora-Mojave Mixed Salt Desert Scrub	100	Veg. Class Unusable by pygmy-owl
7107	Rocky Mountain Gambel Oak-Mixed Montane Shrubland	100	Veg. Class Unusable by pygmy-owl

7116	Madrean Juniper Savanna	100	Veg. Class Unusable by pygmy-owl
7117	Southern Rocky Mountain Ponderosa Pine Savanna	100	Veg. Class Unusable by pygmy-owl
7121	Apacherian-Chihuahuan Semi-Desert Shrub-Steppe	100	Veg. Class Unusable by pygmy-owl
7133	Chihuahuan Sandy Plains Semi-Desert Grassland	100	Veg. Class Unusable by pygmy-owl
7145	Rocky Mountain Subalpine-Montane Mesic Meadow	100	Veg. Class Unusable by pygmy-owl
7256	Apacherian-Chihuahuan Semi-Desert Grassland	100	Veg. Class Unusable by pygmy-owl
7503	Chihuahuan Loamy Plains Desert Grassland	100	Veg. Class Unusable by pygmy-owl
7292	Open Water	100	Veg. Class Unusable by pygmy-owl
7504	Chihuahuan-Sonoran Desert Bottomland and Swale Grassland	100	Veg. Class Unusable by pygmy-owl
9011	North American Arid West Emergent Marsh	100	Veg. Class Unusable by pygmy-owl
7191	Recently Logged-Herb and Grass Cover	100	Veg. Class Unusable by pygmy-owl
7192	Recently Logged-Shrub Cover	100	Veg. Class Unusable by pygmy-owl
7193	Recently Logged-Tree Cover	100	Veg. Class Unusable by pygmy-owl

Table A1-9. LANDFIRE Existing Vegetation Types (EVT) in the Texas analysis unit showing habitat value rankings assigned to each vegetation type.

VALUE	EVT_NAME	Rank	Description
7338	Central and South Texas Coastal Fringe Forest and Woodland	1	Natural/Intact Veg.
7390	Tamaulipan Mixed Deciduous Thornscrub	1	Natural/Intact Veg.
7391	Tamaulipan Mesquite Upland Woodland	1	Natural/Intact Veg.
7392	Tamaulipan Calcareous Thornscrub	1	Natural/Intact Veg.
7434	Texas-Louisiana Coastal Prairie	1	Natural/Intact Veg.
7438	Tamaulipan Savanna Grassland	1	Natural/Intact Veg.
7467	Tamaulipan Floodplain Woodland	1	Natural/Intact Veg.
7474	Tamaulipan Floodplain Shrubland	1	Natural/Intact Veg.
7475	Tamaulipan Floodplain Herbaceous	1	Natural/Intact Veg.
7476	Tamaulipan Riparian Woodland	1	Natural/Intact Veg.
7487	Texas-Louisiana Coastal Prairie Pondshore	1	Natural/Intact Veg.
7560	Tamaulipan Mesquite Upland Scrub	1	Natural/Intact Veg.
7562	Tamaulipan Riparian Shrubland	1	Natural/Intact Veg.
7573	Tamaulipan Riparian Herbaceous	1	Natural/Intact Veg.
9068	Central Texas Coastal Prairie Riparian Forest	1	Natural/Intact Veg.
9268	Tamaulipan Ramadero	1	Natural/Intact Veg.
9270	Tamaulipan Saline Thornscrub	1	Natural/Intact Veg.
9266	Tamaulipan Closed Depression Wetland Woodland	2	Natural Veg., lower value
9766	Tamaulipan Closed Depression Wetland Shrubland	2	Natural Veg., lower value
7192	Recently Logged-Shrub Cover	3	Disturbed/Introduced/Sparse Veg.
7193	Recently Logged-Tree Cover	3	Disturbed/Introduced/Sparse Veg.
7195	Recently Burned-Herb and Grass Cover	3	Disturbed/Introduced/Sparse Veg.
7196	Recently Burned-Shrub Cover	3	Disturbed/Introduced/Sparse Veg.
7197	Recently Burned-Tree Cover	3	Disturbed/Introduced/Sparse Veg.
7198	Recently Disturbed Other-Herb and Grass Cover	3	Disturbed/Introduced/Sparse Veg.
7199	Recently Disturbed Other-Shrub Cover	3	Disturbed/Introduced/Sparse Veg.
7500	South Texas Salt and Brackish Tidal Flat	3	Disturbed/Introduced/Sparse Veg.
9227	Southeastern Coastal Plain Cliff	3	Disturbed/Introduced/Sparse Veg.
9273	Texas Coast Beach	3	Disturbed/Introduced/Sparse Veg.
9290	Southeastern Great Plains Cliff	3	Disturbed/Introduced/Sparse Veg.
9323	Southeastern Ruderal Shrubland	3	Disturbed/Introduced/Sparse Veg.
9324	Southeastern Ruderal Wet Meadow & Marsh	3	Disturbed/Introduced/Sparse Veg.
9325	Great Plains Comanchian Ruderal Shrubland	3	Disturbed/Introduced/Sparse Veg.
9332	Southeastern Exotic Ruderal Flooded & Swamp Forest	3	Disturbed/Introduced/Sparse Veg.
9823	Southeastern Ruderal Grassland	3	Disturbed/Introduced/Sparse Veg.
9825	Great Plains Comanchian Ruderal Grassland	3	Disturbed/Introduced/Sparse Veg.
7910	Western Warm Temperate Urban Deciduous Forest	4	Developed/Urban Veg.
7911	Western Warm Temperate Urban Evergreen Forest	4	Developed/Urban Veg.
7912	Western Warm Temperate Urban Mixed Forest	4	Developed/Urban Veg.

7913	Western Warm Temperate Urban Herbaceous	4	Developed/Urban Veg.
7914	Western Warm Temperate Urban Shrubland	4	Developed/Urban Veg.
7925	Western Warm Temperate Developed Ruderal Deciduous Forest	4	Developed/Urban Veg.
7927	Western Warm Temperate Developed Ruderal Mixed Forest	4	Developed/Urban Veg.
7928	Western Warm Temperate Developed Ruderal Shrubland	4	Developed/Urban Veg.
7929	Western Warm Temperate Developed Ruderal Grassland	4	Developed/Urban Veg.
7945	Western Warm Temperate Developed Ruderal Deciduous Forested Wetland	4	Developed/Urban Veg.
7947	Western Warm Temperate Developed Ruderal Mixed Forested Wetland	4	Developed/Urban Veg.
7948	Western Warm Temperate Developed Ruderal Shrub Wetland	4	Developed/Urban Veg.
7949	Western Warm Temperate Developed Ruderal Herbaceous Wetland	4	Developed/Urban Veg.
7295	Quarries-Strip Mines-Gravel Pits-Well and Wind Pads	5	Developed/Urban/Agriculture
7296	Developed-Low Intensity	5	Developed/Urban/Agriculture
7297	Developed-Medium Intensity	5	Developed/Urban/Agriculture
7298	Developed-High Intensity	5	Developed/Urban/Agriculture
7299	Developed-Roads	5	Developed/Urban/Agriculture
7980	Western Warm Temperate Orchard	5	Developed/Urban/Agriculture
7983	Western Warm Temperate Row Crop - Close Grown Crop	5	Developed/Urban/Agriculture
7984	Western Warm Temperate Row Crop	5	Developed/Urban/Agriculture
7985	Western Warm Temperate Close Grown Crop	5	Developed/Urban/Agriculture
7986	Western Warm Temperate Fallow/Idle Cropland	5	Developed/Urban/Agriculture
7987	Western Warm Temperate Pasture and Hayland	5	Developed/Urban/Agriculture
7988	Western Warm Temperate Wheat	5	Developed/Urban/Agriculture
7989	Western Warm Temperate Aquaculture	5	Developed/Urban/Agriculture
7191	Recently Logged-Herb and Grass Cover	100	Veg. Class Unusable by pygmy-owl
7292	Open Water	100	Veg. Class Unusable by pygmy-owl
7437	Texas Coast Dune and Coastal Grassland	100	Veg. Class Unusable by pygmy-owl
7439	Tamaulipan Lomas	100	Veg. Class Unusable by pygmy-owl
7486	Texas Saline Coastal Prairie	100	Veg. Class Unusable by pygmy-owl
9228	Southeastern Coastal Plain Interdunal Wetland	100	Veg. Class Unusable by pygmy-owl
9274	Texas Coast Fresh and Oligohaline Tidal Marsh	100	Veg. Class Unusable by pygmy-owl
9275	Texas Coast Salt and Brackish Tidal Marsh	100	Veg. Class Unusable by pygmy-owl
9774	Texas Coast Fresh and Oligohaline Tidal Marsh Shrubland	100	Veg. Class Unusable by pygmy-owl
9775	Texas Coast Salt and Brackish Tidal Marsh Shrubland	100	Veg. Class Unusable by pygmy-owl

Table A1-10. North American Environmental Atlas (NAEA) vegetation types in the Mexico analysis units showing habitat value rankings assigned to each vegetation type.

Region	Value	LC Class	Ranking	Decription
MX NE	1	Temperate or sub-polar needleleaf forest	4	Unusable
MX NE	3	Tropical or sub-tropical broadleaf evergreen forest	1	Intact/Usable
MX NE	4	Tropical or sub-tropical broadleaf deciduous forest	1	Intact/Usable
MX NE	5	Temperate or sub-polar broadleaf deciduous forest	4	Unusable
MX NE	6	Mixed Forest	1	Intact/Usable
MX NE	7	Tropical or sub-tropical shrubland	1	Intact/Usable
MX NE	8	Temperate or sub-polar shrubland	4	Unusable
MX NE	9	Tropical or sub-tropical grassland	2	Intact/Other
MX NE	10	Temperate or sub-polar grassland	4	Unusable
MX NE	14	Wetland	2	Intact/Other
MX NE	15	Cropland	5	Developed
MX NE	16	Barren Lands	3	Sparse
MX NE	17	Urban and Built-up	5	Developed
MX NE	18	Water	4	Unusable
N. Son.	1	Temperate or sub-polar needleleaf forest	4	Unusable
N. Son.	3	Tropical or sub-tropical broadleaf evergreen forest	2	Intact/Other
N. Son.	4	Tropical or sub-tropical broadleaf deciduous forest	2	Intact/Other
N. Son.	5	Temperate or sub-polar broadleaf deciduous forest	4	Unusable
N. Son.	7	Tropical or sub-tropical shrubland	1	Intact/Usable
N. Son.	8	Temperate or sub-polar shrubland	4	Unusable
N. Son.	9	Tropical or sub-tropical grassland	2	Intact/Other
N. Son.	10	Temperate or sub-polar grassland	4	Unusable
N. Son.	14	Wetland	2	Intact/Other
N. Son.	15	Cropland	5	Developed
N. Son.	16	Barren Lands	3	Sparse
N. Son.	17	Urban and Built-up	5	Developed
N. Son.	18	Water	4	Unusable
MX W	1	Temperate or sub-polar needleleaf forest	1	Intact/Usable
MX W	3	Tropical or sub-tropical broadleaf evergreen forest	1	Intact/Usable
MX W	4	Tropical or sub-tropical broadleaf deciduous forest	1	Intact/Usable
MX W	5	Temperate or sub-polar broadleaf deciduous forest	1	Intact/Usable
MX W	6	Mixed Forest	1	Intact/Usable
MX W	7	Tropical or sub-tropical shrubland	1	Intact/Usable
MX W	8	Temperate or sub-polar shrubland	4	Unusable
MX W	9	Tropical or sub-tropical grassland	2	Intact/Other
MX W	10	Temperate or sub-polar grassland	4	Unusable
MX W	14	Wetland	2	Intact/Other

MX W	15	Cropland	5	Developed
MX W	16	Barren Lands	3	Sparse
MX W	17	Urban and Built-up	5	Developed
MX W	18	Water	4	Unusable

APPENDIX 2. CLIMATE VARIABLES CONTRIBUTING TO RESILIENCY

Background

Projections of future climate change can help inform decisions when determining the timing of when a species "is in danger of extinction." Most considerations of climate change in classification decisions hinge upon whether climate change will manifest in changing habitat conditions and how a species is likely to respond to these changes *in the future*. FWS does not have formal guidance on how we approach an analysis of climate change information specifically for purposes of determining the foreseeable future. Instead, we rely upon the concept of the foreseeable future articulated in a 2009 opinion from the Department of the Interior, Office of the Solicitor (M–37021, January 16, 2009). Accordingly, the Service describes the foreseeable future on a case-by-case basis, using the best available data and taking into account considerations such as the species' life-history characteristics, threat-projection timeframes, and environmental variability. Generally, we do not identify the "foreseeable future" in terms of a specific number of years, but instead explain the extent to which we can reasonably determine that both the future threats and the species' responses to those threats are likely or probable (USFWS, 2018).

Overview

Assessments of the impacts, vulnerabilities, and risks from climate change in North America are well studied and documented. A general assessment from the Intergovernmental Panel on Climate Change (IPCC) has addressed some of the following key issues (Romero-Lankao, et al.; 2014, p. 1443);

- North America's climate has changed and some societally relevant changes have been attributed to anthropogenic causes. Recent climate changes and individual extreme events demonstrate both impacts of climate-related stresses and vulnerabilities of exposed systems.

- Many climate stresses that carry risk—particularly related to severe heat, heavy precipitation, and declining snowpack—will increase in frequency and/or severity in North America in the next decades.

- North American ecosystems are under increasing stress from rising temperatures, carbon dioxide (CO2) concentrations, and sea levels, and are particularly vulnerable to climate extremes.

- Water resources are already stressed in many parts of North America due to non-climate change anthropogenic forces, and are expected to become further stressed due to climate change.

General Limitations

The direct effects to the Cactus Ferruginous Pygmy Owl (pygmy-owl) and its habitat are not directly correlated. This information is presented only to provide some relative context for specific projected climatic variables to help guide discussions on future conditions for the pygmy-owl. All the climate data and maps used for the pygmy-owl SSA are publicly available and downloadable from the internet. Models and variables analyzed are accepted standard products that are widely used.

Analysis Area

Climate data and information were collected for the 5 analysis units referenced in the main SSA Report (Arizona, Texas, Northern Sonora, Western Mexico, and NE Mexico).

Data Sources

All climate data were downloaded from the *AdaptWest* website. This dataset was selected for its spatial coverage, spanning all of North America (https://adaptwest.databasin.org/pages/adaptwest-climatena), seeing that the analysis units for the pygmy-owl fell within the United States and Mexico.

This dataset uses data from **PRISM** (current climate) and **WorldClim** (downscaled data from the *Coupled Model Intercomparison Project*, phase 5 - CMIP5).

Data Format and Resolution

All data are in ASCII format. The spatial resolution of the data is 1 KM. The projection is Lambert Conformal Conic (meter). The Datum is WGS 1984.

Datasets Used for Comparison

Three sets of data were looked at for this comparison. The Climate normal dataset, 1981-2010 was used as a base or reference point. The following two Projection *Representative Concentration Pathway* (RPC) datasets were downloaded from the *Atmosphere Ocean General Circulation Model* (AOGCM) ensemble projections (ensemble of 15 CMIP5 AOGCMs), covering two dates in the future;

- RCP 4.5 – 2020’s
- RCP 4.5 – 2050’s
- RCP 8.5 – 2020’s
- RCP 8.5 – 2050’s

Each dataset contains 27 bioclimatic variables;

Bioclimatic variables:

- **MAT: mean annual temperature (°C)**
- MWMT: mean temperature of the warmest month (°C)
- MCMT: mean temperature of the coldest month (°C)
- TD: difference between MCMT and MWMT, as a measure of continentality (°C)
- **MAP: mean annual precipitation (mm)**
- MSP: mean summer (May to Sep) precipitation (mm)

- **AHM: annual heat moisture index, calculated as (MAT+10)/(MAP/1000)**
- **SHM: summer heat moisture index, calculated as MWMT/(MSP/1000)**
- DD_0: degree-days below 0°C (chilling degree days)
- DD5: degree-days above 5°C (growing degree days)
- DD_18: degree-days below 18°C
- DD18: degree-days above 18°C
- NFFD: the number of frost-free days
- bFFP: the julian date on which the frost-free period begins
- eFFP: the julian date on which the frost-free period ends
- FFP: frost-free period
- PAS: precipitation as snow (mm)
- EMT: extreme minimum temperature over 30 years
- EXT: extreme maximum temperature over 30 years
- Eref: Hargreave's reference evaporation
- **CMD: Hargreave's climatic moisture deficit**
- MAR: mean annual solar radiation (MJ m-2 d-1) (excludes areas south of US)
- RH: mean annual relative humidity (%)
- Tave_wt: winter (Dec to Feb) mean temperature (°C)
- Tave_sm: summer (Jun to Aug) mean temperature (°C)
- PPT_wt: winter (Dec to Feb) precipitation (mm)
- PPT_sm: summer (Jun to Aug) precipitation (mm)

The highlighted variables were used in the CFOP SSA Study. They show basic projections/changes in temperature, precipitation, and aridity. These were thought to have the most value for the pygmy-owl.

The methods for assessing changes in these variables is described in Wang *et al.*(2016), and the variables utilized here provide an appropriate representation of expected changes in climate, aridity and drought for dryland environments like those utilized by the pygmy-owl. Mean annual temperature and mean annual precipitation are the most fundamental measures of a climate that influence vegetation types and habitat conditions (Whittaker 1970). In addition to mean annual temperature and precipitation, this analysis utilized three variables specifically focused on quantifying the severity of moisture limitation and exposure to drought stress. The balance between high air temperatures and low moisture availability exert pronounced stress on plants, and extreme hot-dry conditions have been identified as important drivers of how dryland plants will respond to climate change (Adams *et al. 2*009, Seneviratne *et al. 2*010, Williams *et al. 2*013, Breshears *et al. 2*018). Annual heat moisture index (AHM), summer heat moisture index (SHM), and the climatic moisture index (CMD) are all metrics designed to be sensitive to this balance between temperature and moisture. AHM and SHM utilize the ratio of precipitation to temperature to assess hot-dry stress during the entire year and the summer, respectively. CMD provides a complimentary perspective on temperature-moisture conditions by estimating water balance as reference evapotranspiration minus precipitation (Wang *et al. 2*016). In combination, this suite of variables provide a quantitative measure of the direction, magnitude, and general ecological impacts of climate change for pygmy-owl habitat that is consistent with the approach utilized in scientific investigations of ecological drought in the 21st century (Vicente-Serrano *et al. 2*012, Diffenbaugh *et al. 2*017, Bradford *et al. 2*020).

Basic Geoprocessing of the Data

For the most part, climate data will be simply compared from the climate normal set to the 2020 and 2050 datasets (for each RPC, 4.5 & 8.5). These will be displayed in map form.

1. Data downloaded from website. The ASCII files converted to ArcGIS raster files.

2. Raster data were clipped to all analysis units.

3. Raster values were dissolved to get min/max values to be used for map legends.

4. Applying the ESRI ArcGIS 10.7 raster calculator, created rasters showing value difference between base (2010) data and the 2020 and 2050 datasets.

5. Applying ESRI ArcGIS 10.7 raster calculator, created rasters showing percent change between base (2010) data and the 2020 and 2050 datasets.

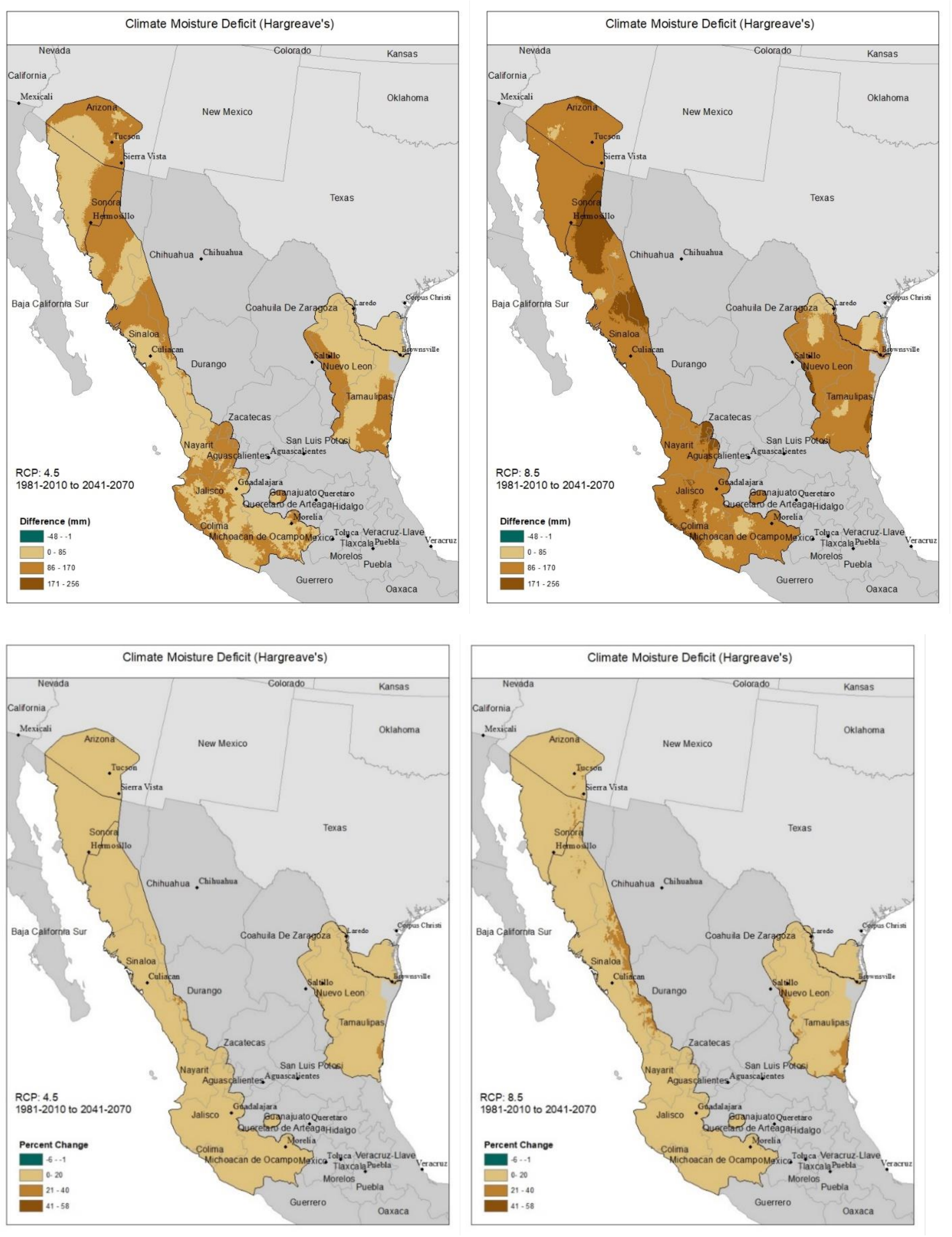


Figure A2-1 Difference (mm) and percent change in Climate Moisture Deficit (CMD) from 1981-2010 and 2041-2070.

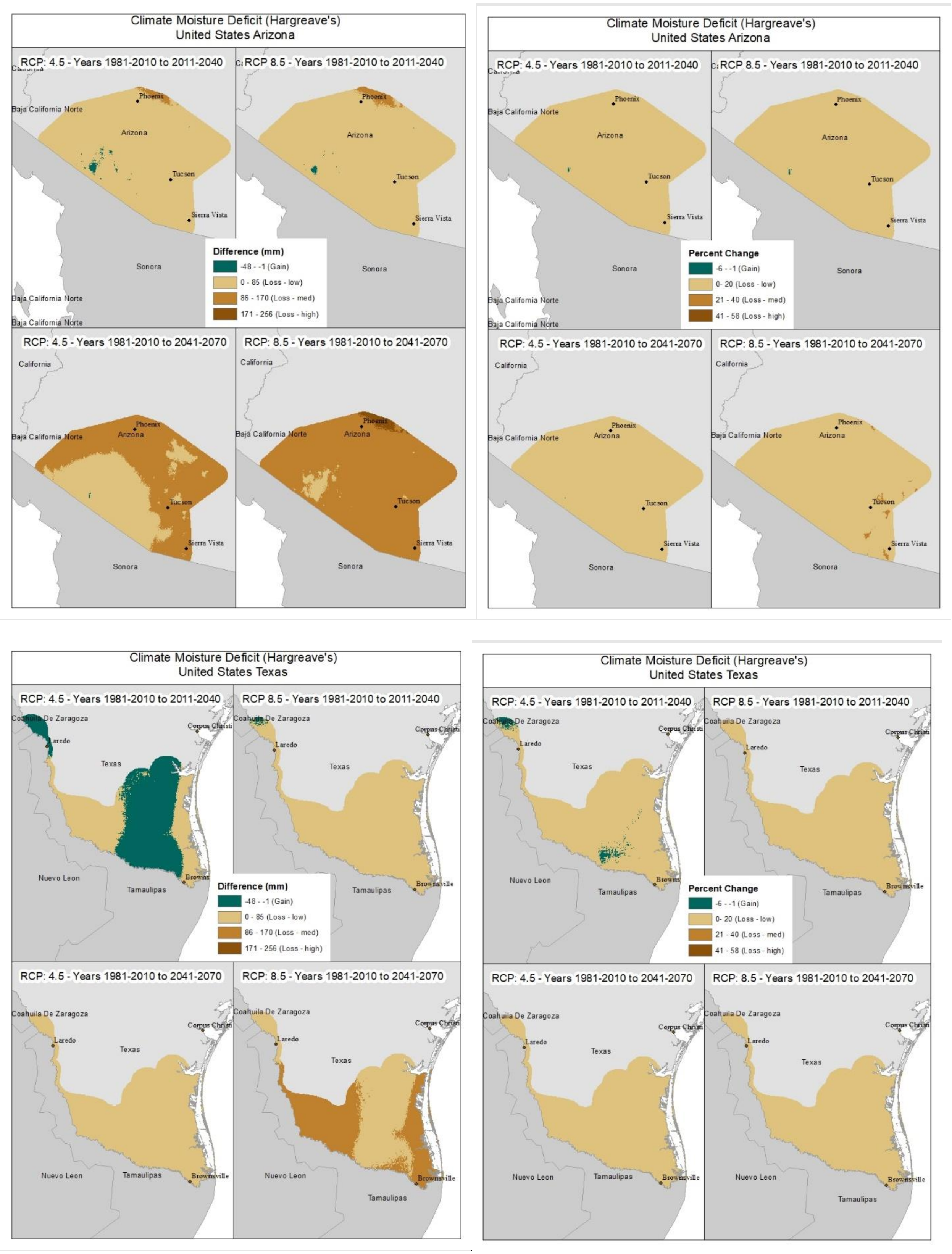


Figure A2-2 Difference (mm) and percent change in Climate Moisture Deficit (CMD) from 1981-2010 and 2041-2070 for the United States Analysis Units (Arizona and Texas).

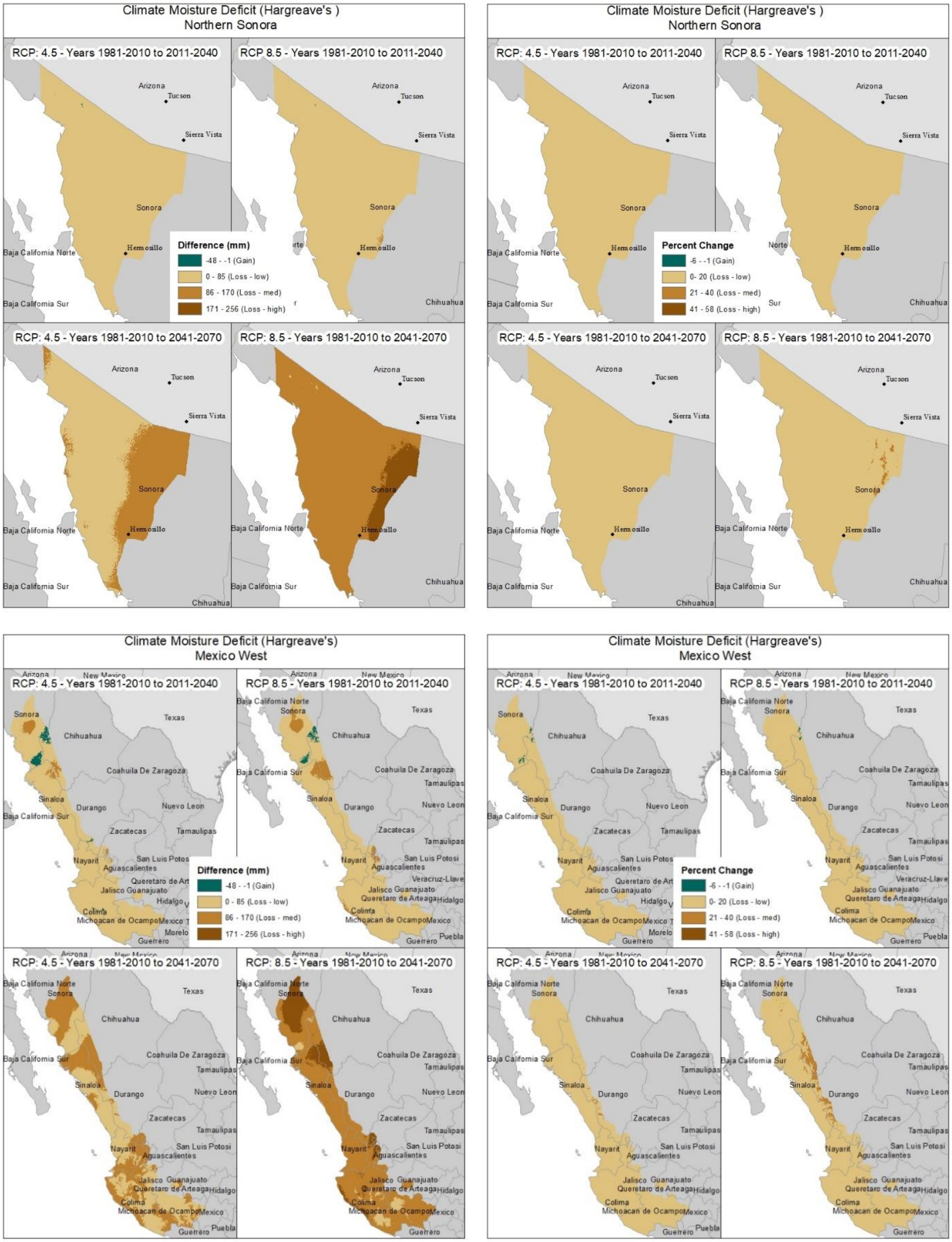


Figure A2-3 Difference (mm) and percent change in Climate Moisture Deficit (CMD) from 1981-2010 and 2041-2070 for the Western Mexico Analysis Units (Northern Sonora and Western Mexico).

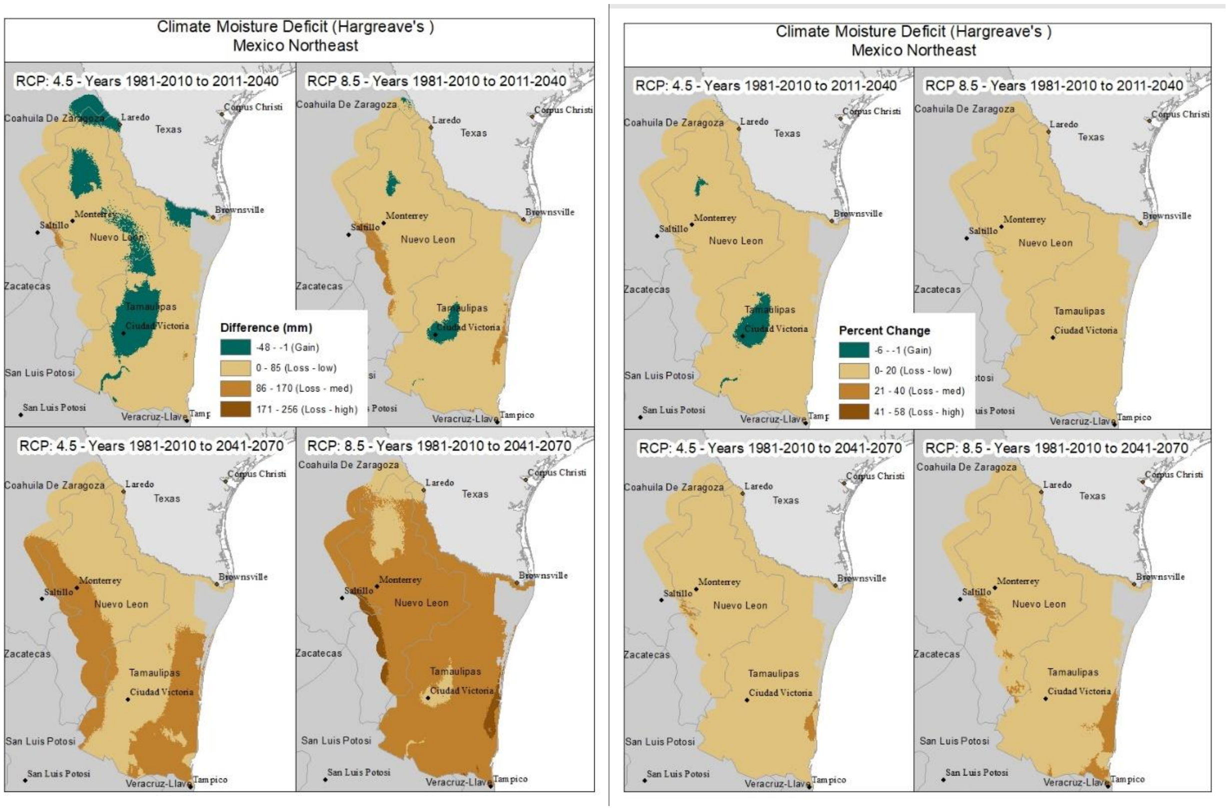


Figure A2-4 Difference (mm) and percent change in Climate Moisture Deficit (CMD) from 1981-2010 and 2041-2070 for the Northeastern Mexico Analysis Unit.

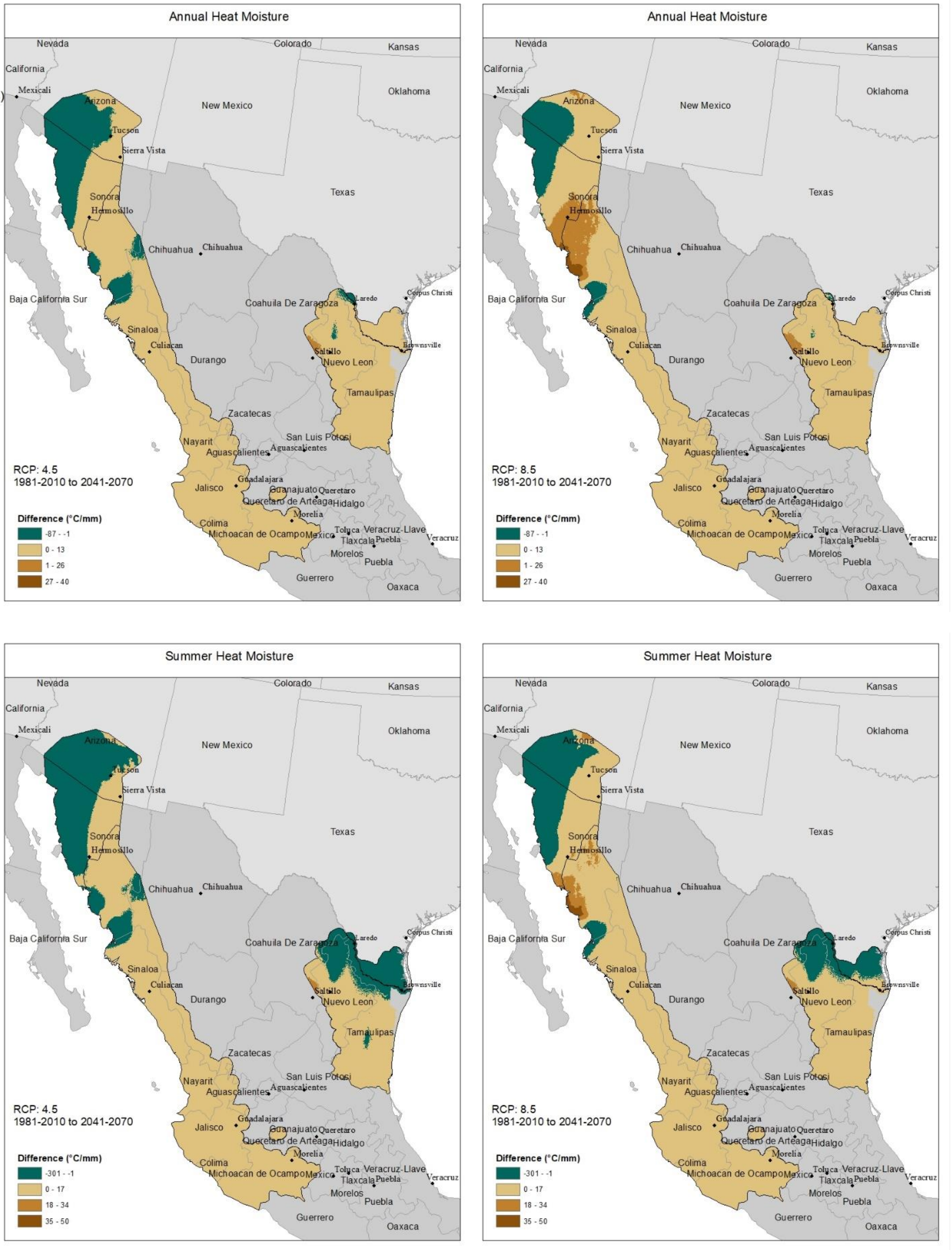


Figure A2-5 Differences (ºC/mm) in annual heat moisture and summer heat moisture indices between 1981-2010 and 2041-2070.

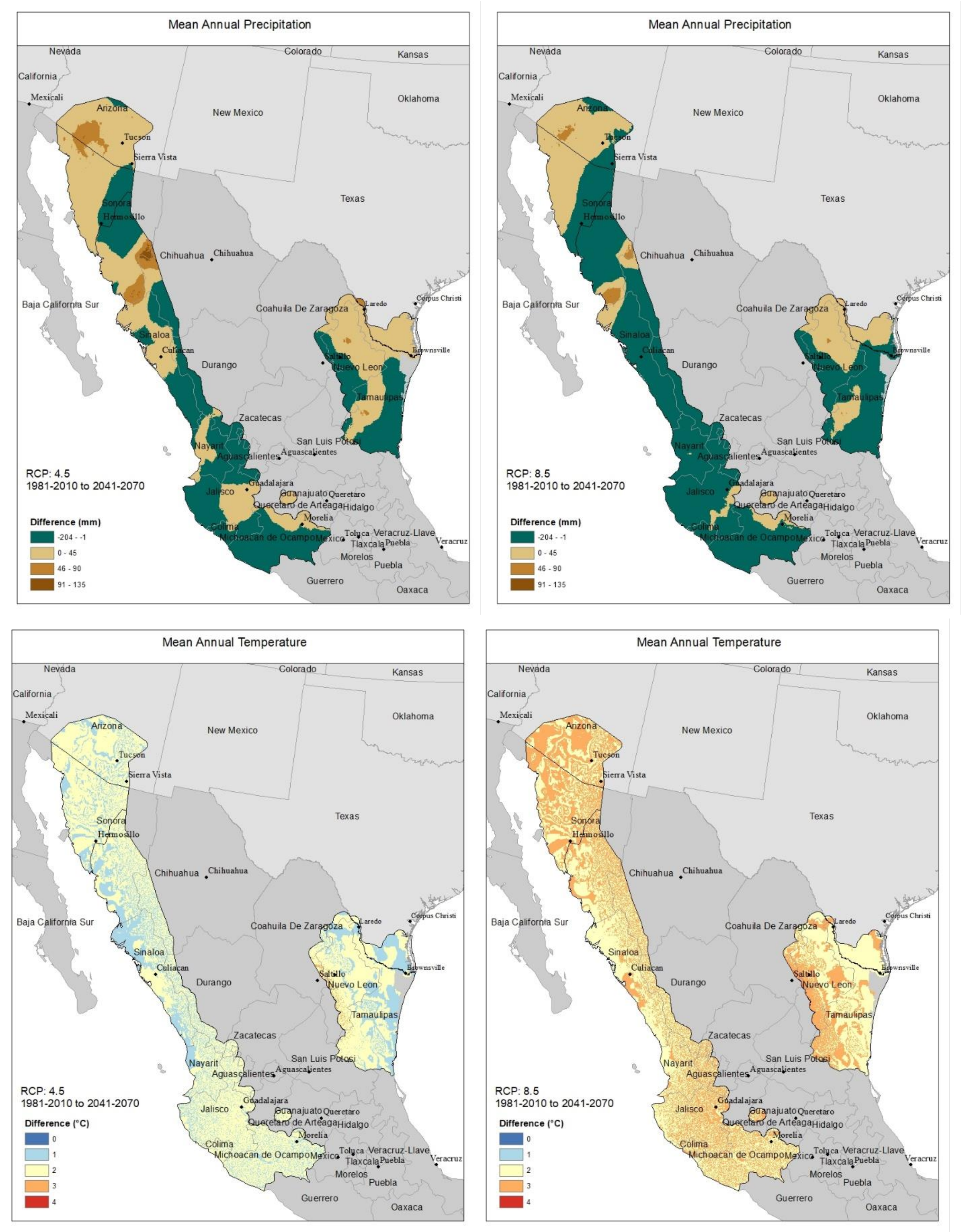


Figure A2-6. Difference in mean annual precipitation (mm) and mean annual temperature (°C) from 1981-2010 and 2041-2070.

References

Adams, H. D., M. Guardiola-Claramonte, G. A. Barron-Gafford, J. C. Villegas, D. D. Breshears, C. B. Zou, P. A. Troch, and T. E. Huxman. 2009. Temperature sensitivity of drought-induced tree mortality portends increased regional die-off under global-change-type drought. Proceedings of the National Academy of Sciences of the United States of America 106:7063-7066.

AdaptWest Project. 2015. Gridded current and projected climate data for North America at 1km resolution, interpolated using the ClimateNA v5.10 software (T. Wang et al., 2015). Available at adaptwest.databasin.org.

Bradford, J. B., D. R. Schlaepfer, W. K. Lauenroth, and K. A. Palmquist. 2020. Robust ecological drought projections for drylands in the 21st century. Global Change Biology 26:3906-3919.

Breshears, D. D., C. J. W. Carroll, M. D. Redmond, A. P. Wion, C. D. Allen, N. S. Cobb, N. Meneses, J. P. Field, L. A. Wilson, D. J. Law, L. M. McCabe, and O. Newell-Bauer. 2018. A Dirty Dozen Ways to Die: Metrics and Modifiers of Mortality Driven by Drought and Warming for a Tree Species. Frontiers in Forests and Global Change 1:4.

Diffenbaugh, N. S., D. Singh, J. S. Mankin, D. E. Horton, D. L. Swain, D. Touma, A. Charland, Y. Liu, M. Haugen, M. Tsiang, and B. Rajaratnam. 2017. Quantifying the influence of global warming on unprecedented extreme climate events. Proceedings of the National Academy of Sciences 114:4881-4886.

Romero-Lankao, P., J.B. Smith, D.J. Davidson, N.S. Diffenbaugh, P.L. Kinney, P. Kirshen, P. Kovacs, and L. Villers Ruiz, 2014: North America. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1439-1498.

Seneviratne, S. I., T. Corti, E. L. Davin, M. Hirschi, E. B. Jaeger, I. Lehner, B. Orlowsky, and A. J. Teuling. 2010. Investigating soil moisture–climate interactions in a changing climate: A review. Earth-Science Reviews 99:125-161.

U.S. Fish and Wildlife Service (USFWS). 2018. Fish and Wildlife Service Consideration of Climate Change information in Endangered Species Act Decisions: 1-2.

Vicente-Serrano, S. M., S. Beguería, J. Lorenzo-Lacruz, J. J. Camarero, J. I. López-Moreno, C. Azorin-Molina, J. Revuelto, E. Morán-Tejeda, and A. Sanchez-Lorenzo. 2012. Performance of Drought Indices for Ecological, Agricultural, and Hydrological Applications. Earth Interactions 16:1-27.

Wang, T., A. Hamann, D. Spittlehouse, and C. Carroll. 2016. Locally Downscaled and Spatially Customizable Climate Data for Historical and Future Periods for North America. PLOS ONE 11:e0156720.

Whittaker, R. H. 1970. Communities and ecosystems. Communities and ecosystems.

Williams, P. A., C. D. Allen, A. K. Macalady, D. Griffin, C. A. Woodhouse, D. M. Meko, T. W. Swetnam, S. A. Rauscher, R. Seager, H. D. Grissino-Mayer, J. S. Dean, E. R. Cook, C. Gangodagamage, M. Cai, and N. G. McDowell. 2013. Temperature as a potent driver of regional forest drought stress and tree mortality. Nature Clim. Change 3:292-297.

APPENDIX 3. NDVI SEASONAL-TREND DECOMPOSITION OUTPUTS

Arizona

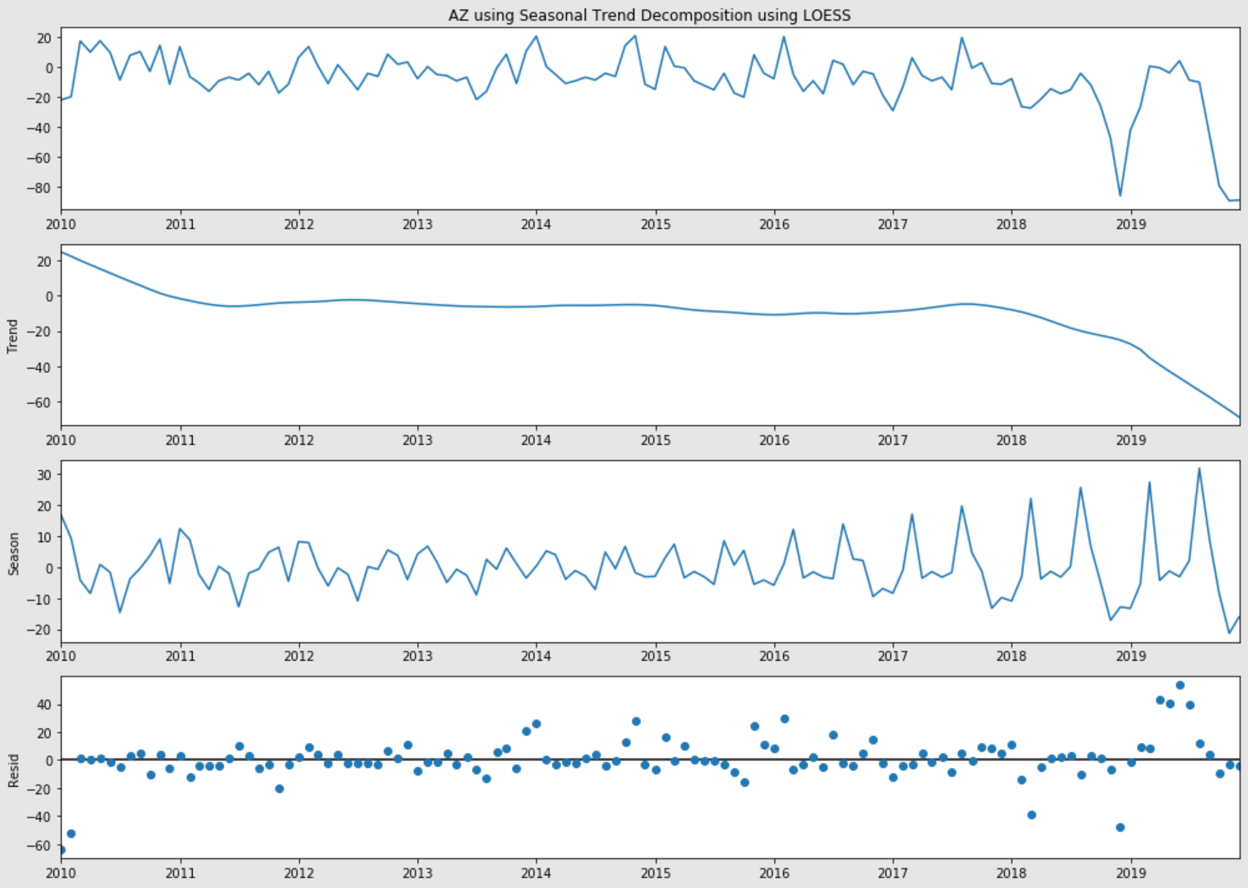


Figure A3-1. Output from our Normalized Difference Vegetation Index (NDVI) analysis for the Arizona analysis unit. Plate 1: NDVI anomalies by month from 2010 through 2019. Plate 2: Seasonal trend decomposition with locally estimated scatterplot smoothing (LOESS) using a 13-month floating window. Plate 3: The variation ascribed to seasonality. Plate 4: Residuals from the model.

Northern Sonora

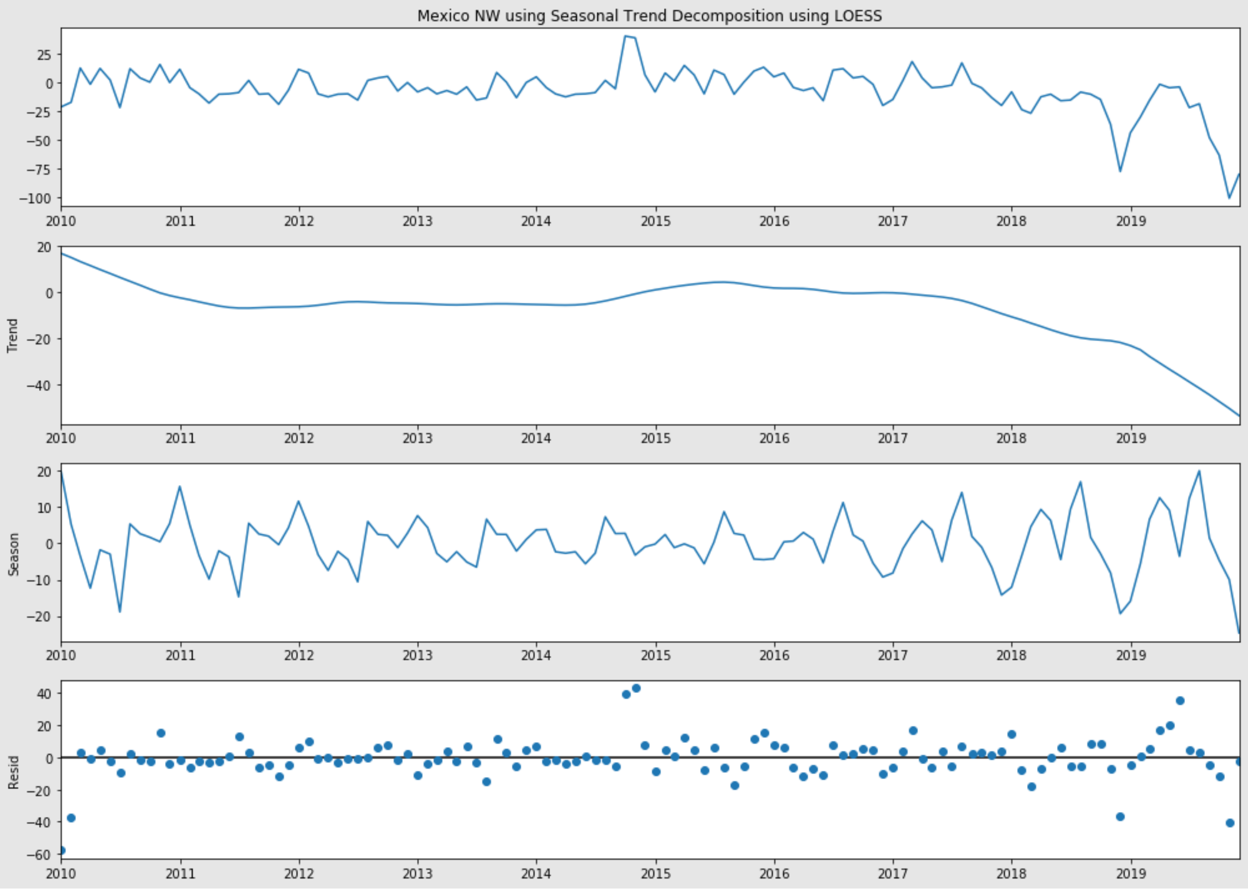


Figure A3-2 Output from our Normalized Difference Vegetation Index (NDVI) analysis for the northern Sonora analysis unit. Plate 1: NDVI anomalies by month from 2010 through 2019. Plate 2: Seasonal trend decomposition with locally estimated scatterplot smoothing (LOESS) using a 13-month floating window. Plate 3: The variation ascribed to seasonality. Plate 4: Residuals from the model.

Western Mexico

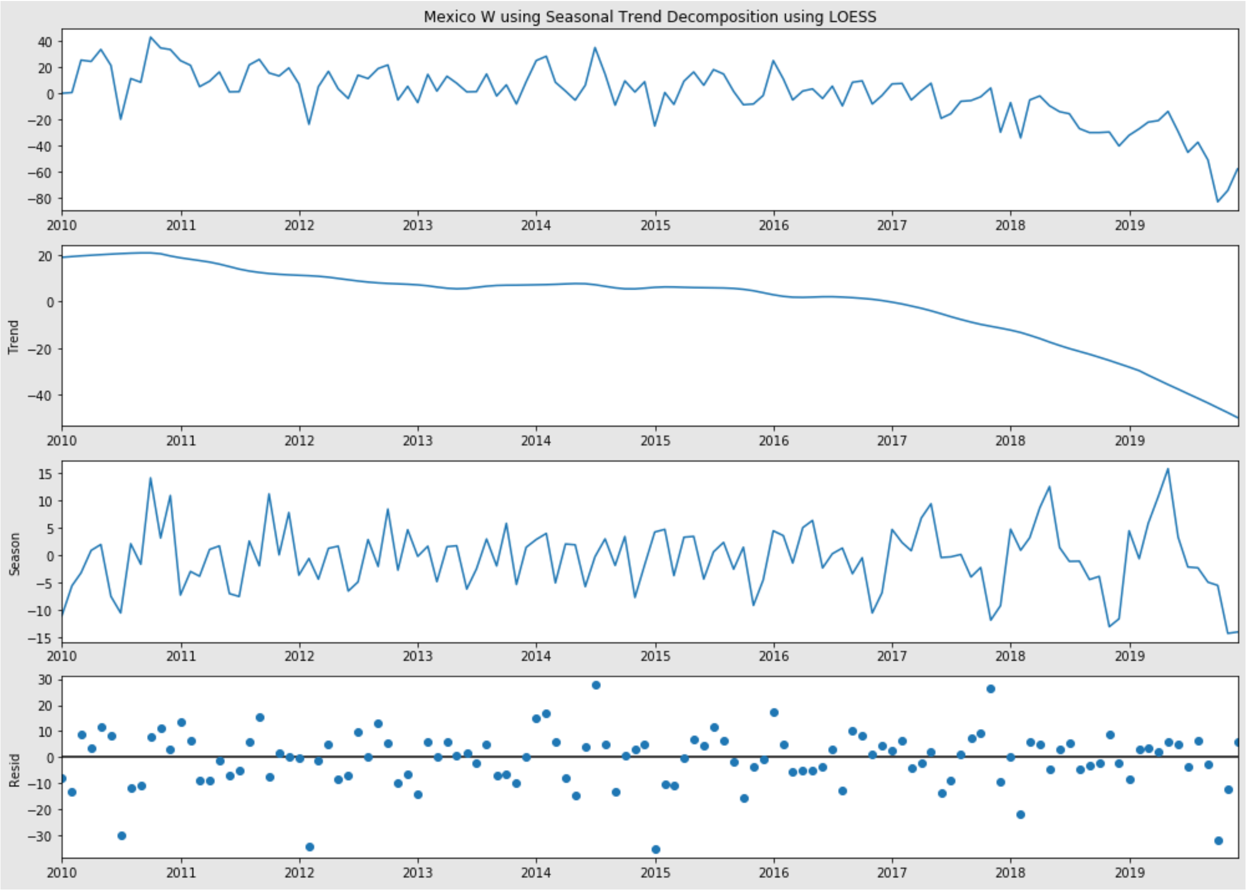


Figure A3-3. Output from our Normalized Difference Vegetation Index (NDVI) analysis for the western Mexico analysis unit. Plate 1: NDVI anomalies by month from 2010 through 2019. Plate 2: Seasonal trend decomposition with locally estimated scatterplot smoothing (LOESS) using a 13-month floating window. Plate 3: The variation ascribed to seasonality. Plate 4: Residuals from the model.

Texas

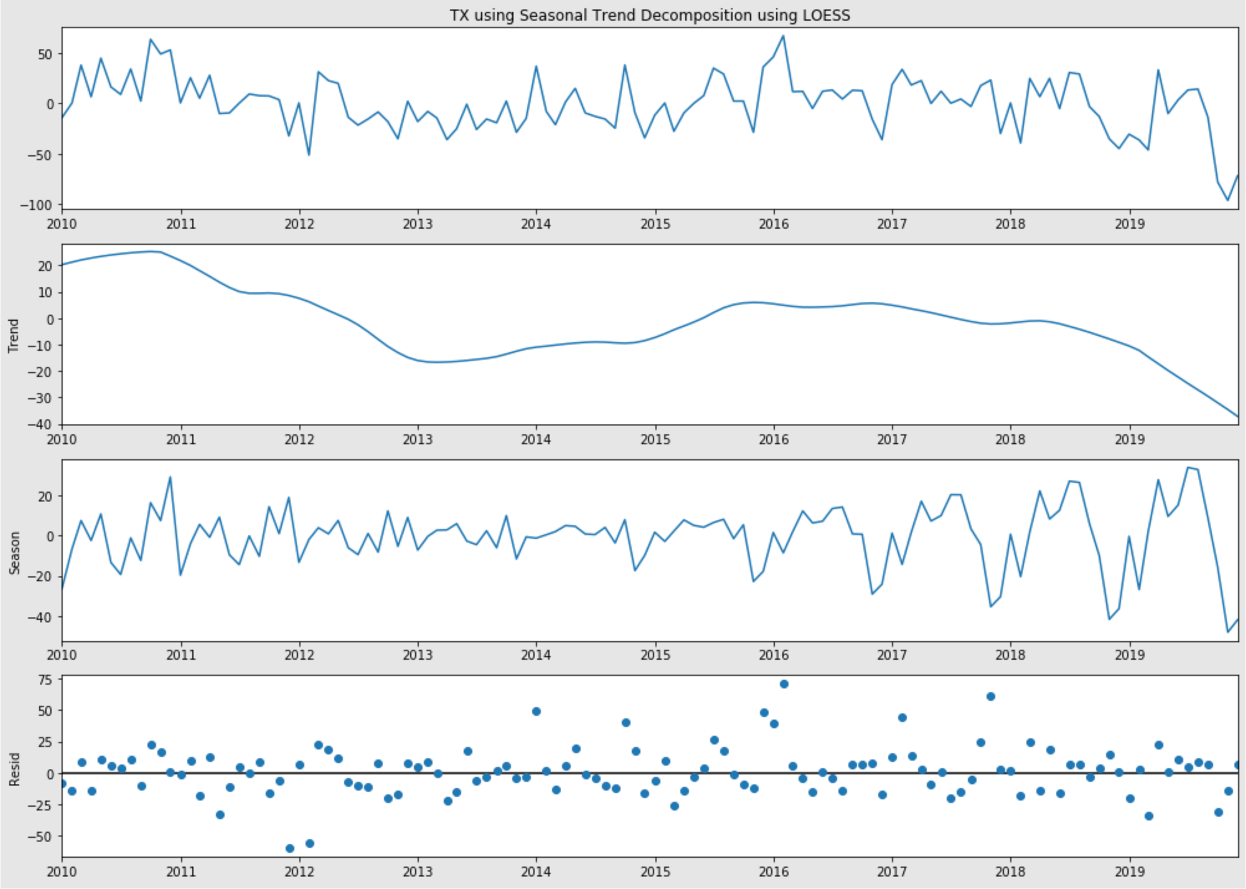


Figure A3-4. Output from our Normalized Difference Vegetation Index (NDVI) analysis for the Texas analysis unit. Plate 1: NDVI anomalies by month from 2010 through 2019. Plate 2: Seasonal trend decomposition with locally estimated scatterplot smoothing (LOESS) using a 13-month floating window. Plate 3: The variation ascribed to seasonality. Plate 4: Residuals from the model.

Northeast Mexico

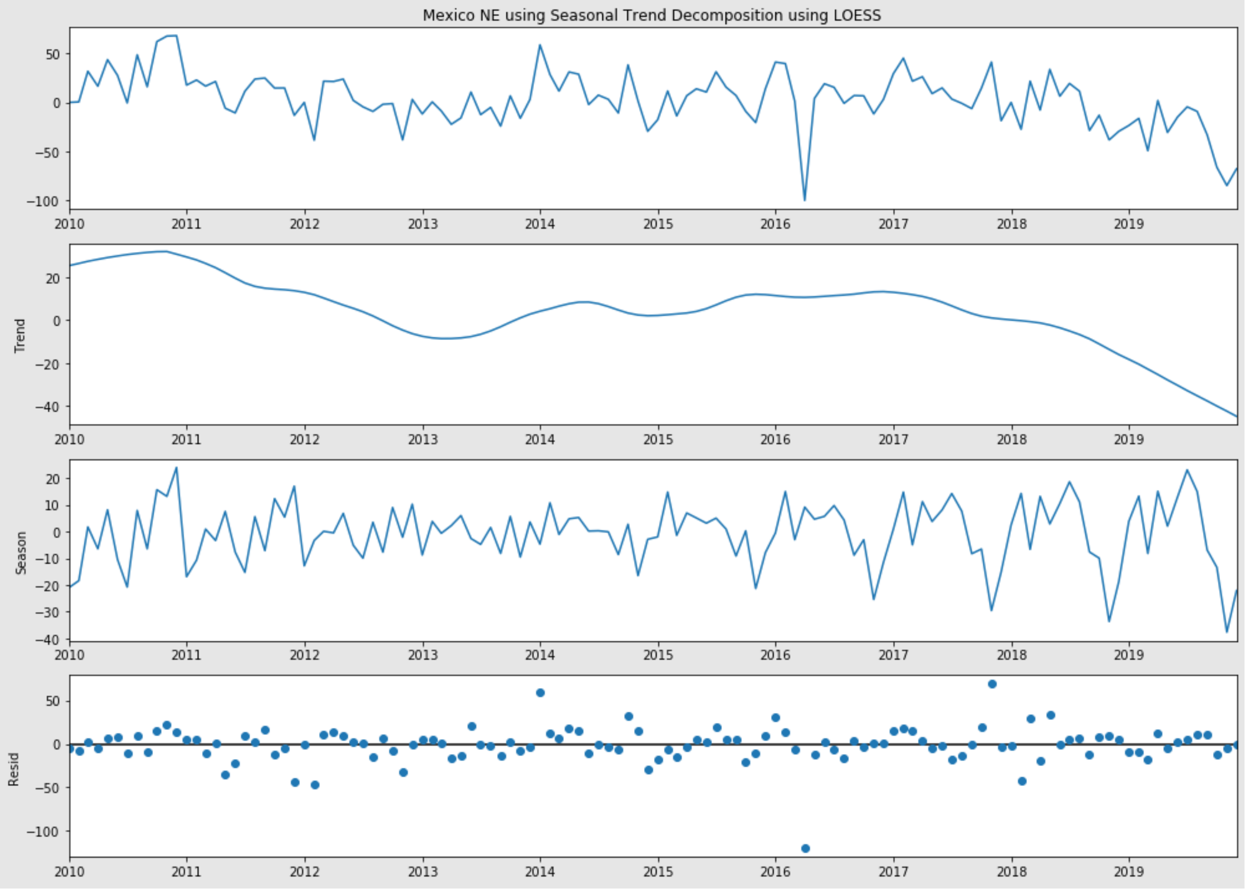


Figure A3-5. Output from our Normalized Difference Vegetation Index (NDVI) analysis for the northeast Mexico analysis unit. Plate 1: NDVI anomalies by month from 2010 through 2019. Plate 2: Seasonal trend decomposition with locally estimated scatterplot smoothing (LOESS) using a 13-month floating window. Plate 3: The variation ascribed to seasonality. Plate 4: Residuals from the model.

APPENDIX 4. VIABILITY UNDER A CONSERVATION PLANNING SCENARIO

Appendix 4 reviews the viability (Resiliency, Redundancy, and Representation) of the cactus ferruginous pygmy-owl under a Conservation Planning scenario (also Table 8.1 in Chapter 8). As with the other three scenarios (Continuation, Increased Effects, and Reduced Effects) discussed in Chapter 8, the output of the Conservation Planning scenario at 30 years and synopses of the effects to the populations over time are included below.

Viability (Resiliency, Redundancy, and Representation)

Scenario 4 – Conservation Planning

Scenario 4 follows a RCP 4.5 climate change scenario, but also considers a range of conservation actions that could be implemented in the next 30 years. If implemented, these actions could lead to improvements in the viability of the pygmy-owl and its habitat in the next 30 years. These positive conservation actions are not exhaustive, but represent the range of potential conservation actions that could contribute to maintaining and enhancing pygmy-owl population resiliency and viability over the next 30 years. These actions include:

- Establish a Pygmy-owl Conservation and Management Group that develops and coordinates implementation of the pygmy-owl conservation strategies. Ensure that this group includes representation from all portions of the pygmy-owls range, especially Mexico. In Mexico, this could be with universities and research institutions (Enríquez 2021, pers. comm.). This group should focus on developing an international effort for pygmy-owl conservation.
- Coordinate ongoing survey and monitoring among all conservation partners in both the United States and Mexico on a regular basis across the range of the pygmy-owl focusing on extending data collection in areas where historical survey and monitoring has occurred, as well as initiating survey and monitoring work in portions of the range where such activities have not historically occurred. These data are key to understanding the status of the pygmy-owl across its range and to assessing the effectiveness of conservation and management activities.
- Captive rearing and release of owls into portions of the pygmy-owl's range: Continue to investigate appropriate methods to improve captive breeding and population augmentation. Investigate the need for and develop implementation strategies for areas outside of Arizona that may be appropriate for population augmentation (Figure A4).
- Investigate the potential use of facilitated dispersal to contribute to population augmentation and population group expansion.
- Conservation planning efforts: Continue the implementation of existing plans such as the Pima County MSCP and the Altar Valley Watershed Management Plan. Investigate the

potential to develop additional conservation plans with municipalities and State, Federal, and Tribal entities.

- Improved land management: Work with municipalities and State, Federal, and Tribal entities to address land management issues in ways that protect key areas of pygmy-owl habitat and maintain habitat connectivity across the landscape.
- Increased nest cavity availability on the landscape: Through work in Sonora, Flesch *et al.*(2015, p. 30) found that the abundance of potential nest cavities had strong positive effects on pygmy-owl resiliency, especially in areas with high woody vegetation cover. Thus, management that promotes the survival and recruitment of saguaros and other nest substrates will benefit pygmy-owls. Additionally, augmenting cavity abundance by erecting nest boxes or translocating saguaros will enhance habitat quality, especially when guided by recommendations regarding preferred nest cavity features and focused in areas that support large, unfragmented woodlands. Investigate the potential to revive nest box studies in Texas and Arizona and evaluate the potential benefit of nest box programs elsewhere within the range of the pygmy-owl.
- Develop land use management plans that address invasive plant species and fire management as conservation tools for the pygmy-owl.
- Implement habitat restoration in areas where fire, drought, extreme weather events, or human activities have reduced or eliminated habitat suitability for pygmy-owls. This is particularly important in both hydro-, meso-, and xeroriparian systems. Improving cover, particularly woodland cover, and restoring core habitats and habitat connectivity should be the focus of restoration efforts.
- Investigate the potential for developing a potential reintroduction program to National Wildlife Refuge tracts or other protected lands along the Rio Grande in South Texas.
- Develop a public education and outreach program to help the public and land managers understand the benefits of pygmy-owl and pygmy-owl habitat conservation. Specific efforts should be made in those portions of the pygmy-owl’s range where the pygmy-owl is currently viable to ensure that pygmy-owl viability is maintained. It is way more ecologically effective to maintain pygmy-owl viability where it exists as opposed to trying to restore viability where it has been lost.

Figure A4-1. Placing a radio transmitter on a pygmy-owl as part of the captive breeding and population augmentation pilot program (Photo credit: Paul Bannick)

A.1 Resiliency

Because many of the factors affecting pygmy-owl population resiliency now and in the future are tied to climate change and extreme weather events, implementing conservation actions cannot effectively address such effects because of the global and long-term solutions needed to address them. In addition, ongoing human activities, including urbanization, are unlikely to be able to be reduced over the next 30 years as a result of conservation activities. Influences on the location of such activities through conservation planning is probably the most likely influence of conservation activities. We cannot create more land as a conservation activity. The best outcome regarding pygmy-owl habitat loss and fragmentation would be to see such impacts to habitat fragmentation be maintained at current levels and in more appropriate locations. Therefore, with regard to the habitat factors under this Conservation Scenario, we will classify them the same as we did for Scenario 1 – the Continuation Scenario. However, the demographic factors assessed under the Conservation Scenario are likely to be influence by the described conservation activities. Our discussion will focus on how these conservation activities, if implemented, can influence the resiliency of pygmy-owls within each of the analysis units.

Arizona

The Arizona analysis unit is the analysis unit most likely to be influenced by enhanced efforts to develop and implement conservation actions outlined in this scenario. There is a foundation of conservation efforts already in place and the groundwork has been laid to improve the effectiveness of these ongoing conservation actions. As a result of the enhanced conservation under this scenario, we anticipate that the demographic factors related to resiliency will be improved for the Arizona analysis unit and both abundance and occupancy will be improved.

In Mexico there are federal, state, or municipal protected Natural Areas. These areas can work well as conservation strategies for the species. There is now a new option for protected areas called Voluntary Conservation Areas (Áreas Destinadas Voluntariamente a la Conservación; ADVA) which are areas for conservation and can be a good conservation strategy(https://www.gob.mx/conanp/articulos/areas-destinadas-voluntariamente-a-la-conservacionparticipacion-social-por-el-ambiente-193042) (Enríquez 2021, p.2).

Northern Sonora

We are unaware of any specific conservation actions that may be developed or enhanced in the Northern Sonora analysis unit under the conservation scenario. Dr. Flesch continues to investigate opportunities for additional resources to continue his long-term monitoring and research activities in the Northern Sonora analysis unit, but those actions are dependent on funding availability. Because the Northern Sonora analysis unit is adjacent to the Arizona analysis unit, any improved resiliency in that analysis unit may result in improved resiliency in the Northern Sonora analysis unit via improved demographic support (interchange of individuals among population groups).

Western Mexico

While we do not currently know of any potential conservation efforts that could occur in the Western Mexico analysis unit under the Conservation scenario, with strong resiliency related to the demographic factors already present, conservation planning efforts that would reduce habitat fragmentation and improve habitat conditions related to maintaining available nest cavities and prey availability, we anticipate that the Western Mexico analysis unit would maintain its moderate resiliency.

Texas

Because habitat intactness occurs currently at a low level in the Texas analysis unit, the conservation action that could potentially improve resiliency in this analysis would be the revival of the nest box project that was initiated by Proudfoot back in the late 1990s and that continued with monitoring through the early 2000s. Placement and maintenance of nest boxes in appropriate areas would enhance resiliency by improving abundance and occupancy across the landscape because of more consistent nest cavity availability. Additionally, planning for restoration of oak motte habitat and working cooperatively with land owners by providing resources and support for such restoration would help overcome conservation limitations occurring because of reduced habitat intactness.

Northeast Mexico

Similar to the Western Mexico analysis unit, we do not currently know of any potential conservation efforts that could occur in the Northeastern Mexico analysis unit under the Conservation scenario. However, with the resiliency related to the demographic factors already present, conservation planning efforts that would reduce habitat fragmentation and improve habitat conditions related to maintaining available nest cavities and prey availability would likely improve the overall resiliency within the Northeastern Mexico analysis unit.

Table A4-1 Resiliency of pygmy-owl populations under Scenario 4, Conservation Planning over the next 30 years.

		Demographic Factors			**Habitat Factors**			
	Analysis Unit	**Abundance**	**Occupancy**	**Evidence of reproduction**	**Vegetation intactness**	**Climate Moisture Deficit**	**Vegetative greenness**	**Future Condition**
Western Population	**Arizona**	Moderate	High	Yes	Low	Moderate	Low	Moderate
	Northern Sonora	Moderate	High	Yes	Moderate	Moderate	Low	Moderate
	Western Mexico	High	Unknown[1]	Yes	Moderate	Moderate	Moderate	High
Eastern Population	**Texas**	Moderate	High	Yes	Low	Moderate	Low	Moderate
	Northeast Mexico	High	Unknown[1]	Yes	Low	Moderate	Moderate	Moderate

[1]. Presumed common due to anecdotal evidence; will assume High condition for these categories for analysis purposes

A.2 Representation

In the Conservation Planning scenario, the current level of representation in the U.S. and Mexico would be maintained for 30 years. All analysis units across the range of the pygmy-owl will continue to be occupied by pygmy-owls, thus maintaining genetic diversity and occupancy within the diverse range of environmental conditions represented by the large overall range of the pygmy-owl. In the Arizona and Texas analysis units, implementation of conservation measures will increase both the numbers of population groups and increase the occupancy likelihood for those population groups. This will improve representation within both the western and eastern populations of the pygmy-owl.

A.3 Redundancy

The eastern and western pygmy-owl populations include multiple analysis units. The Western Population is divided into three analysis units and the Eastern Population contains two analysis units and these analysis units contribute to redundancy. In the Conservation Planning scenario, within 30 years, the number of population groups, as well as the occupancy of those population groups is anticipated to increase in both the Arizona and the Texas analysis units. This will increase the redundancy within those analysis units and strengthen the redundancy within both the eastern and western populations of the pygmy-owl.

In summary, under Scenario 4 – Conservation, we would expect viability of the pygmy-owl to be characterized by similar levels of resiliency and higher levels of representation and redundancy in 30 years than it exhibits under the current condition (Table 6.1 and Sections 6.2 and 6.3). Under the Scenario 4 – Conservation, pygmy-owl population groups within analysis areas are projected to have two analysis units in moderate resiliency condition and three analysis units in low resiliency condition. This is primarily due to overall resiliency being capped at the level of the vegetation intactness. We do anticipate that under this Conservation scenario, representation and redundancy would increase, primarily in Arizona, but also in Texas, thus improving the overall viability of both the eastern and western populations of pygmy-owls. If conservation actions are able to be implemented in Mexico, representation and redundancy will also increase in Mexico and improve viability across the range of the pygmy-owl. Regardless, we anticipate all of the current population groups in all analysis units persisting under the Conservation Scenario.

Figure A4-2. Resiliency of pygmy-owl analysis units under the Conservation Planning scenario.

APPENDIX 5. SUMMARY OF FACTORS AFFECTING PYGMY-OWL VIABILITY BY ANALYSIS UNIT

Table A5-111. Factors affecting pygmy-owl viability in the Arizona analysis unit.

Influences on Viability	**Current Status**	**Trend of Effects**
Invasive Species	Extensive distributions	Increasing
Conservation Actions	Some ongoing (captive breeding, surveys, monitoring, conservation plans)	Stable
Climate Change	Current impacts to temperatures, precipitation, and seasonality influencing fire, invasive species, erosion, and moisture/water availability	Increasing
Urbanization	Residential and commercial development continue in pygmy-owl habitat	Increasing
Agriculture/Wood Harvesting	Limited effects to pygmy-owl habitat, but agriculture in Avra Valley causing some fragmentation. Mesquite control contributing to some fragmentation in Altar Valley	Increasing
Improper Livestock Grazing	Livestock grazing occurs in much of the pygmy-owls habitat in Arizona, but effects to habitat are limited to small areas of improper grazing.	Stable
Human activities and disturbance	Impacts from birding recently becoming an issue in certain parts of AZ. Research is ongoing in AZ with associated impacts. Recreation activities are increasing.	Increasing
Disease and Predation	Ectoparasites have been documented on pygmy-owls and in nest cavities. Screech owl predation is thought to be a contributor to pygmy-owl mortality.	Stable
Small population size	The number of pygmy-owls in this analysis unit is ly small and have low genetic diversity.	Increasing
Inadequacy of existing regulations	Protected under Migratory Bird Treaty Act and State Regulations, however, these regulations do not address the loss and fragmentation of habitat.	Increasing
Border Issues	Cross-border traffic and interdiction result in impacts to pygmy-owl habitat. Recent construction of over 400 miles of border wall in AZ present a potential impediment to pygmy-owl movements across the border.	Increasing in general. Human movement and trash have decreased and is limited mostly to drug traffic now. Interdiction efforts are increasing.

Table A5-212. Factors affecting pygmy-owl viability in the Northern Sonora analysis unit.

Influences on Viability	**Current Status**	**Trend of Effects**
Invasive Species	Extensive distributions	Increasing
Conservation Actions	None specific to pygmy-owls being implemented	Stable
Climate Change	Current impacts to temperatures, precipitation, and seasonality influencing fire, invasive species, erosion, and moisture/water availability	Increasing
Urbanization	Urban development mainly in proximity to Hermosillo	Increasing
Agriculture/Wood Harvesting	Some areas causing substantial fragmentation as a result of both agriculture and wood harvesting, including charcoal production.	Increasing
Improper Livestock Grazing	Little regulation of grazing. Regular occurrence of improper grazing.	Increasing
Border Issues	Cross-border traffic, staging, and cartel activities result in impacts to pygmy-owl owl habitat. Recent construction of over 400 miles of border wall in AZ present a potential impediment to pygmy-owl movements across the border.	Increasing
Human Activities and Disturbance	Some ecotourism and birding effects in some locations. Recreation is limited. Research activities are limited and periodic.	Stable
Human Caused Mortality	Some documentation of cultural uses and illegal trafficking	Stable
Small Population Size	The number of pygmy-owls in this analysis unit is relatively small and they have low genetic diversity.	Increasing
Inadequacy of Existing Regulations	Existing regulations limited and do not protect loss and fragmentation of habitat.	Increasing

Table A5-3. Factors affecting pygmy-owl viability in the Western Mexico analysis unit.

Influences on Viability	**Current Status**	**Trend of Effects**
Invasive Species	Present, but extent unknown	Unknown
Conservation Actions	None specific to pygmy-owls being implemented	Stable
Climate Change	Current impacts to temperature but less impact to precipitation. Impacts to moisture/water availability.	Increasing
Urbanization	Current rates unknown, but in association with cities.	Increasing
Agriculture/Wood Harvesting	Some areas of deforestation and agriculture resulting in habitat fragmentation	Increasing
Improper Livestock Grazing	Little regulation of grazing	Unknown
Human Activities and Disturbance	Some ecotourism and birding effects.	Stable
Human Caused Mortality	Some documentation of cultural use and illegal trafficking	Stable
Inadequacy of Existing Regulations	Limited existing regulations and the do not address the loss and fragmentation of habitat.	Increasing

Table A5-4. Factors affecting pygmy-owl viability in the Texas analysis unit.

Influences on Viability	**Current Status**	**Trend of Effects**
Invasive Species	Extensive distributions	Increasing
Conservation Actions	Limited ongoing (surveys, monitoring, State assessments, habitat protection)	Stable
Climate Change	Current impacts to temperatures, precipitation, and seasonality influencing fire, tropical storm/hurricane frequency, invasive species, erosion, and moisture/water availability	Increasing
Urbanization	Some residential and commercial development limited to areas around cities.	Increasing
Agriculture/Wood Harvesting	Extensive areas of agriculture in border areas, particularly the Lower Rio Grande Valley. Impact of deforestation along Rio Grande and some areas of mesquite control on ranches.	Stable
Improper Livestock Grazing	Livestock grazing occurs in much of the pygmy-owls habitat in Texas, but effects to habitat are limited to small areas of improper grazing.	Stable
Border Issues	Cross-border traffic and interdiction result in impacts to pygmy-owl owl habitat. Recent construction of a total of 151 miles of border wall in three counties of the lower Rio Grande in TX present a potential impediment to pygmy-owl movements across the border.	Increasing
Human Activities and Disturbance	Impacts from ongoing birding and ecotourism in some areas of TX. Research is currently limited in TX. Recreation activities occur in some areas.	Stable
Disease and Predation	Ectoparasites have been documented on pygmy-owls and in nest cavities. Screech owl predation is thought to be a contributor to pygmy-owl mortality	Stable
Small Population Size	The number of pygmy-owls in this analysis unit is relatively small and has low genetic diversity.	Increasing
Inadequacy of Existing Regulations	Protected under Migratory Bird Treaty Act and State Regulations, however, these regulations do not address the loss and fragmentation of habitat.	Increasing

Table A5-5. Factors affecting pygmy-owl viability in the Northeastern Mexico analysis unit.

Influences on Viability	**Current Status**	**Trend of Effects**
Invasive Species	Present, but extent unknown	Unknown
Conservation Actions	None specific to pygmy-owls being implemented	Stable
Climate Change	Current impacts to temperature but less impact to precipitation. Impacts to moisture/water availability	Increasing
Urbanization	Current rates unknown, but in association with cities.	Increasing
Agriculture/Wood Harvesting	Extensive areas of agriculture along northern border. Some areas of deforestation.	Increasing
Improper Livestock Grazing	Little regulation of grazing	Unknown
Border Issues	Cross-border traffic, staging, and cartel activities result in impacts to pygmy-owl owl habitat. Recent construction of border wall in TX present a potential impediment to pygmy-owl movements across the border.	Increasing
Human Activities and Disturbance	Some effects from birding and ecotourism.	Stable
Human Caused Mortality	Some documentation of cultural use and illegal trafficking	Stable
Inadequacy of Existing Regulations	Limited existing regulations and they do not address the loss and fragmentation of habitat	Increasing

APPENDIX 6. MODELING LAND COVER CHANGES

CFPO Land Cover Change Analysis

Historical, 2010-2020 (30m resolution)

Source: USGS LCMap (usgs.gov/special-topics/lcmap/data) CONUS Collection 1.2

1. Reclass 2010 Landcover;

LC Class	Original Class Code	Reclass Code
Developed	1	10
Ag.	2	20
Herbaceous	3	30
Forest	4	40
Water	5	50
Wetland	6	60
Ice/Snow	7	Not Used
Barren/Dist.	8	80

2. Reclass 2020 Landcover;

LC Class	Original & Reclass Code
Developed	1
Ag.	2
Herbaceous	3
Forest	4
Water	5
Wetland	6
Ice/Snow	Not Used
Barren/Dist.	8

3. Use Cell Stats (ArcMap Spatial Analyst) to combine.
4. Results by range;

AZ Changes

2010	2020	Pixels	Acres	% of Range
Ag	Dev	119973	26,681.4	0.15
Herb	Dev	229335	51,003.0	0.29
Forest	Dev	236	52.5	0.00
Herb	Ag	1265169	281,367.3	1.59
Forest	Ag	2	0.4	0.00
Herb	Dist	107876	23,991.1	0.14
Forest	Dist	19530	4,343.4	0.02
Forest	Herb	244379	54,348.7	0.31

441,787.7

TX Changes

2010	2020	Pixcels	Acres	% of Range
Ag	Dev	74681	16,608.7	0.28
Herb	Dev	62116	13,814.3	0.24
Forest	Dev	2218	493.3	0.01
Herb	Ag	1211178	269,359.9	4.60
Forest	Ag	38553	8,574.0	0.15
Herb	Dist	26425	5,876.8	0.10
Forest	Dist	594	132.1	0.00
Forest	Herb	245611	54,622.7	0.93
			369,481.7	

Future Projection, 2020-2050 (90m Resolution)

Source; a. USGS LCMap (usgs.gov/special-topics/lcmap/data) CONUS Collection 1.2

b. EPA, (iclus.epa.gov) Integrated Climate and Land Use Scenarios (ICLUS), v 2.1.1, SSP5 RCP 8.5

1. Resampled 2020 to 90m cell size using ArcMap/Data Management/Raster/Raster Processing/Resample (Nearest Neighbor Method).

2. Reclass 2020 Landcover (LCMap);

LC Class	Original Class Code	Reclass Code
Developed	1	10
Ag.	2	20
Herbaceous	3	30
Forest	4	40
Water	5	50
Wetland	6	60
Ice/Snow	7	Not Used
Barren/Dist.	8	80

3. Reclass 2050 Landcover (ICLUS);

LC Class	Original Code	Reclass Code
Water (natural)	0	Not Used
Reservoirs	1	Not Used
Wetlands	2	Not Used
Recreation/Conserv.	3	Not Used
Timber	4	Not Used
Grazing	5	Not Used
Pasture	6	Not Used
Cropland	7	1

Mining/Barren	8	7
Parks/Golf	9	Not Used
Exurban Low	10	2
Exurban High	11	2
Suburban	12	3
Urban Low	13	4
Urban High	14	4
Commercial	15	5
Industrial	16	5
Institutional	17	Not Used
Transportation	18	6

4. Use Cell Stats (ArcMap Spatial Analyst) to combine.
5. R**es**ults by range;

AZ changes:

Code	2020	2050	Pixels	Acres	% of Range
1	Herb	Ag	5018	10,044.0	0.057
2	Herb	Rural Dev	304155	608,796.6	3.437
3	Herb	Suburban	116708	233,602.7	1.319
4	Herb	Urban	62421	124,941.9	0.705
5	Herb	Comm/Ind	46134	92,341.8	0.521
6	Herb	Transport	19865	39,761.8	0.224
7	Herb	Barr/Dist/Mine	346	692.6	0.004
				1,110,181.4	6.267

Code	2020	2050	Pixels	Acres	% of Range
1	Forest	Ag	1	2.0	0.00001
2	Forest	Rural Dev	362	724.6	0.00409
3	Forest	Suburban	120	240.2	0.00136
4	Forest	Urban	6	12.0	0.00007
5	Forest	Comm/Ind	133	266.2	0.00150
6	Forest	Transport	33	66.1	0.00037
7	Forest	Barr/Dist/Mine	0	0.0	0.00000
				1,311.0	0.00740

TX Changes:

Code	2020	2050	Pixels	Acres	% of Range
1	Herb	Ag	21146	42,325.8	0.72
2	Herb	Rural Dev	106320	212,810.1	3.64
3	Herb	Suburban	14966	29,955.9	0.51
4	Herb	Urban	14990	30,004.0	0.51
5	Herb	Comm/Ind	3985	7,976.4	0.14
6	Herb	Transport	3312	6,629.3	0.11
7	Herb	Barr/Dist/Mine	0	0.0	0.00
				329,701.6	5.63

Code	2020	2050	Pixels	Acres	% of Range
1	Forest	Ag	901	1,803.4	0.031
2	Forest	Rural Dev	2947	5,898.7	0.101
3	Forest	Suburban	541	1,082.9	0.018
4	Forest	Urban	486	972.8	0.017
5	Forest	Comm/Ind	146	292.2	0.005
6	Forest	Transport	17	34.0	0.001
7	Forest	Barr/Dist/Mine	0	0.0	0.000
				10,084.1	0.172

6. Converted suitable landcover and kappa 4 model results polygon layers to 90 meter raster layers (to match the EPA land change layers) using ArcMap / Conversion Tools / To Raster / Polygon to Raster (90m ; default settings).

7. Use Combine Tool (Spatial Analyst Tools / Local / Combine) to generate tables.

8. Results by Range and Suitable Landcover

AZ Changes:

Total SSA Suitable (ac):	13,162,345.20
Total with <20% cover (ac):	5,280,849.57
Total with >20% cover (ac):	7,881,495.62

SSA % cover	Landcover Conversion	Pixels	Acres	% of SSA % cover	% of Total Suitable
<20%	Herb to Ag (31)	1210	2422.42	0.04587	0.01840
<20%	Herb to Rural Dev (32)	69019	138176.04	2.61655	1.04978
<20%	Herb to Suburban (33)	41798	83679.60	1.58459	0.63575
<20%	Herb to Urban (34)	22736	45517.47	0.86193	0.34582
<20%	Herb to Comm/Ind (35)	13221	26468.44	0.50122	0.20109
<20%	Herb to Transport (36)	5310	10630.62	0.20131	0.08077
<20%	Herb to Barr/Dist/Mine (37)	22	44.04	0.00083	0.00033
Total <20% cover			306938.63	5.81230	2.33194
>20%	Herb to Ag (31)	341	682.68	0.00866	0.00519
>20%	Herb to Rural Dev (32)	172305	344954.61	4.37677	2.62077
>20%	Herb to Suburban (33)	59036	118190.07	1.49959	0.89794
>20%	Herb to Urban (34)	29445	58948.89	0.74794	0.44786
>20%	Herb to Comm/Ind (35)	27659	55373.32	0.70257	0.42069
>20%	Herb to Transport (36)	6129	12270.26	0.15568	0.09322
>20%	Herb to Barr/Dist/Mine (37)	85	170.17	0.00216	0.00129
>20%	Forest to Ag (41)	1	2.00	0.00003	0.00002
>20%	Forest to Rural Dev (42)	2	4.00	0.00005	0.00003
Total >20% cover			590596.01	7.49345	4.48701
Total SSA Suitable			1204473.27		9.15090

TX Changes:

Total SSA Suitable (ac): 3,677,495.82
Total with <20% cover (ac): 2,184,055.87
Total with >20% cover (ac): 1,493,439.95

SSA % cover	Landcover Conversion	Pixels	Acres	% of SSA % cover	% of Total Suitable
<20%	Herb to Ag (31)	12522	25069.044	1.147820635	0.681687899
<20%	Herb to Rural Dev (32)	60722	121565.444	5.566040935	3.305658249
<20%	Herb to Suburban (33)	5731	11473.462	0.525328227	0.311991163
<20%	Herb to Urban (34)	3566	7139.132	0.326874971	0.194130255
<20%	Herb to Comm/Ind (35)	1518	3039.036	0.13914644	0.082638734
<20%	Herb to Transport (36)	688	1377.376	0.063065053	0.037454183
<20%	Forest to Ag (41)	287	574.574	0.02630766	0.015624056
<20%	Forest to Rural Dev (42)	796	1593.592	0.0729648	0.043333618
<20%	Forest to Suburban (43)	236	472.472	0.02163278	0.012847656
<20%	Forest to Urban (44)	193	386.386	0.017691214	0.010506769
<20%	Forest to Comm/Ind (45)	50	100.1	0.004583216	0.002721961
<20%	Forest to Transport (46)	6	12.012	0.000549986	0.000326635
Total <20% cover			172802.63	7.912005918	4.698921178
>20%	Herb to Ag (31)	3929	7865.858	0.52669396	0.213891691
>20%	Herb to Rural Dev (32)	39817	79713.634	5.337585492	2.167606378
>20%	Herb to Suburban (33)	8151	16318.302	1.092665428	0.443734073
>20%	Herb to Urban (34)	9131	18280.262	1.224037299	0.497084508
>20%	Herb to Comm/Ind (35)	1058	2118.116	0.141827999	0.057596694
>20%	Herb to Transport (36)	1032	2066.064	0.138342623	0.056181274
>20%	Forest to Ag (41)	444	888.888	0.059519501	0.024171013
>20%	Forest to Rural Dev (42)	1943	3889.886	0.260464842	0.105775402
>20%	Forest to Suburban (43)	277	554.554	0.037132661	0.015079664
>20%	Forest to Urban (44)	258	516.516	0.034585656	0.014045318
>20%	Forest to Comm/Ind (45)	89	178.178	0.011930711	0.00484509
>20%	Forest to Transport (46)	5	10.01	0.000670265	0.000272196
Total >20% cover			132400.268	8.865456437	3.600283302
Total SSA Suitable			305202.898		8.29920448

9. Results by Range and Kappa 4 model results

AZ Changes:

Total K4 (ac): 2148053.9

Landcover Conversion	Pixels	Acres	% of Total K4
Herb to Ag (31)	2	4.004	0.000186401
Herb to Rural Dev (32)	38035	76146.07	3.54488636
Herb to Suburban (33)	7466	14946.93	0.695835982
Herb to Urban (34)	776	1553.552	0.072323697
Herb to Comm/Ind (35)	3235	6476.47	0.301504072
Herb to Transport (36)	1264	2530.528	0.11780561
Total		101657.6	4.732542122

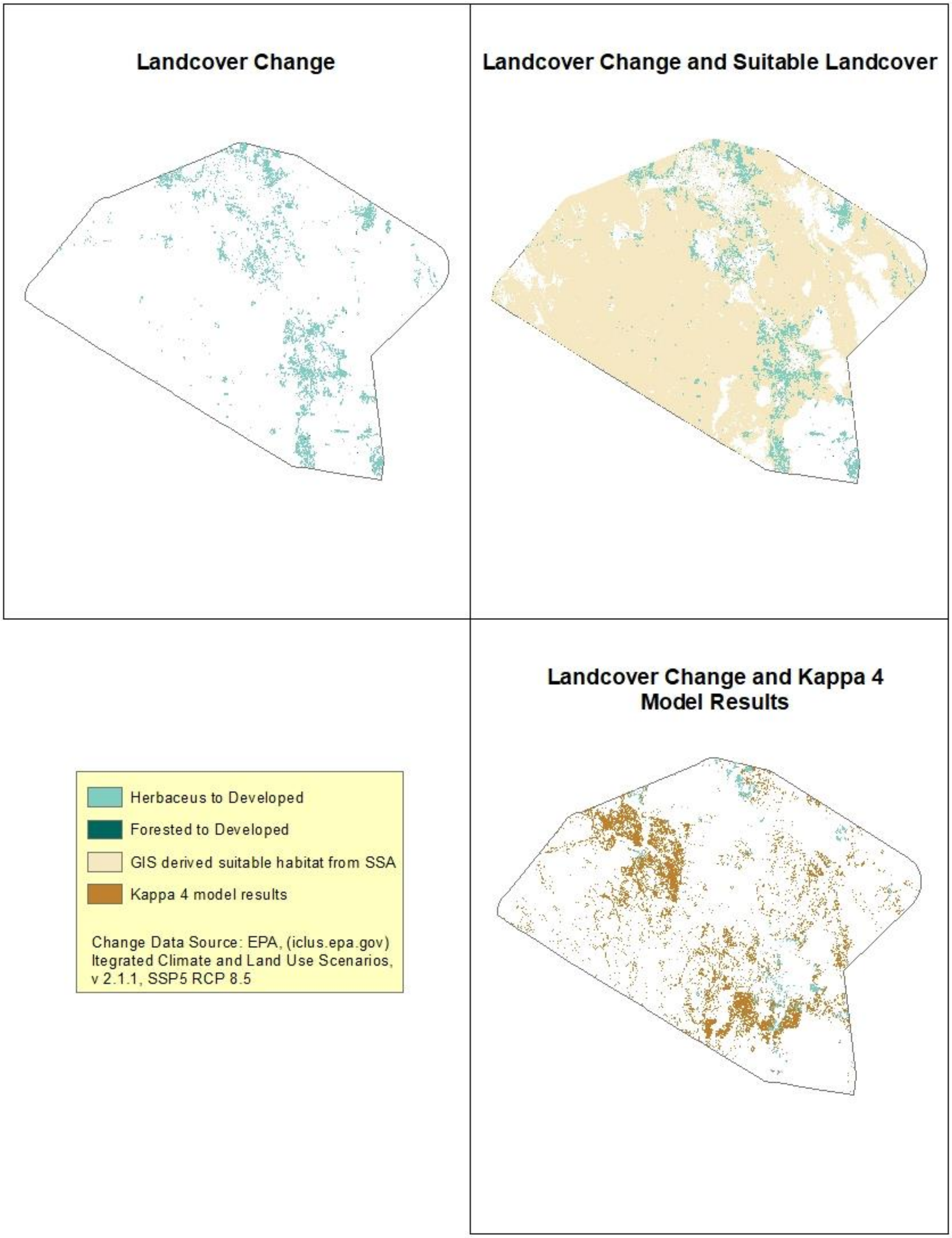
TX Changes:

Total K4 (ac): 1045946.902

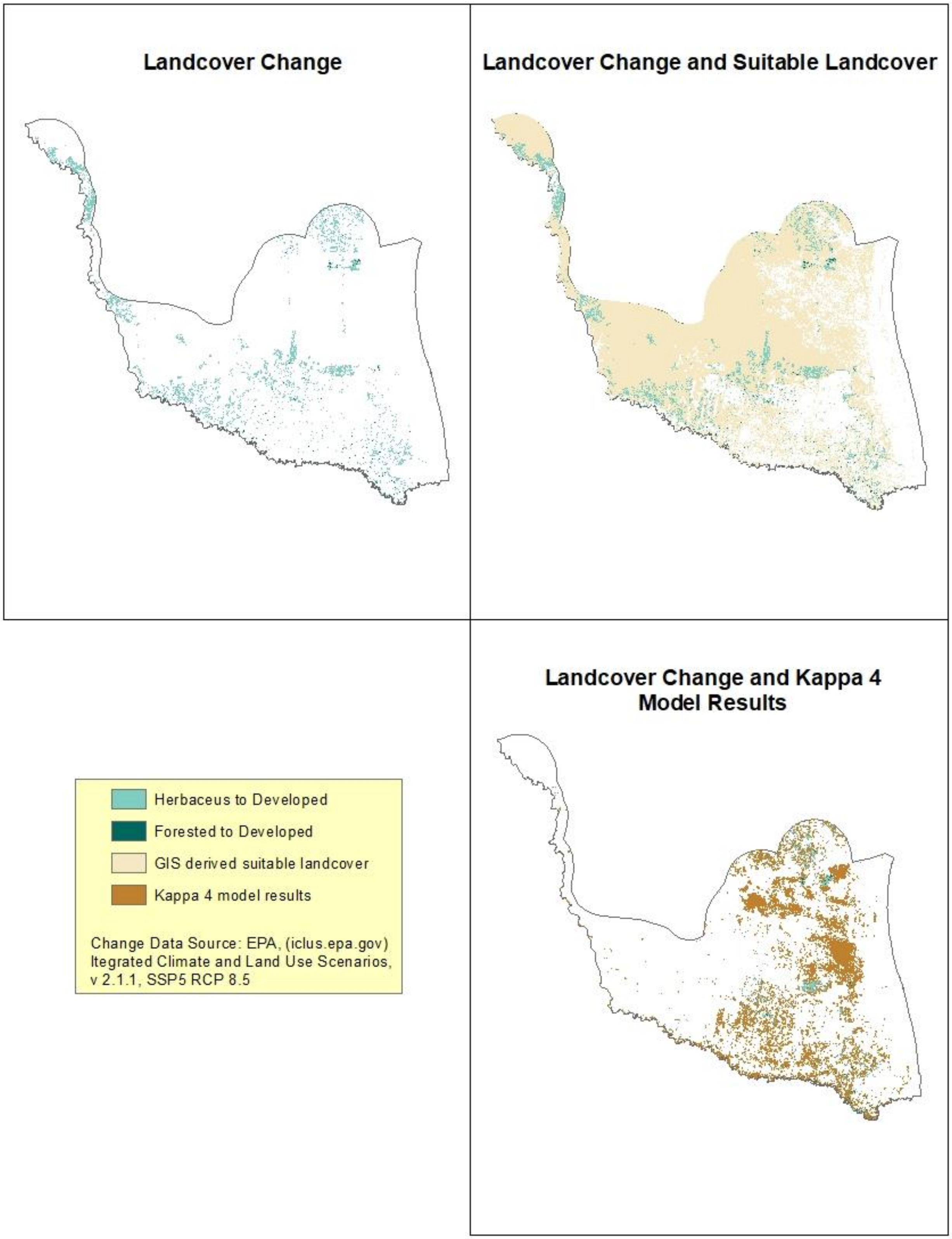
Landcover Conversion	Pixels	Acres	% of Total K4
Herb to Ag (31)	8332	16680.664	1.594790708
Herb to Rural Dev (32)	23883	47813.766	4.571337791
Herb to Suburban (33)	2429	4862.858	0.464923983
Herb to Urban (34)	1084	2170.168	0.207483573
Herb to Comm/Ind (35)	762	1525.524	0.145850998
Herb to Transport (36)	398	796.796	0.076179393
Forest to Ag (41)	644	1289.288	0.123265148
Forest to Rural Dev (42)	1868	3739.736	0.357545492
Forest to Suburban (43)	304	608.608	0.058187275
Forest to Urban (44)	286	572.572	0.054741976
Forest to Comm/Ind (45)	91	182.182	0.017417901
Forest to Transport (46)	5	10.01	0.000957028
Total		80252.172	7.672681266

Maps:

AZ


Landcover Change
Landcover Change and Suitable Landcover
Landcover Change and Kappa 4 Model Results
Herbaceus to Developed
Forested to Developed
GIS derived suitable habitat from SSA
Kappa 4 model results
Change Data Source: EPA, (iclus.epa.gov) Itegrated Climate and Land Use Scenarios, v 2.1.1, SSP5 RCP 8.5

TX:



Change Data Source: EPA, (iclus.epa.gov) Itegrated Climate and Land Use Scenarios, v 2.1.1, SSP5 RCP 8.5