Biological Report for the Upper Virgin River Recovery Unit population of Mojave desert tortoise (*Gopherus agassizii*)

Prepared by the Utah Ecological Services Field Office
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Contents

EXECUTIVE SUMMARY

On April 2, 1990, the U.S. Fish and Wildlife Service (USFWS) listed the Mojave desert tortoise (*Gopherus agassizii* or *G. agassizii*) as a threatened species pursuant to the Endangered Species Act of 1973, as amended (ESA; 55 FR 12178 12191). The emergency listing was prompted by population declines thought to result in part from an upper respiratory tract disease (URTD). On February 24, 1994, USFWS designated 6,446,200 acres of critical habitat for the threatened *G. agassizii* (59 FR 5820). The original recovery plan identified six recovery units across the range of the species (USFWS 1994a). USFWS reevaluated and condensed the recovery units into five areas in the revised recovery plan (USFWS 2011) (Critical Habitat and Recovery Units). USFWS determined each of the five recovery units are individually necessary to conserve the genetic, behavioral, morphological, and ecological diversity necessary for long-term sustainability of the entire listed population (USFWS 2011). The Upper Virgin River recovery unit (UVR recovery unit) includes all critical and suitable *G. agassizii* habitat east of the Beaver Dam Mountains in Washington County, Utah (USFWS 2011) and contiguous habitat in Mohave County, Arizona as described in this document).

This biological report is based on a 2019 workshop of local *G. agassizii* experts that included the USFWS, Bureau of Land Management (BLM), Utah Division of Wildlife Resources (UDWR), Washington County, and other experts. The purpose of the workshop was to develop a framework to evaluate viability within the UVR recovery unit among naturally connected and unnaturally fragmented sub-populations and within known occupied *G. agassizii* habitat. This report is a summarization of best available science and information and applies a methodology to evaluate the viability of sub-populations, their connectivity, and their potential condition based on a demographic construct referred to as analytical units (AUs). The AUs are based on topographical, anthropogenic, and ecological discussions with the biological experts. These experts identified 11 AUs in the UVR recovery unit.

This group of experts at the workshop used the Species Status Assessment (SSA) framework (USFWS 2016) to project the future viability of the *G. agassizii* by evaluating six scenarios. In Scenarios 1, 3, and 5, we evaluated slow climate and environmental change under three future conservation management strategies: continued, improved, and reduced. In Scenarios 2, 4, and 6 we evaluated rapid climate and environmental changes under the same three future conservation strategies: continued, improved, and reduced. Current and future projections for each AU are summarized in Table ES-1. This table helps to summarize the viability of the *G. agassizii* currently, and into the future. This report provides support that improved conservation management in the future will be necessary to prevent further declines of tortoise within this recovery unit. Efforts should be focused on increasing and protecting habitat connectivity, habitat restoration, reduction of non-native invasive plant species, and full-time law enforcement.

Table ES- 1. Summary of AUs with current and future conditions under each scenario

Analytical Unit Name	Current Value to RU	Current Condition	Slow Climate & Environmental Change (slow increase in temperatures, invasive plants, and wildfires)				Rapid Climate & Environmental Change (Rapid increase in temperatures, invasive plants and wildfire)		
			Conservation Management				Conservation Management		
			Scenario 1 Continued	Scenario 3 Improved	Scenario 5 Reduced		Scenario 2 Continued	Scenario 4 Improved	Scenario 6 Reduced
Far West	6%	Poor	Poor	Moderate	Critical		Poor	Moderate	Critical
Arizona	7%	Moderate	Moderate	Moderate	Critical		Poor	Good	Critical
Green Valley	6%	Good	Moderate	Good	Poor		Moderate	Good	Critical
Snow Canyon (*Zone 1 and 2*)	12%	Moderate	Moderate	Moderate	Poor		Moderate	Moderate	Critical
Urban Interface	4%	Poor	Critical	Critical	Critical		Critical	Critical	Critical
West Cottonwood (*Zone 3*)	31%	Moderate	Moderate	Good	Poor		Poor	Good	Critical
East Cottonwood (*Zone 3*)	18%	Moderate	Poor	Good	Poor		Poor	Good	Critical
Sand Mountain	3%	Moderate	Poor	Good	Poor		Poor	Good	Critical
Babylon (*Zone 4*)	8%	Moderate	Poor	Moderate	Poor		Poor	Moderate	Critical
Cinder Knolls (*Zone 5*)	3%	Moderate	Poor	Moderate	Poor		Poor	Moderate	Critical
Springdale	0%	Poor	Poor	Moderate	Critical		Poor	Moderate	Critical
Unassigned Areas	2%	NA	NA	NA	NA		NA	NA	NA
Recovery Unit TOTAL	**100%**	**Moderate**	**Poor**	**Moderate**	**Critical**		**Poor**	**Moderate**	**Critical**

Chapter 1: INTRODUCTION

This biological report discusses the status of *G. agassizii* in the UVR recovery unit in southwestern Utah and northwestern Arizona. The USFWS listed the Mojave population of desert tortoise (all tortoises north and west of the Colorado River in Arizona, Utah, Nevada, and California) as threatened on April 2, 1990 [55 Federal Register (FR) 12178]. The USFWS issued an initial recovery plan (USFWS 1994a) and a revised recovery plan (USFWS 2011) for the *G. agassizii*. A five-year review was completed in 2010 (USFWS 2010). This report documents our biological analysis for *G. agassizii* in the UVR recovery unit, and provides an in-depth, scientific review of the species' biology and local stressors, biological status, and an assessment of the resources and conditions needed to maintain this recovery unit population over time. In this biological report, we identified 11 AUs in the recovery unit based on anthropogenic and topographical barriers. Collectively, this information characterizes UVR recovery unit viability, which we define as the recovery unit's ability to maintain itself in the wild over time with little management assistance.

This biological report does not result in any regulatory decision by the USFWS under the ESA. Instead, it provides a thorough review and summary of the best available scientific and commercial information regarding the biological status of *G. agassizii* in the UVR recovery unit. This report will help support recovery planning and implementation for the UVR recovery unit and may also support other functions of our Ecological Services program, including section 7 consultations, section 10 permit reviews, and National Environmental Policy Act analyses. This is intended to be a living document and will be updated as needed to support conservation and provide the scientific foundation for other decisions and documents needed under the ESA for the UVR recovery unit and our Endangered Species program.

1.1 Analytical Framework

The Species Status Assessment (SSA) framework (USFWS 2016) is the standard method that we apply in evaluating the status of threatened, endangered, or petitioned species and can be used to evaluate the species rangewide or within discrete populations. Using the SSA framework (Figure 1), we considered what the UVR recovery unit population needs to maintain viability by characterizing the status of the UVR recovery unit in terms of the three conservation biology principles of resiliency, redundancy, and representation, collectively known as the three Rs (Shaffer and Stein 2000, USFWS 2016, Smith *et al.* 2018). To sustain populations over time, a species must have the capacity to withstand: (1) environmental and demographic stochasticity and disturbances (Resiliency), (2) catastrophes (Redundancy), and (3) novel changes in its biological and physical environment (Representation).

- **Resiliency** is the ability of the UVR recovery unit population as a whole to withstand environmental stochastic disturbance (normal, year-to-year variations in environmental conditions such as temperature, rainfall), periodic disturbances within the normal range of variation (fire, floods, storms), and demographic stochasticity (normal variation in demographic rates such as mortality and fecundity) (Redford et al. 2011). Resiliency is positively related to population size and growth rate and may be influenced by connectivity among AUs. AUs need abundant individuals within habitat patches of adequate area and quality to maintain survival and reproduction under disturbance.

- **Redundancy** is the ability of the UVR recovery unit population as a whole to withstand catastrophic events. It is a measure of spreading risk among multiple AUs to minimize the potential loss of this recovery unit from catastrophic events. Redundancy is characterized by the presence of multiple, resilient AUs distributed within the species' ecological settings and across the UVR recovery unit. It can be measured by AU number, resiliency, spatial extent, and degree of connectivity. Our analysis explores the influence of the number, distribution, and connectivity of AUs on the UVR recovery unit population's ability to withstand catastrophic events (e.g., an AU overcoming a catastrophic event by being repopulated from a nearby AU or rescue effect).

- **Representation** is the ability of the population across the UVR recovery unit to adapt to both near-term and long-term changes in environmental conditions over time. It is characterized by the breadth of genetic and environmental diversity within and among AUs. Measures may include the number of varied niches occupied, the gene diversity, heterozygosity, or alleles per locus. Our analysis explores the relationship between the species life history, the influence of environmental factors, and the UVR recovery units' ability to adapt to changing environmental conditions over time.

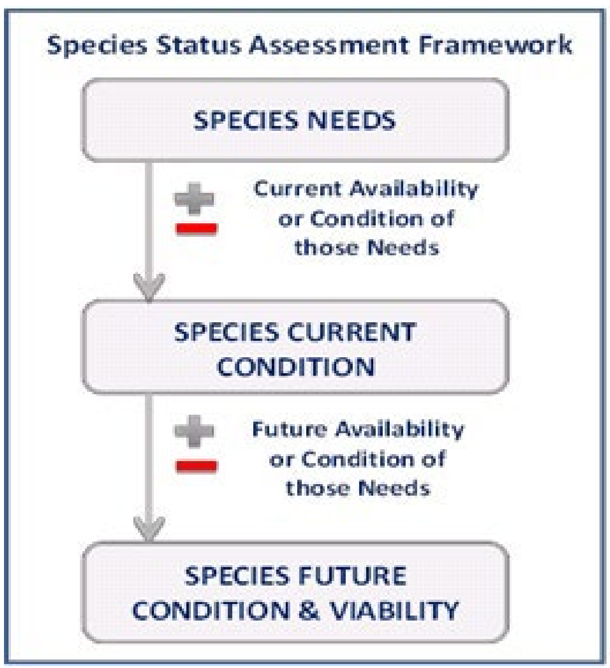

Figure 1. Species Status Assessment Framework

Using the three Rs, we evaluated the current and future viability of the UVR recovery unit based on the presence of multiple (redundancy), self-sustaining (resiliency) AUs distributed across the recovery unit (redundancy), and their contributions to adaptive capacity of the species in the face of changing environmental conditions (representation). The three Rs are our common terminology used throughout our analysis to discuss condition and risk to the UVR recovery unit, and in turn viability. Our approach for assessing *G. agassizii* viability in the UVR recovery unit using the SSA framework (Smith *et al.* 2018, entire) involved three primary phases of analysis.

- In Phase 1, Species Ecology and Needs, we described the ecological requirements, or needs, for survival and reproduction at the individual, AU, and recovery unit levels using the resiliency, redundancy, and representation (Chapter 2).

- In Phase 2, Current Condition, we assessed the UVR recovery unit current condition in terms of the 3Rs and ongoing factors (stressors and beneficial factors) that influence the current condition (Chapters 3 and 4).

- In Phase 3, Future Condition, we used the baseline conditions established in Phase 2 and the projections for future stressors and beneficial factors to evaluate potential future conditions of *G. agassizii* in the UVR recovery unit under plausible future scenarios (Chapter 5).

We emphasize that the scale of our analysis is not the *G. agassizii* as an entire species, but rather our analysis is restricted to the UVR recovery unit. Any analyses or conclusions summarized in this report apply only to the UVR recovery unit and should not be extrapolated to the entire species.

1.2 Information Compilation

We collaborated with biological experts on *G. agassizii* ecology and habitat during a local *G. agassizii* expert workshop (*Workshop for biological experts on the Mojave desert tortoise in the Upper Virgin River recovery unit, September 2019 (*USFWS 2019a); hereafter Workshop) and through subsequent phone calls, emails, and draft maps and reports. Experts at the Workshop included biologists from the UDWR, BLM and one of their consultants, and the Washington County Habitat Conservation Plan (HCP). The Workshop participants discussed research efforts, the factors influencing *G. agassizii*, and the current and future conditions of the species in UVR recovery unit. We used the information from the Workshop to help us define what *G. agassizii* populations and sub-populations need to be considered resilient (healthy).

Following the Workshop, we sought input from the Workshop participants as well as experts that work for non-government organizations, academic institutions, and private research institutions, including experts from the Shivwits Band of the Paiute Tribe, the U.S. Geological Survey (USGS), the U.S. Forest Service (USFS), the Natural Resources Conservation Service (NRCS), the National Park Service (NPS), and the USFWS Arizona Ecological Services office (Appendix 1). We used the expert input from and following the Workshop to develop an analysis of population resiliency using available metrics for some of the demographic and habitat requirements.

Chapter 2: SPECIES ECOLOGY AND NEEDS

In this chapter, we summarize basic biological information about the *G. agassizii*, including its habitats, taxonomy, morphological description, life stages, and reproductive and other important life history traits, which help inform our analysis for *G. agassizii* in the UVR recovery unit. Where specific information is lacking for *G. agassizii* in the recovery unit, we rely on available information for the species at the rangewide level. This is not an exhaustive review of all information known about the *G. agassizii* but rather a focused summary of important ecological information needed to help inform our analysis in the UVR recovery unit, as summarized in this biological report. Finally, we identify the resource needs of individuals, populations, and the UVR recovery unit.

Resource needs, also known as habitat needs, are those habitat or other environmental factors that individual *G. agassizii* in the UVR recovery unit need to breed, feed, and shelter, and to complete each phase of the species' life cycle. Population needs are the demographic needs, also known as demographic factors, such as population size and growth rate, needed for populations within the recovery unit to withstand stochastic events (resiliency). The recovery unit needs are the number and distribution (redundancy) of resilient populations and the full breadth of their diversity (representation) within the recovery unit.

2.1 Species Description and Taxonomy

The *G. agassizii* is a large, herbivorous (plant-eating) burrowing reptile in the family *Testudinoidea* (tortoises). *Gopherus agassizii* reach 8 to 15 inches in carapace (upper shell) length and 4 to 6 inches in shell height. Hatchlings are about 2 inches in length when they emerge from eggs. Adults have a domed carapace and relatively flat, unhinged plastrons (lower shell). Their shells are greenish-tan to dark brown in color with tan scute (horny plate on the shell) centers. Adult *G. agassizii* weigh 8 to 15 pounds. The forelimbs have heavy, claw-like scales and are flattened for digging. Hind limbs are more elephantine (Ernst and Lovich 2009).

The generic assignment of the *G. agassizii* has gone through a series of changes since its original description by Cooper (1861) as *Xerobates agassizii*. It has also been referred to in the literature as *Scaptochelys agassizii*. Currently, the accepted scientific name is *G. agassizii* (Crumly 1994). Differentiation between the Mojave and Sonoran assemblages of the *G. agassizii* are supported via multiple forms of evidence, including morphology, ecology, and genetics (Weinstein *et al.* 1987; Lamb *et al.* 1989; Lamb and Lydeard 1994; Berry *et al.*2002; Van Devender 2002a; Van Devender 2002b; Murphy *et al*. 2007). Although fewer data are available to compare Sinaloan *G. agassizii* to the Sonoran and Mojave assemblages, the Sinaloan population is considerably more isolated, and differentiation in mitochondrial DNA is considerable (Lamb *et al.* 1989, Van Devender 2002b). We accept the current taxonomy and consider the *G. agassizii* a valid species.

2.2 Range and Distribution for the Species

Gopherus agassizii occurs in the Mojave and Sonoran deserts in southern California, southern Nevada, Arizona, and the southwestern tip of Utah in the U.S., as well as Sonora and northern Sinaloa in Mexico (USFWS 1990, USFWS 1994a, USFWS 2011). The *G. agassizii* occurs in the broadest latitudinal range, climatic regimes, habitats, and biotic regions of any North American tortoise species (Auffenberg and Franz 1978, Bury 1982, Patterson 1982, Bury *et al.* 1994, Germano 1994). Records of *G. agassizii* range from below sea level to an elevation of 7,300 feet [ft] (Luckenbach 1982), however *G. agassizii* in the Mojave Desert are usually found below 5,500 ft where precipitation ranges from 2 to 8 inches.

2.2.1 Critical Habitat

Critical habitat was designated for the *G. agassizii* on February 24, 1994 (59 FR 5820), encompassing over 6,000,000 acres in portions of the Mojave and Colorado deserts. This designation includes primarily Federal lands in southwestern Utah, northwestern Arizona, southern Nevada, and southern California (USFWS 1994b, USFWS 2011). Critical habitat is a term defined and used in the ESA. It is specific geographic areas that contain features essential to the conservation of an endangered or threatened species and that may require special management and protection. The USFWS identified the following essential features: 1) sufficient space to support viable populations within the recovery units and to provide for movement, dispersal, and gene flow, 2) sufficient quantity and quality of forage species and the proper soil conditions to provide for the growth of such species, 3) suitable substrates for burrowing, nesting, and overwintering, 4) burrows, caliche caves, and other shelter sites, 5) sufficient vegetation for shelter from temperature extremes and predators, and 6) habitat protected from disturbance and human-caused mortality (USFWS 1994b, USFWS 2011).

2.2.2 Recovery Units

In the 2011 revised Recovery Plan, USFWS reviewed updated information and delineated five recovery units for the *G. agassizii* (Figure 2). These five recovery units are necessary to conserve the genetic, behavioral, morphological, and ecological diversity necessary for long-term sustainability of the entire listed species (Avise 2004, Mace and Purvis 2008, USFWS 2011). There are two recovery units in Utah, the UVR recovery unit which occurs mostly within Washington County, Utah east of the Beaver Dam Mountains and to a lesser degree within Mohave County in northwestern Arizona, and the Northeastern Mojave (NEM) recovery unit located on the west side of the Beaver Dam Mountains in Washington County, Utah and extending into Nevada and Arizona (Figure 2). The UVR recovery unit is at the edge of the species' northeastern range, with natural population boundaries to the north and east of the recovery unit. The rest of the information in this biological report focuses on an understanding of the status of the *G. agassizii* and its habitat in the UVR recovery unit.

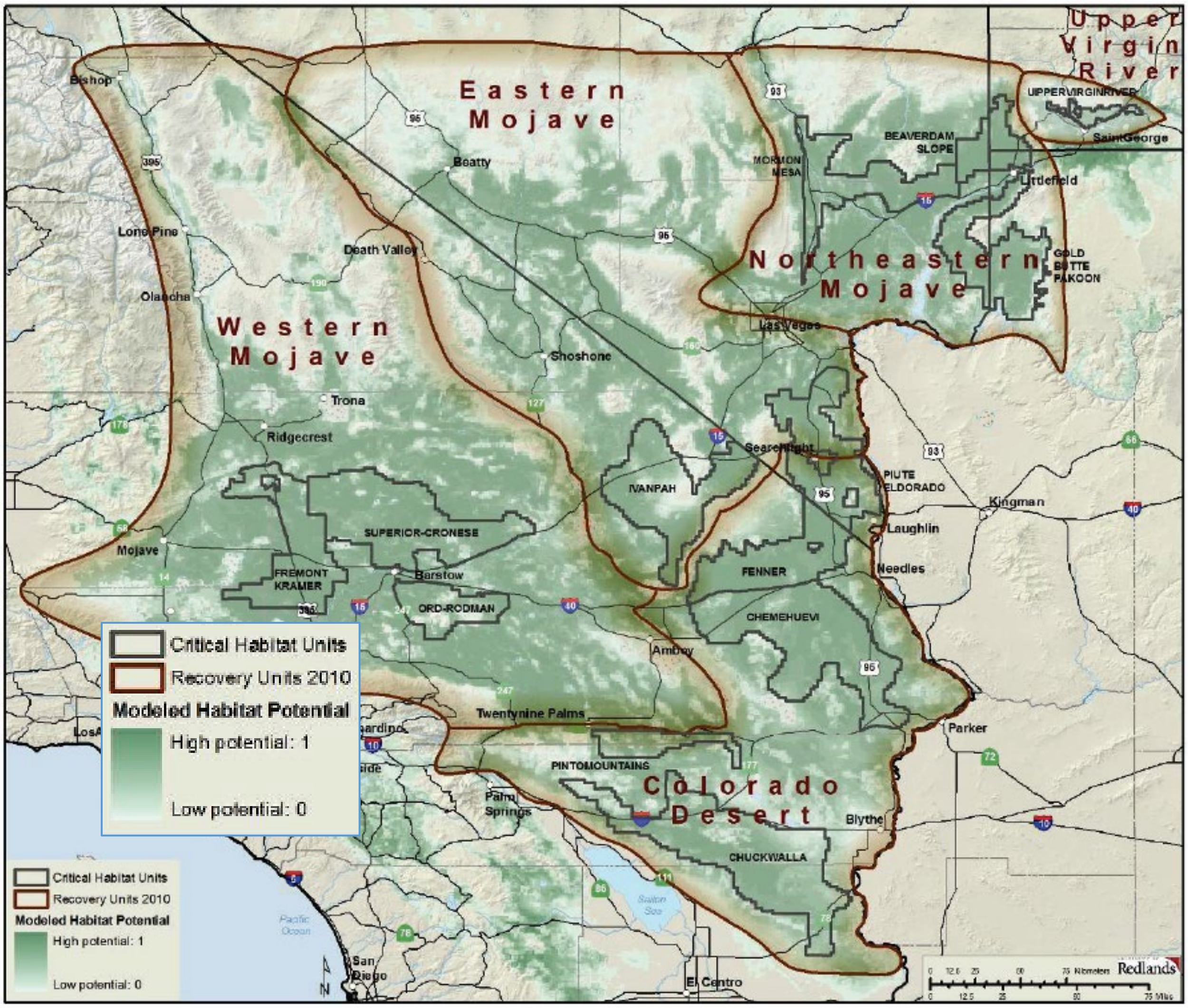

Figure 2. Gopherus agassizii recovery units and occurrence model.

2.3 Upper Virgin River Recovery Unit Distribution and Abundance

The UVR recovery unit includes 325,898 acres of suitable *G. agassizii* habitat of which 56,187 acres (17 percent) was designated critical habitat in 1994 (59 FR 5820, February 24, 1994; Table 1, Figure 4). *G. agassizii* have a broad geographic range throughout the UVR recovery unit, but with varying densities and clusters. The land is owned by a mixture of Federal, state, tribal and private entities (Figure 3). In this section we discuss the history and information currently known about abundance within the Red Cliffs Desert Reserve and the recent development of AUs (Figure 5) and our process for evaluating abundance outside of the Red Cliffs Desert Reserve. We also discuss the methods for calculating habitat acreage and abundance calculations.

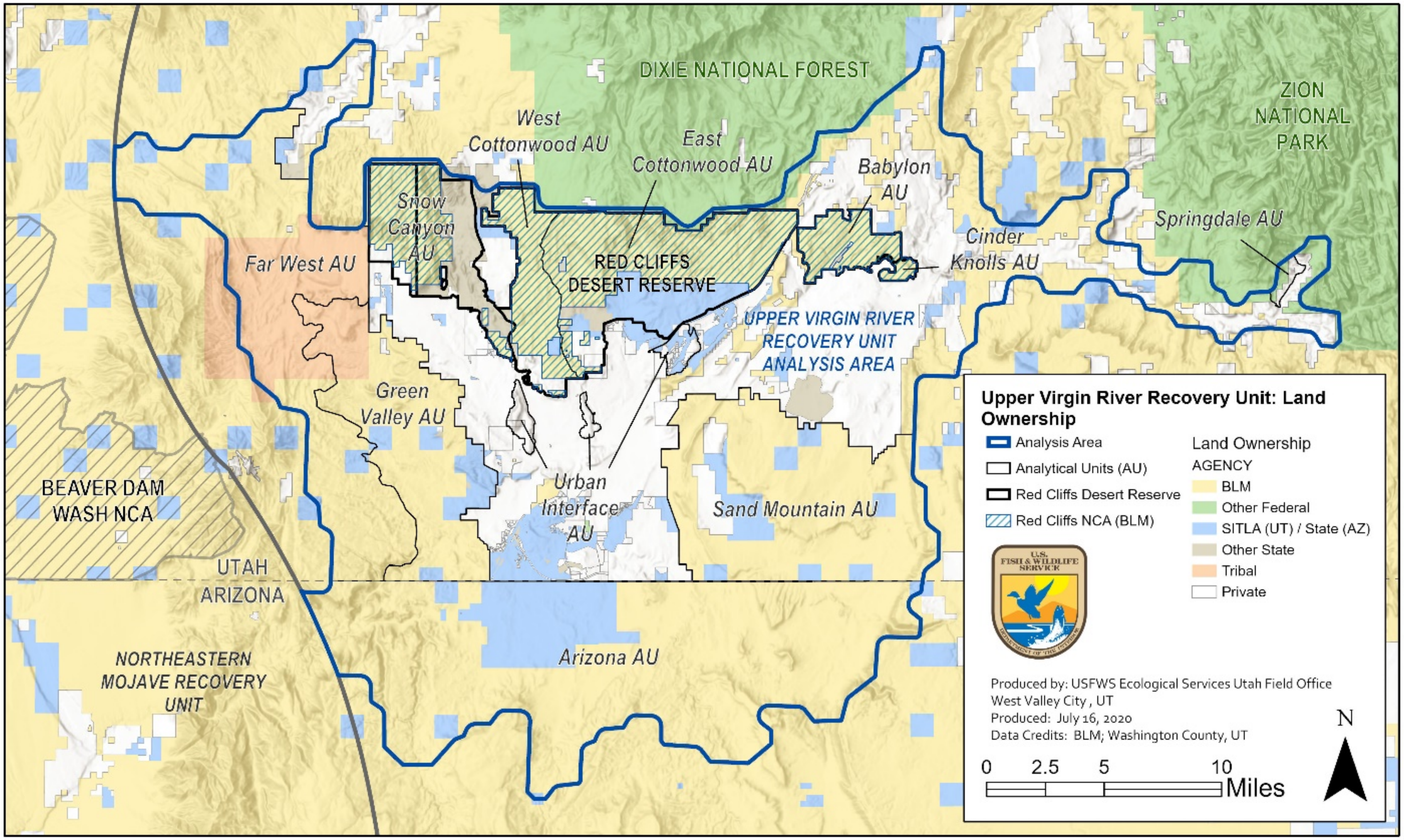

Figure 3. UVR recovery unit Land Ownership

2.3.1 Red Cliffs Desert Reserve

The *G. agassizii* population for the UVR recovery unit is primarily concentrated in the Red Cliffs Desert Reserve. The majority (49,856 acres; 93 percent) of remaining designated critical habitat in the UVR recovery unit occurs in the Red Cliffs Desert Reserve (Table 1 and Figure 4). The Red Cliffs Desert Reserve (approximately 62,000 acres) is located north of St. George, Utah and adjacent to several other cities in Washington County and was established in 1996 and is a key component of the conservation strategy to offset the impacts of development in Washington County. The Red Cliffs Desert Reserve's primary purpose is to protect the *G. agassizii* and its habitat per the Washington County Habitat Conservation Plan [HCP] (Washington County 1995). The 1995 HCP was developed for an incidental take permit (USFWS 1996) that allowed development on *G. agassizii* habitat on private and State lands in the UVR recovery unit. That permit expired in 2016 and a proposed amendment to that plan is currently being reviewed (Washington County 2020, USDOI 2020). The HCP is adaptively managed by the HCP Partners, which include Federal, State, and local entities. In 2009, Congress designated 45,000 acres of federally managed lands in the Red Cliffs Desert Reserve as a National Conservation Area (NCA). The purposes as outlined in Sec. 1974 of Public Law 111-11 for the Red Cliffs NCA are (1) to conserve, protect, and enhance for the benefit and enjoyment of present and future generations the ecological, scenic, wildlife, recreational, cultural, historical, natural, educational, and scientific resources of the National Conservation Area; and (2) to protect each species that is— (A) located in the National Conservation Area; and (B) listed as a threatened or endangered species on the list of threatened species or the list of endangered species published under section 4(c)(1) of the ESA of 1973 (16 U.S.C. 1533(c)(1)).

Table 1. Suitable and critical habitat for the G. agassizii in the Upper Virgin River recovery unit.

Area	**Suitable habitat (acres)**	**Critical habitat (acres)**
Red Cliffs Desert Reserve	41,300	49,856 (651 developed)
Outside Red Cliffs Desert Reserve	284,598	6,510 (2,170 developed)
Total for recovery unit	325,898	53,366 (2,821 developed)

The Red Cliffs Desert Reserve, and *G. agassizii* distribution therein, is segmented into five management zones, separated by topographical and human barriers (Figure 5). Red Cliffs Desert Reserve, zones 1, 2, and 3 are north of the cities of Ivins, St. George, and Washington and west of Interstate 15 (I-15). Red Cliffs Desert Reserve, zones 4 and 5 are north of the city of Hurricane, south of Leeds, and east of I-15 (Figure 5). The zones are described in detail in the 1995 HCP and the State's bi-annual Red Cliffs monitoring report published by the State (Washington County 1995, McLuckie *et al*. 2020). Healthy wild *G. agassizii* found during clearance surveys for development on private lands in other areas are usually translocated to zone 4. Zone 4 previously had few to no *G. agassizii* though *G. agassizii* sign indicated past occupancy; translocation efforts have repopulated the area, at least temporarily. Healthy *G. agassizii* with likely captive origin are placed in the State's adoption program, which requires

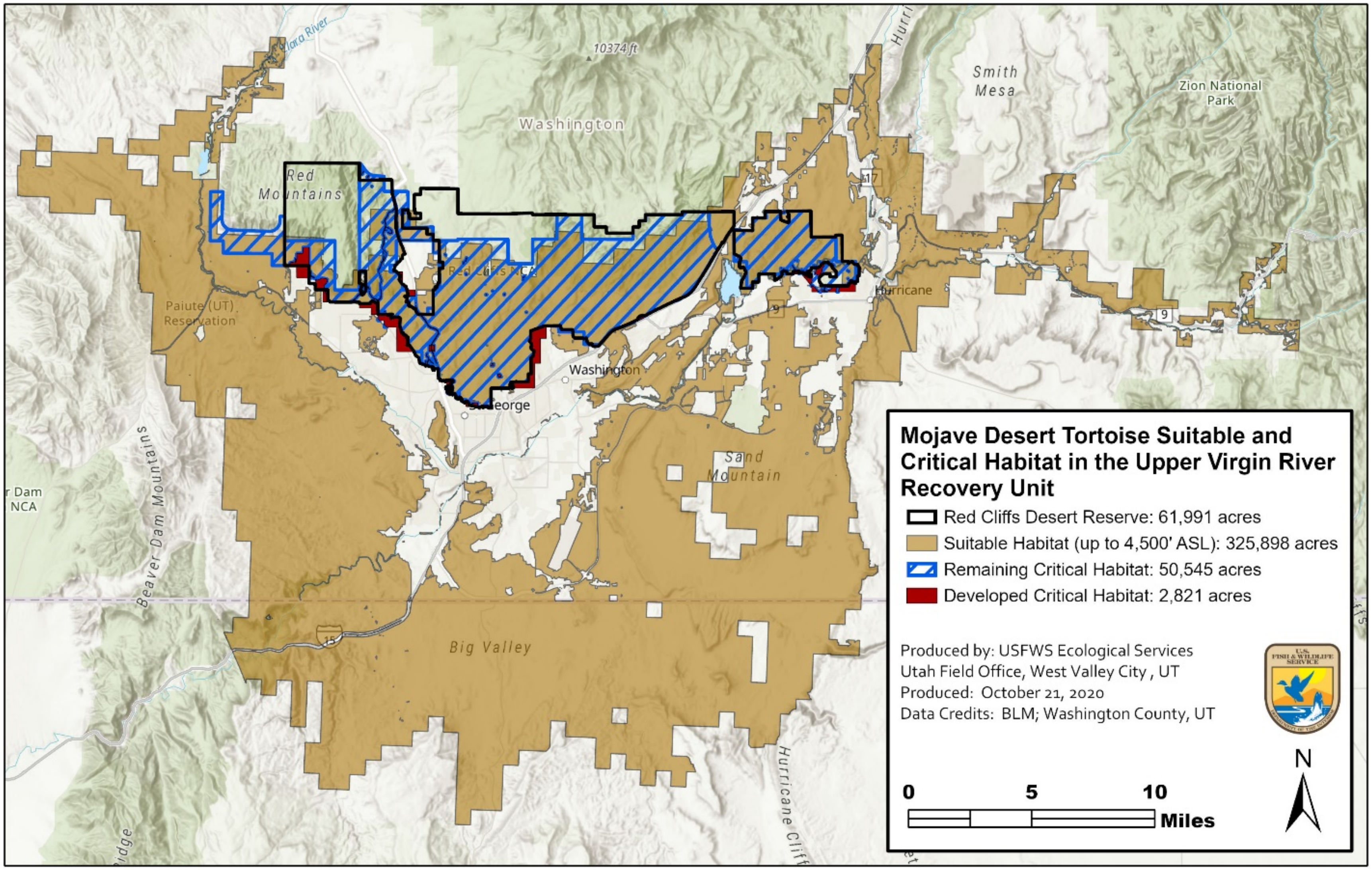

Figure 4. Suitable and critical habitat for the G. agassizii in the Upper Virgin River recovery unit.

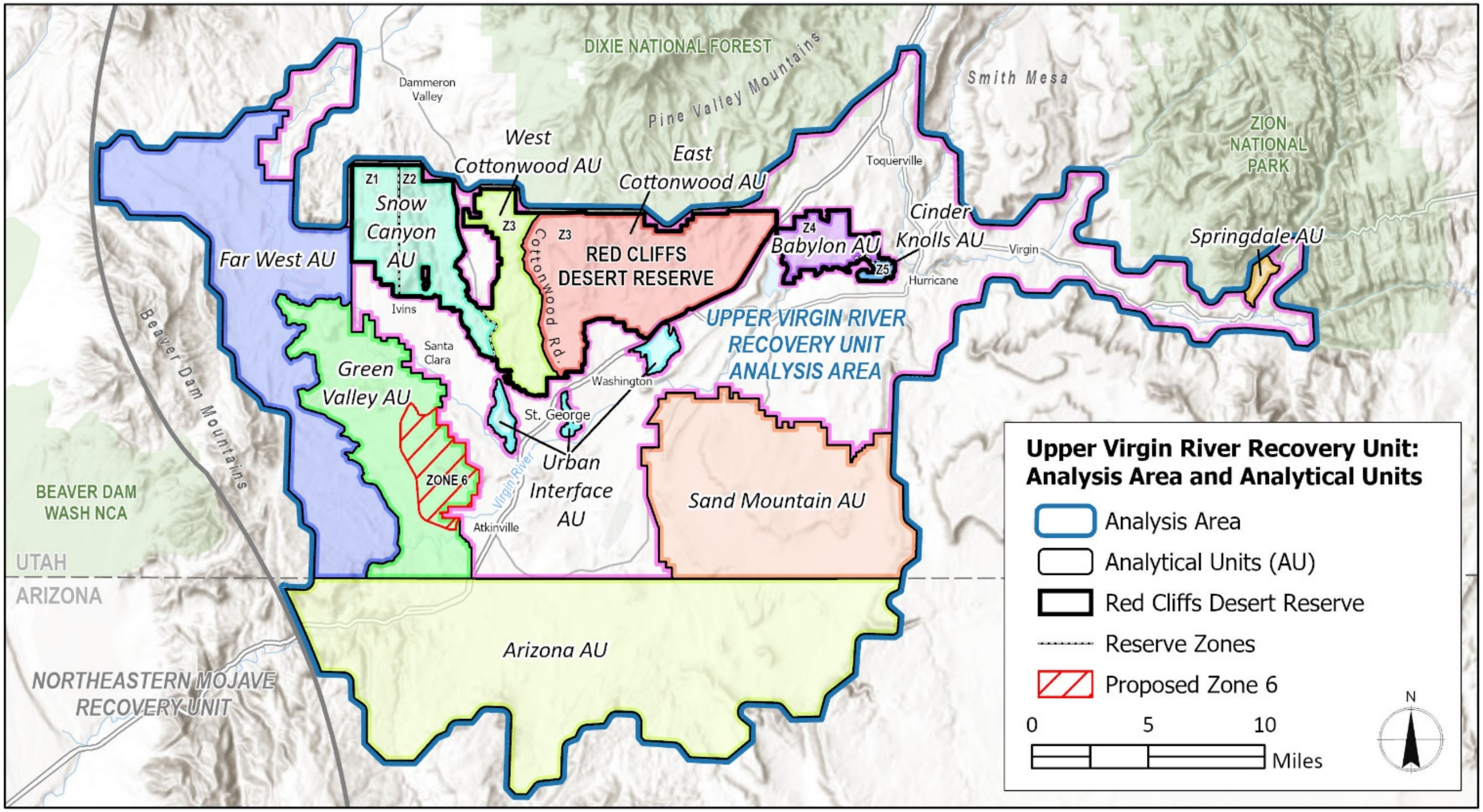

Figure 5. The Upper Virgin River (UVR) recovery unit analysis area, 11 Analytical Units, and proposed Zone 6 (USFWS 2019a). Unassigned areas are the non-colored areas within the analysis area. Note Z1-Z5 are the previously established Zones 1-5 in the Red Cliffs Desert Reserve

movement outside the species' range and distribution. A portion of the proposed zone 6 (6,818 acres) may be added to the Red Cliffs Desert Reserve as part of a current proposal to help offset impacts from a proposed highway in Red Cliffs Desert Reserve, zone 3 (Washington County 2020; Figure 5).

Distribution of *G. agassizii* is well known within most of the Red Cliffs Desert Reserve due to systematic surveys that are completed bi-annually in Red Cliffs Desert Reserve, zones 2, 3, 4, and 5 (McLuckie *et al*. 2020). Red Cliffs Desert Reserve, zone 1 is primarily on private lands and inaccessible terrain that was removed from the survey effort. In Red Cliffs Desert Reserve surveys are only conducted below 4,000 ft elevation, and slopes less than 45 degrees (for human safety) (Table 3).

2.3.2 Analytical Units

While most of our data has historically been gathered within the Red Cliffs Desert Reserve, at the Workshop we developed AUs for our evaluation of the entire UVR recovery unit. The Workshop experts identified 11 AUs in the UVR recovery unit, 10 units in Utah and 1 unit in Arizona (Table 2 and Figure 5). The AUs are sized based on topographical, anthropogenic, and ecological discussions with the biological experts. Topographical and anthropogenic barriers, as well as differences in habitat types, geography, stressors, conservation efforts, and other factors allowed us to delineate biologically meaningful AUs with resident sub-populations, within the larger UVR recovery unit population. Given our limited knowledge about occupancy outside Red Cliffs Desert Reserve, the factors that went into defining separate AUs included areas with known *G. agassizii* clusters, surrounding suitable habitat, and barriers to connectivity other AUs. The Red Cliffs Desert Reserve zones (1-5) are all nested within corresponding *G. agassizii* AUs (Table 2; Figure 5). Throughout this document when we refer to the Red Cliffs Desert Reserve it also applies to the corresponding AUs (Table 2, Table 3 and Figure 5). Our distributional knowledge in more than half (six) of the AUs are low, thus some uncertainty about the population distribution remains. Despite these limitations, this report identifies AUs that may be important for future conservation actions such as genetic or land protections, habitat restoration (which includes non-native invasive species management), or *G. agassizii* population augmentations. Overall, breaking the UVR recovery unit into smaller AUs distributed across the recovery unit has allowed us to evaluate current and future resiliency at smaller scales and then roll up our analysis into recovery unit resiliency.

Methods for calculating habitat acreage and abundance

In 2009, the USGS developed a habitat model for the G. agassizii using 16 environmental variables such as precipitation, geology, vegetation, and slope (Figure 6; Nussear et al. 2009). The model is based on G. agassizii occurrence data from sources spanning more than 80 years, including data from the 2001 to 2005 range-wide monitoring surveys (USFWS 2006). The model estimates the probability that a G. agassizii would occur in 1-km^2 pixels across the range given the habitat variables associated with each pixel. We estimated the suitable G. agassizii habitat areas by using modeled habitat projections (≥ 0.5 Habitat Potential Index Value, as defined in the layer provided by Nussear et al. 2009), removing impervious surfaces and other

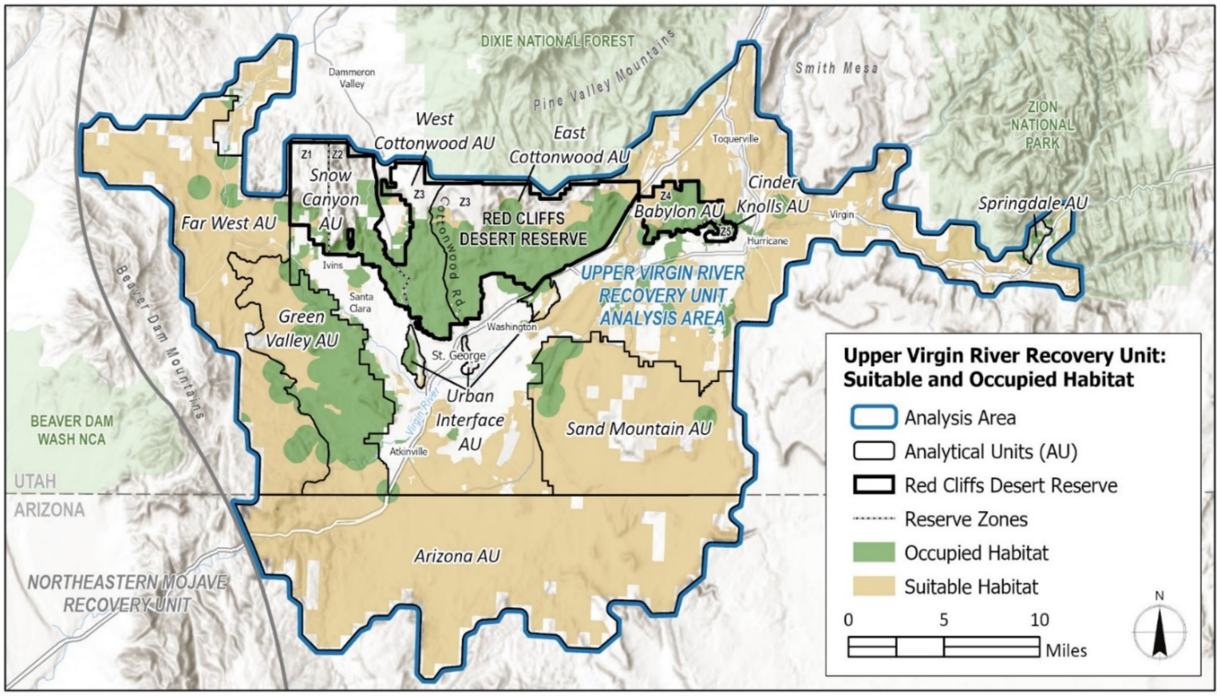

Figure 6. G. agassizii suitable and occupied habitat based on historical observation data buffered by 1 kilometer (Washington County 2020).

developed land cover, and applying a 4,500 ft elevation threshold (excluded areas higher than 4,500 ft). Impervious surfaces are those that are developed or otherwise impacted to such an extent that they cannot support *G. agassizii* habitat (i.e. unsuitable or uninhabitable). *Gopherus agassizii* within the recovery unit are not generally known to occur at elevations exceeding 4,500 ft, but these higher elevation habitats could become occupied under projected climate change scenarios and will thus be evaluated under future conditions (USFWS 2019b).

Estimated *G. agassizii* abundances are calculated based on bi-annual line distance surveys in Red Cliffs Desert Reserve, Beaver Dam Slope in the adjacent NEM recovery unit, and an area outside Red Cliffs Desert Reserve known as the proposed Zone 6 (Table 3 and Figure 5). Portions of this proposed Zone 6 have been surveyed, because this area is part of a proposal to add Zone 6 to the Red Cliffs Desert Reserve to offset impacts of a proposed highway in Zone 3 within the Red Cliffs Desert Reserve (USDOI 2020).

The UVR recovery unit population outside the Red Cliffs Desert Reserve includes known pockets of occupancy and higher densities (Figure 4; Rognan *et al.* 2017), but the overall occupancy and accurate density estimates remain uncertain in many areas in the absence of formal surveys. Local ecological knowledge suggests occupancy is low in most of these areas outside the Red Cliffs Desert Reserve. In all areas without line distance surveys, we used 3.4 *G. agassizii* per mi^2 based on the local density derived using similar survey techniques in the Beaver Dam Slope of the adjacent NEM recovery unit (Table 3; USFWS 2018a). This number represents an average of high and low density areas throughout the UVR recovery unit. The proposed Zone 6 area is one exception of line distance sampling in the UVR recovery unit that is outside the Red Cliffs Desert Reserve, because this area was surveyed with line distance sampling in 2017 (Table 3; Rognan *et al.* 2017 surveyed a 5,150-acre area within the 30,830-acre Green Valley AU 5).

Prior to 1998, *G. agassizii* adult abundance and density surveys were completed using different methods, but in 1998 the UDWR adopted line distance sampling, which was adopted rangewide in 1999. For all areas not surveyed with line distance sampling, we used the 3.4 adult *G. agassizii* per mi^2 estimate in the closest adjacent tortoise conservation area, the Beaver Dam National Conservation Area (Table 3; USFWS 2018a). Lack of formal surveys result in high uncertainty about this estimate. Community science data has detected desert tortoise presence in some parts of unsurveyed Zone 6. These data are opportunistically collected and they cannot be used to derive density estimates, but the information can be used to document presence and distribution. The 3.4 *G. agassizii* per mi^2 density is a very low density estimate, representing the lowest density estimate throughout the range (USFWS 2018a). This estimated density is three times lower than what we consider a depleted population in our translocation guidance (USFWS 2019c). This estimate is therefore conservative in that it may under-estimate densities in some areas and over-estimate in others. The resulting UVR recovery unit population abundance estimate of approximately 4,300 adult *G. agassizii* is considered reasonable because it includes lower density habitat with more than half of the animals considered to reside in the Red Cliffs Desert Reserve (Table 3). Formal surveys are needed for a more accurate estimate of population abundance in the UVR recovery unit and to derive more accurate local densities among all AUs.

Allison and McLuckie (2018) recently provided a summary of long-term population changes throughout the range which showed the population has declined at a rate of 3.2 percent annually of *G. agassizii* in the Red Cliffs Desert Reserve (standard error 2.0 percent). The calculation for the UVR recovery unit is based on densities derived using standard methodology and included data from the Red Cliffs Desert Reserve. Areas outside the Red Cliffs Desert Reserve may be exhibiting similar declines as they are generally less protected, and land managers do not intensively manage these areas. The population decline is considered to accurately represent loss of individuals from the population, likely due to episodic losses from fire and drought; however to determine if declines in population abundance are resulting in a long-term downward population trend, more information is needed. *G. agassizii* is a long-lived species. Population variables such as generation length, reproduction rate, fecundity and recruitment rate are critical to fully understand long-term population trends. There is evidence that reproduction and recruitment are occurring, although limited data are available on rates of these variables. The natural variability in population size as well as inherent measurement error make it extremely difficult to discern real declines from natural or unnaturally exacerbated population changes (*i.e.*, less than 2 percent per year) in *G. agassizii* populations when looking at data from a time period under 25 years (one *G. agassizii* generation, USFWS 2006). While large decreases in population abundance can be detected over shorter time frames, populations may retain the ability to recover. Actual trend data requires the parameterization of population variables and data on population dynamics over 25 years or more in order to make biologically meaningful conclusions. Declines in population abundance are of concern, however and may be affecting distribution. Declines in adult desert tortoises ultimately could impact the overall population trend; however, uncertainty is high, and more data must be collected over longer time periods to better understand causal relationships within the population dynamics.

Table 2. The 11 AUs, west to east, for the UVR recovery unit, including size and amount of suitable habitat and major land ownership.

Analytical Unit Name	Total Acres	Suitable Habitat Acres	Majority Land Owners – Suitable Habitat Acres	Unit Description and Distributional Knowledge
Far West	52,773	45,300	BLM 27,124 Tribal 16,069 SITLA 2,079	Area of primarily Federal, Tribal, and State lands adjacent to the Beaver Dam Mountain region; largely fire-disturbed. Potentially important area for connectivity but limited distributional knowledge.
Arizona	99,537	86,894	BLM 72,625 State 14,265	Located in northern Arizona. Limited distributional knowledge; some observation in Virgin River Gorge. (AU not included in 2011 recovery unit definition, which was limited to Utah).
Green Valley	31,433	30,661	BLM 21,272 Tribal 4,963 SITLA 4,195 Private 161	Area of primarily Federal, Tribal, and State lands located west of St. George; bounded by the Santa Clara River and private lands to the east, and fire-disturbed lands to the west. Heavy recreation impacts in the east including roads, trails, shooting, and dumping. Limited distributional knowledge in most of this area, one year of intensive surveys on 5,150 acres.
Snow Canyon (*Zone 1 and 2*)	16,434	6,290	State 3,989 BLM 1,796 Private 500	Red Cliffs Desert Reserve, zones 1 and 2. Limited distributional knowledge in zone 1; extensive distributional knowledge in zone 2 through systematic surveys.
Urban Interface	3,229	1,555	Private 1,087 SITLA 455	Three isolated sub-units occur within the urban matrix; includes West Black Ridge, Black Ridge, and Sleepy Hollow. The first two occur in St. George City and the last area is south of I-15 near Exit 13. Several clearance surveys were conducted prior to construction and development. No systematic surveys.
West Cottonwood (*Zone 3*)	10,446	7,489	BLM 5,952 Private 030 State 265 SITLA 241	Portion of Red Cliffs Desert Reserve, zone 3, located west of Cottonwood Springs Road. Extensive distributional knowledge through systematic surveys.
East Cottonwood (*Zone 3*)	28,909	21,669	BLM 3,552 SITLA 6,157 State 986 Private 973	Portion of Red Cliffs Desert Reserve, zone 3, located east of Cottonwood Springs Road. Extensive distributional knowledge through systematic surveys. Burned habitat on west end, east end mostly unburned.
Sand Mountain	47,432	41,115	BLM 2,831 SITLA 5,521 Private 2,763	Sand Mountain and environs; includes primarily Federal and State lands east of Highway 7 and south of Sand Hollow Lake. Limited distributional knowledge.
Babylon (*Zone 4*)	5,489	5,404	BLM 5,251 State 102	Red Cliffs Desert Reserve, zone 4 (current translocation site). Distributional knowledge through systematic surveys. Diverse terrain and habitat types; burned habitat on northwest end of unit.
Cinder Knolls (*Zone 5*)	741	429	BLM 410	Red Cliffs Desert Reserve, zone 5. Extensive distributional knowledge through systematic surveys.
Springdale	906	280	NPS 176 Private 103	West of Springdale, Utah; bounded by Zion Park Boulevard to the east, Lion Boulevard to the north, and Valley View Drive to the south. Distributional knowledge through distribution and density surveys and several years of radio-transmitter data.

Table 3. 2017 estimated population size and suitable habitat in each UVR recovery unit analytical unit. Zones refer to the Red Cliffs Desert Reserve, zones 1 to 5 and proposed zone 6.

Habitat Unit	**Source or calculation steps**	**Number of adult *G. agassizii***
Snow Canyon (zone 1)	2.2 mi^2 (1,397 acres) * 3.4 DT per mi^2	7 (2 - 24)
Snow Canyon (zone 2)	McLuckie *et al*. 2018	201 (161 - 252)
West Cottonwood and East Cottonwood (zone 3)	McLuckie *et al*. 2018	1,749 (1,286 - 2,380)
Babylon (zone 4)	McLuckie *et al*. 2018	285 (160 - 507)
Cinder Knolls (zone 5)	McLuckie *et al*. 2018	99 (75 - 131)
Total in the Red Cliffs Desert Reserve		**2,341 (1,684 – 3,294)**
Far West AU	70.8 mi^2 (45,300 acres) *3.4 DT per mi^2	238 (73 - 770)
Arizona AU	135.8 mi^2 (86,894) * 3.4 DT per mi^2	457 (141 - 1,477)
Green Valley AU (excluding proposed zone 6)	37.4 mi^2 (23,916 acres) Surveyed Areas: 58.2 DT per mi^2 * 1.9 mi^2 Unsurveyed Areas: 3.4 DT per mi^2 * 35.4 mi^2	232 (103 - 578)
Proposed zone 6* *Systematic survey data available from one year	8.0 mi^2 surveyed in Rognan *et al*. 2017 (468 DT) + 2.54 mi^2 (unsurveyed) * 3.4 DT per mi^2	361 (208 - 642)
Urban interface AU	2.4 mi^2 (1,555 acres) * 3.4 DT per mi^2	8 (3 - 26)
Sand Mountain AU	64.2 mi^2 (41,115 acres) * 3.4 DT per mi^2	216 (67 - 699)
Springdale AU	0.4 mi^2 (280 acres) suitable habitat; 0.1 mi^2 surveyed with an estimated 95 percent confidence interval of 4 – 59 (McLuckie et al. 2000), the remaining 0.3 mi^2 * 3.4 DT per mi^2 (CI: 0 - 3); however, 36 individuals were recently radio tracked within this AU (J. Stroud-Settles, Zion National Park Wildlife Program Manager, personal communication, March 24, 2020). [1]	36 (36 - 62)
Total for all AUs	AUs outside Red Cliffs Desert Reserve + AUs within Red Cliffs Desert Reserve	**3,889 (2,315 to 7,548)**
Unassigned areas[1]	123.1 mi^2 (78,813 acres) * 3.4 DT per mi^2	415 (128 - 1,340)
Total *G. agassizii* outside Red Cliffs Desert Reserve	AUs outside Red Cliffs Desert Reserve + Unassigned Areas	**1,963 (759–5,594)** **In Utah: 1,506 (618 in 4,117)**
Total *G. agassizii*	Red Cliffs Desert Reserve + Outside Red Cliffs Desert Reserve	**4,306 (2,443 to 8,888)**

[1] Estimate based on the number of *G. agassizii* monitored by Zion National Park in 2017 (not based on survey data). Because no confidence intervals were available from monitoring data, we estimate the upper confidence by applying the upper density estimates from McLuckie et al. (2000) to the surveyed area, and used the density estimate from Beaver Dam Slopes to estimate density in unsurveyed habitats. We adjusted our median and minimum estimates to the known number of tortoises monitored in a recent radio tracking study (J. Stroud-Settles, Zion National Park Wildlife Program Manager, personal communication, March 14, 2019).

[2]Unassigned areas are potential habitat areas not included in the above AUs. They represent large areas of modeled suitable habitat with developed areas removed, and they are scattered throughout the recovery unit.

2.3 Life Stages and Basic Life History

Here, we describe the ecological resources that each *G. agassizii* life stage (eggs, hatchlings, subadults, and adults) needs to breed, feed, and shelter. We used information for the entire species if we lacked information specific to the UVR recovery unit. Additionally, all non-egg life stages feed on grasses and forbs. Adults also need burrow networks to successfully breed. Below, we describe these resources in more detail, Table 6 summarizes the resource needs by life stage, and Figure 7 illustrates the individual habitat needs used in the conceptual model.

The size of *G. agassizii* home ranges varies with respect to location and year (Berry 1986), and serves as an indicator of resource availability and opportunity for reproduction and social interactions (O'Connor *et al.* 1994). Male home ranges can be larger than 200 acres while female home ranges are generally less than 100 acres (Burge 1977, Turner *et al.* 1980, Berry 1986, Duda *et al*. 1999, Harless *et al*. 2009). Recent work indicates that estimates based on minimum convex polygons may underestimate annual home ranges by 75 percent or greater (Averill-Murray *et al.* 2020). Core areas within the larger home range are comprised of a network of burrows in which the *G. agassizii* spends most of its life (Harless *et al*. 2009). Cumulative home ranges may be four to six times larger than annual home ranges (R.C. Averill-Murray, USFWS, personal communication, December 23, 2019). Over its lifetime, each *G. agassizii* may use more than 1.5 mi^2 of habitat and may make periodic forays of more than 7 miles at a time (Berry 1986). The *G. agassizii* exhibits high site fidelity (Freilich *et al*. 2000), even after fires impacted parts of their home ranges (Drake *et al*. 2015, Lovich *et al*. 2018).

Gopherus agassizii require extensive contiguous (connected) landscapes to find enough potential mates and successfully pass on genetic material and mixing. The quality and quantity of the habitats *G. agassizii* use dictates the resources available to each individual, which they need to complete each life stage of the life cycle. Table 4 characterizes *G. agassizii* habitats according to their quantity and quality.

Table 4. Gopherus agassizii habitat quantity and quality.

Habitat Quantity	Sufficient seasonally and geographically specific quantity and quality of habitat to support breeding, feeding, and sheltering.	200 acres of habitat per male home range.
Habitat Quality	The ability of the environment to provide conditions appropriate for feeding, breeding, and sheltering.	Sufficient available shrubs with an understory of grasses and forbs for feeding, breeding, and sheltering.

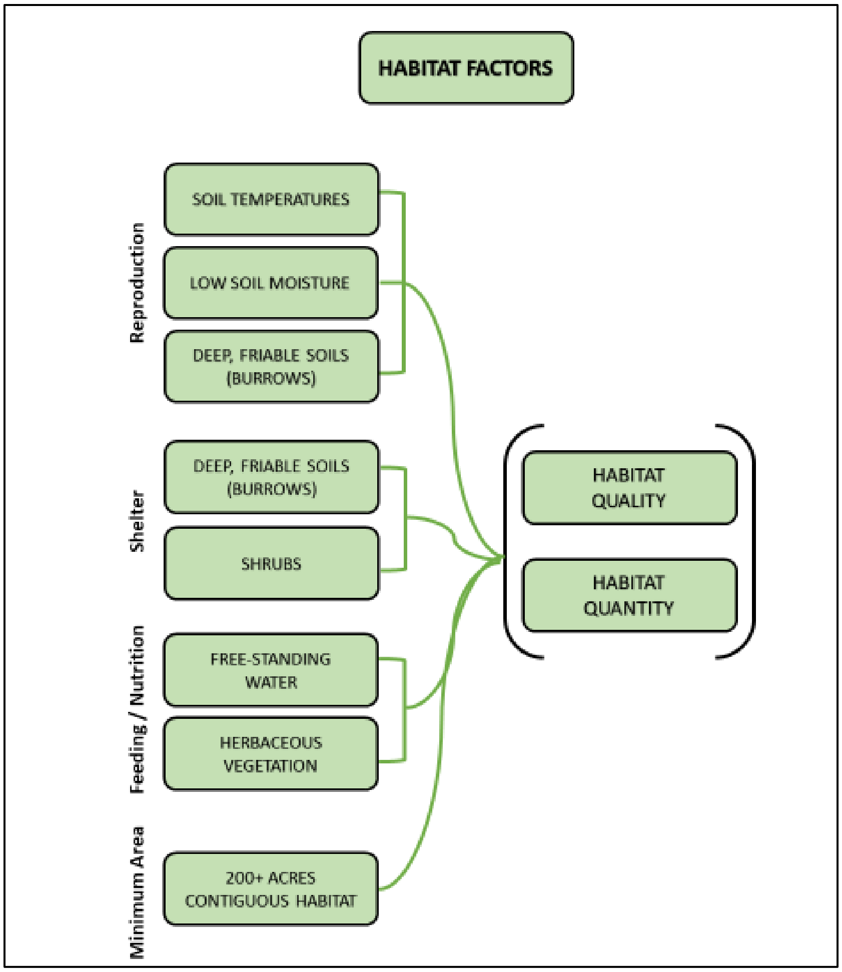

Figure 7. Conceptual model of the habitat factors (green boxes), needed by individual G. agassizii to breed, feed, and shelter, and complete each life stage of its life cycle.

2.3.1 Reproduction

Gopherus agassizii females start nesting in the spring and may lay 0 to 3 clutches with 1 to 10 eggs per clutch depending on environmental conditions (Turner *et al*. 1986, Mueller *et al*. 1998, McLuckie and Fridell 2002, Lovich *et al*. 2015). While mating activity occurs in the spring and summer, some studies suggest this may be courtship behavior with active mating primarily in the fall (Rostal *et al.* 1994, Palmer *et al*. 1998, Mulder *et al*. 2017; Berry and Murphy 2019). It is unknown if this varies by geographic location or annual conditions and more research is needed.

Females can store sperm for two to five years (Palmer *et al*. 1998, Mulder *et al*. 2017). In addition to the adult reproductive needs mentioned above (network of burrows, forage, and available water), *G. agassizii* eggs require specific conditions to hatch successfully and with equivalent sex ratios (USFWS 2011). *Gopherus agassizii* typically deposit eggs in friable soil that is within or near the entrance to burrows or at the base of shrubs. These burrows provide the eggs with shelter from predators and extreme temperatures.

This ability to adjust nest location and number of clutches is an important adaptive strategy for the species because *G. agassizii* sex is determined during incubation and is dependent on soil temperatures (Rostal *et al*. 1994, Baxter *et al*. 2008, USFWS 2011, Telemeco *et al*. 2013). Egg deposition soil characteristics include ideal soil temperatures that increase hatching success and juvenile size and influence population sex ratios (USFWS 2011). Soil temperatures influence *G. agassizii* population sex ratios and higher soil temperatures (88 to 91 °F) produce all females (USFWS 2011). Soil temperature not only influences the sex of the *G. agassizii* upon hatching, but also affects survival (Spotila *et al.* 1994, Rostal *et al.* 2002). Eggs incubated at temperatures ranging between 82.6 °F and 91 °F experience a higher hatching success (90 to 96 percent) than those incubated at 78.8 °F (≤ 50 percent) or 95.5 °F (29 percent). Higher soil temperatures decrease the time it takes for eggs to hatch (incubation time) and decreases the size (mass) of emerging hatchlings (Spotila *et al.* 1994). Hatching occurs at 89 days at 82.6 °F or in 68 days at 91 °F. It is believed that smaller hatchlings occur during hotter temperatures because the embryo has fewer days to consume the yolk and grow within the egg. Both incubation time and hatchling size may have direct impacts on predation rates and survival (Spotila *et al*. 1994, Rostal *et al*. 2002).

Ideal soil moisture levels increases hatching success (Spotila *et al*. 1994). In the 1994 study, approximately 90 to 93 percent of eggs hatched in nests that had low levels of soil moisture (0.4 percent). In contrast, only 11 percent of all *G. agassizii* eggs hatched without human intervention in soils with higher levels of moisture (4 percent). Water is absorbed though the soil by rigid shells of *G. agassizii* (capillary action) faster than water can evaporate through the portion of the shell exposed to air, and this increased water in the embryo impedes its viability (Spotila *et al*. 1994).

Gopherus agassizii are long-lived and grow slowly, requiring 13 to 20 years to reach sexual maturity, and have low reproductive rates during a long period of reproductive potential (Turner *et al.* 1984, Bury 1987, Germano 1994). Growth rates are greater in wet years with higher annual plant production (e.g., an average of 0.5 inches in an El Niño year compared 0.07 inches in a drought year in Rock Valley, Nevada; Medica *et al*. 1975). Data are not available at what age female *G. agassizii* stop laying eggs (Averill-Murray *et al.* 2018). Generation times (average time between two consecutive generations in the lineages of a population) are estimated to be 20 to 25 years (Turner *et al*. 1987, USFWS 1994, USFWS 2011), and individuals may survive 40 to 50 years or more (Germano 1992, Curtin *et al.* 2009, Medica *et al.* 2012).

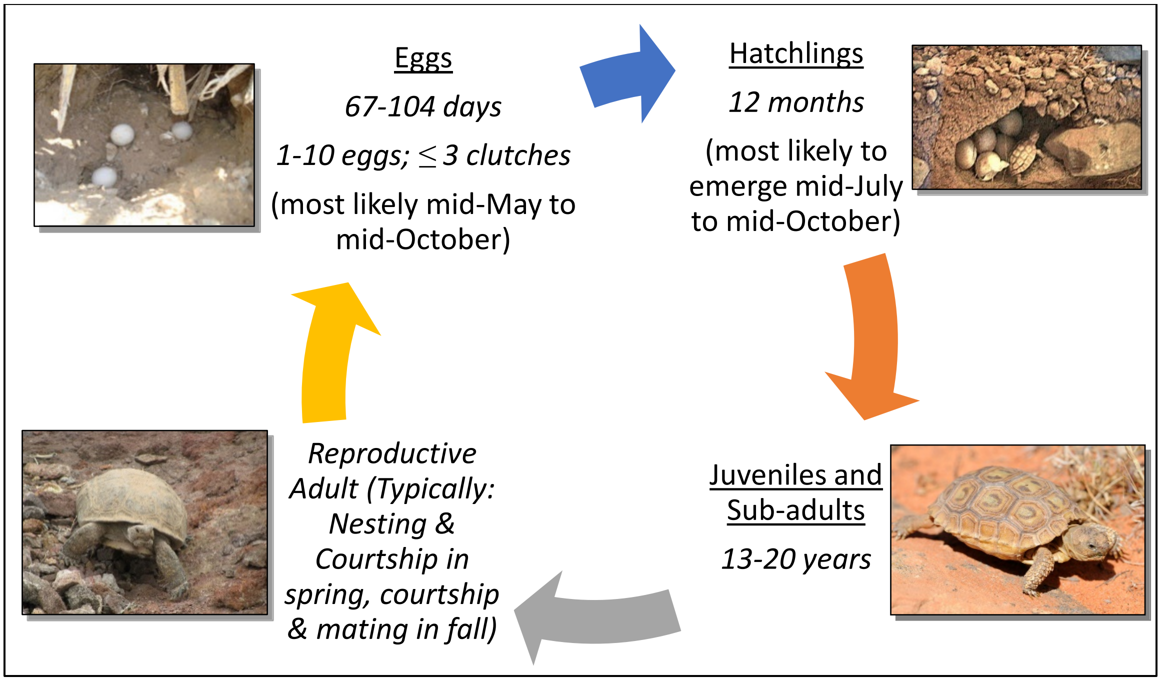

Figure 8. Life cycle diagram for the G. agassizii illustrating the five main life stages.

Table 5. Life cycle Gant chart summarizing G. agassizii monthly activities by life stage. Darkest cells indicate higher likelihood of aboveground activity. Lighter cells indicate lower likelihood of aboveground activity.

Life stage (activity)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Eggs (incubating)												
Hatchlings (emerging)												
Hatchlings, juveniles, sub-adults, and adults (above ground and feeding & dispersing)												
Adults (courtship)												
Adults (mating)												

The number of eggs (ranging from 1 to 10) as well as the number of clutches (ranging from 0 to 3; set of eggs laid at a single time) that a female *G. agassizii* can produce in a season is dependent on a variety of factors including environment, habitat, availability of forage and drinking water, and physiological condition (Turner *et al.* 1986, 1987, Henen 1997, Mueller *et* *al*. 1998, McLuckie and Fridell 2002). Success rate of clutches is difficult to measure, but predation appears to play an important role in clutch failure (Germano 1994). However, nest predation is highly variable (Bjurlin and Bissonette 2004). In addition, the regular presence of researchers may facilitate predator detection of *G. agassizii*, and systematic studies should be undertaken to better understand predator behavior as it relates to research and other human activities (Bjurlin and Bissonette 2004).

While spring and fall represent peak seasons of activity, *G. agassizii* have been sighted above ground in every season, including when snow is on the ground. However, wintertime above-ground activity is rare, especially in the UVR recovery unit (Table 5). Eggs are typically laid in the spring, but can be laid in the fall as well (Table 5; Berry and Murphy 2019). Incubation time can range from 67 to 104 days, taking longer when temperatures are cooler (Table 5; Spotila *et al.* 1994, McLuckie and Fridell 2002, Ennen *et al*. 2012), and mathematically eggs are least likely to be present in February and March. High numbers of hatchlings (young-of-year) die in the first year (Bjurlin and Bissonette 2004, Nagy *et al.* 2015), thus they are likely present in the highest numbers immediately following emergence from eggs in late summer (Table 5). However, we do not have data on mortality and recruitment rates for hatchlings.

2.3.2 Feeding, Nutrition, and Water

The species' habitat includes a diversity of perennial plants, and production of annual plants is high (Luckenbach 1982, Turner 1982, Turner and Brown 1982, Bury *et al.* 1994, Germano *et al.* 1994). The Mojave Desert is relatively rich in winter annual forbs, which serve as an important food source for the *G. agassizii* (USFWS 2011). During activity periods, *G. agassizii* eat a wide variety of herbaceous vegetation, particularly grasses and the flowers of annual plants (Berry 1974, Luckenbach 1982, Esque 1994). During periods of inactivity, they reduce their metabolism and water loss and consume very little food.

Gopherus agassizii will also forage on perennial grasses, woody perennials, and cacti as well as non-native species such as *Bromus rubens* and *Bromus tectorum* (*Bromus* spp.; red brome and downy brome) and *Erodium cicutarium* (redstem filaree). However, the non-native, cool-season annual grasses such as *Bromus* spp. do not have enough water or nitrogen to help *G. agassizii* excrete excess potassium. Excess potassium can cause health complications for *G. agassizii* (USFWS 2011, Drake *et al*. 2016) and *Bromus* seeds can become lodged and cause mechanical injury (Medica and Eckert 2007). Overall, *G. agassizii* activity is linked to the abundance of preferred food resources (Henen *et al.* 1998, Duda *et al*. 1999, Freilich *et al*. 2000, Krzysik 2002, Jennings and Berry 2015), and an increase in the abundance of vegetation is positively correlated with increases in *G. agassizii* egg production (Henen 1997, Mueller *et al*. 1998).

In unfavorable drought years, *G. agassizii* significantly decrease surface activity, home range size, burrows used, and average distances traveled per day; they remain mostly inactive or dormant underground (Duda *et al.* 1999), which reduces water loss and minimizes energy expenditures (Nagy and Medica 1986). Adult *G. agassizii* lose water at such a slow rate already that they can survive (though not necessarily thrive) for more than a year without access to free water of any kind and can apparently tolerate large imbalances in their water and energy budgets (Nagy and Medica 1986; Peterson 1996a, b; Henen *et al.* 1998). However, during extended drought periods, the ability of *G. agassizii* to drink while surface water is available following rains may be crucial for survival (Nagy and Medica 1986). Drought periods of at least two years combined with little or no plant biomass can cause high mortality (Longshore *et al.* 2003).

Availability of free-standing water for hydration (drinking) is critical to the survival of *G. agassizii* (Berry and Murphy 2019). Summer and winter rain storms provide an immediate source of drinking water, as well as stimulating and sustaining the plant forage essential to the survival of the species (USFWS 2011). *Gopherus agassizii* activity increases after rainstorms as they emerge to drink standing water, thereby reestablishing osmotic homeostasis (Peterson 1996b, Henen 2002). *Gopherus agassizii* can drink up to 20 percent of their body mass in water after a rainstorm. Yearly precipitation rates also influence reproduction (Berry and Murphy 2019). Egg production by female *G. agassizii* increases during years with wet conditions. While they may not be thriving, individuals can survive for more than a year without access to free water and can tolerate large imbalances in their water and energy budget (Henen 1997, USFWS 2011). However, drought combined with little or no plant biomass can cause high mortality rates in as few as two years (Longshore *et al.* 2003). *Gopherus agassizii* are typically found in areas that receive 2 to 8 inches of precipitation per year. While the species can endure periodic lapses in precipitation, extended droughts have been attributed to increases in dehydration and starvation mortality rates in *G. agassizii* (USFWS 2011).

2.3.3 Shelter

Gopherus agassizii spend much of their lives in burrows, even during their seasons of activity (Table 5). In late winter or early spring, they emerge from over-wintering burrows and typically remain active through fall. Activity decreases in summer, but *G. agassizii* often emerge after summer rainstorms. Throughout most of the Mojave Desert, *G. agassizii* occur most commonly on gently sloping terrain with sandy-gravel soils (Germano *et al.* 1994, USFWS 1994a, USFWS 2019a). *Gopherus agassizii* burrows require soils that are friable (easily crumbled) enough for digging burrows, but firm enough so that burrows do not collapse (USFWS 1994a). During the winter, *G. agassizii* will opportunistically use burrows of various lengths, deep caves, rock and caliche (hard layer of subsoil typically containing calcium carbonate) crevices, or overhangs for cover (Bury *et al.* 1994). *Gopherus agassizii* use burrows for predator avoidance, thermoregulation, overwintering, and reproduction. Burrows may be excavations into the soil, shallow scrapes under vegetation, or naturally occurring caliche caves, rock crevices or overhangs (Berry and Murphy 2019). *Gopherus agassizii* habitat is usually characterized by creosote bush scrub dominated by *Larrea tridentata* (creosote bush) and *Ambrosia dumosa* (white bursage) at lower elevations as well as rocky slopes in blackbrush scrub (*Coleogyne ramosissima*) and juniper woodland (*Juniperus* spp.) ecotones (transition zone) at higher elevations (Germano *et al.* 1994).

As a cold-blooded species, all *G. agassizii* life stages need burrows to shelter from cold and hot temperatures. *Gopherus agassizii* avoid thermal extremes (< 66 °F and > 100 °F) by taking shelter in burrows during the hottest part of the day and by brumating (i.e., ectotherm hibernation-like state) in burrows during low winter temperatures. They are most active when temperatures are between 69 °F and 91 °F (USFWS 2009). While inactive in burrows, *G. agassizii* lose extremely little water or energy while avoiding extreme temperatures. Burrows are also used for the deposition of eggs and for courtship behavior during nesting (Berry and

Murphy 2019). In the UVR recovery unit, winter burrows are typically south-facing and deep (USFWS 2019a).

Gopherus agassizii are found in a range of soil types but only if the texture is friable (not too much clay) yet stable enough to dig (not too rocky) (USFWS 2011). Sandy soils are only usable to the extent that they are stabilized by vegetation (USFWS 1994a) or biocrusts. *Gopherus agassizii* do not need to construct burrows at all if rock shelters are present, but these are only available in some parts of the desert such as washes in the lower parts of alluvial fans (Berry and Murphy 2019). Where rock forms a bedrock too close to the soil surface, it logically limits ability to dig deep enough shelters. Burrows are generally ≥ 3.3 yards in length with > 1.1 yard of soil over the deepest section (Berry and Murphy 2019). Rodent burrows are an additional burrow type that *G. agassizii* hatchlings and juveniles use for protection from predators and temperatures (Nafus *et al*. 2017). They are pre-dug by the rodents and opportunistically found. Rodent burrows serve the same function as rock and soil burrows but only benefit smaller size classes of *G. agassizii*.

2.3.4 Summary of Individual Resource Needs

Individual *G. agassizii* in the UVR recovery unit need burrows, native herbaceous vegetation, and water in order to complete each stage of the species' life cycle (Table 6). Networks of burrows covering about 200 acres are needed for breeding. In general, burrows and vegetation are the common resource needs across life-stages and function, providing shelter throughout the year and food in the active seasons. Free-standing water is needed to encourage above-ground movement necessary for breeding.

In summary, the resource needs of all life stages of *G. agassizii* individuals in the UVR recovery unit include:

- Nutrition resources to support growth that are provided by:
    - Forage – especially forbs, and
    - Availability of free-standing water spatially and temporally - especially in fall.
- Resources to support individual breeding and fecundity that are provided by:
    - Suitable soils (friable but firm), rocks, and shrubs to provide a network of burrows,
    - Overlap and connectivity between home ranges (about 200 acres per male home range),
    - Forage and water, and
    - Air temperatures 69 to 91 °F.
- Habitat characteristics to support the species physiological requirements for hatching, growth, and reproduction that are provided by:
    - Suitable soils, rocks, and shrubs for burrows,

- Soil temperatures ≤ 91 °F,
- Low soil moisture (0.4 percent), and

- Seasonal precipitation (primarily winter and spring).

Table 6. Resources needed by each G. agassizii life stage to breed, feed, and shelter.

Life Stage	Resources Need	Function & Description of the Resource Need
Eggs	Burrows Soil temperatures ≤ 91 °F Low soil moisture—0.4 percent	Burrows are important to *G. agassizii* courtship. Ideal soil temperatures increase hatching success of eggs, hatchling size, and influence sex ratios. Ideal soil moisture increases hatching success.
Life Stage	**Resources Need**	**Function & Description of the Resource Need**
Hatchlings, Juveniles, and Adults	Free-standing water	The occasional availability of free-standing water is crucial to the survival and reproduction of individual *G. agassizii*. More frequent availability of water during the fall active season is necessary for breeding.
Hatchlings, Juveniles, and Adults	Forbs & cacti for forage Shrubs for shelter	The species eats a wide variety of herbaceous vegetation, but a diet of primarily grasses may impact *G. agassizii* health. *Gopherus agassizii* activity and fecundity (fertility) is linked to the abundance of preferred food resources (forbs, cacti). *Gopherus agassizii* also use vegetation as shelter and can be found sheltering in pallets under shrubs.
Hatchlings, Juveniles, and Adults	Rock and soil burrows Friable and deep soils	*Gopherus agassizii* avoid thermal extremes and conserve water and energy by taking shelter in burrows. Hatchlings will sometimes use pre-dug rodent burrows for shelter. Burrows are also used by reproductive adults for the deposition of eggs and for courtship behavior. *Gopherus agassizii* burrows are found in a range of soil types but only if the texture is friable (not too much clay) yet stable enough to dig (not too rocky). Burrows are generally ≥ 3.3 yards in length with > 1.1 yard of soil over the deepest section.
Adults	200 acres of contiguous habitat	Male home ranges can be larger than 200 acres (0.31 mi^2) and individuals have been documented to travel up to 7 miles. This home range sizes allows individuals to support the genetic mixing necessary for long-term survival of wild populations.

2.3.5 Uncertainties Regarding Individual Needs

Overall, individual needs of *G. agassizii* are well understood and easily identified. However, the precise quality and quantity of these resources needed by *G. agassizii* are unknown. For example, we understand that *G. agassizii* need shrubs for cover and forbs for forage, but the quantity, structure, and diversity metrics of these habitat components necessary to support *G. agassizii* survival are not well understood.

2.4 Demographic Needs for Analytical Units within the UVR recovery unit

In this section, we determine the demographic factors important for populations of *G. agassizii* within the UVR recovery unit AUs to be resilient to and withstand stochastic events or fluctuations in environmental conditions. To evaluate AU demographic needs we evaluated each discrete AU. The demographic or distribution factors that each *G. agassizii* AU needs to be resilient are influenced by the presence of resource and habitat factors, which correspond to the needs of individual *G. agassizii* (Figure 7).

In general, resilient AUs in the UVR recovery unit provide habitat conditions that support *G. agassizii* demographic factors such as abundance, density, and growth rates that allow sub-populations to recover from stochastic events. Stochastic events that may affect the 11 *G. agassizii* AUs include drought, wildfires, disease, and weather such as harsh winters, late freezes, and high spring and fall temperatures (USFWS 2011; Risk Factors). Figure 9 and Table 7 summarize the demographic factors and their contribution to *G. agassizii* resiliency in the AUs.

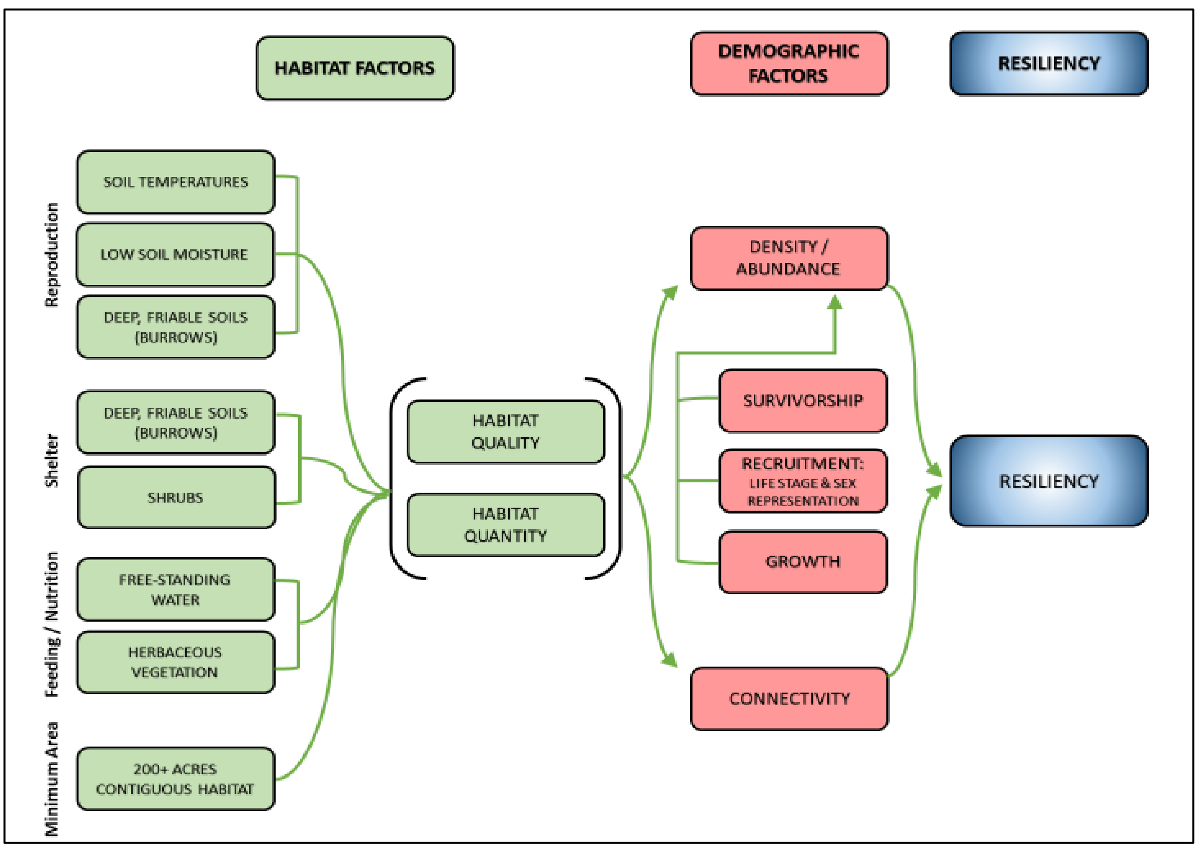

Figure 9. Relationship of habitat factors to demographic factors.

Table 7. Demographic factors that contribute to G. agassizii AU resiliency.

Demographic Factors	Need for Resiliency	Metric
Abundance and Density	Sufficient abundance to withstand periodic abundance crashes and avoid inbreeding depression	Adult count (abundance and density)
Recruitment	Successful reproduction and addition of new individuals reaching reproductive adult status	Juvenile count
Survivorship	Survival of reproductive *G. agassizii* individuals.	Adult annual survival (averaged over 5 years)
Population Growth	Sufficient population growth rate to maintain or increase abundance	Trend in adult count over time
Connectivity within AUs	Connectivity within AU to allow recovery following stochastic events, and promote the exchange of genes	Human or topographical barriers
Connectivity between AUs	Connectivity between AUs to allow demographic recovery following stochastic events, and promote the exchange of genes	Distance and amount of suitable habitat between AUs, human or topographical barriers, and genetics

For *G. agassizii* in the UVR recovery unit, all of the AUs require recruitment and survivorship to maintain sufficient abundances and growth rates (USFWS 2011, USFWS 2019a). Sufficient habitat quantity and quality that provide the resources needed by individual *G. agassizii* to breed, feed, and shelter, are directly linked to the fulfillment of the demographic requirements (Figure 9).

2.4.1 Abundance and Density

Sufficient abundance of animals is important to avoid inbreeding depression, loss of genetic variation, and accumulation of new mutations. Abundance also provides resiliency, or the ability of a sub-population to withstand stochastic events (USFWS 2011).

For the 1994 recovery plan, the USFWS established a minimum abundance target of 5,000 to 10,000 adult *G. agassizii* to maintain healthy populations, and effective population sizes of 500 - 5,000 *G. agassizii* to support long-term evolutionary potential (USFWS 1994a). However, because *G. agassizii* life spans and responses to management exceed most management timeframes, some have suggested that relaxing minimum viable abundance targets for long-lived organisms may be more realistic in some management situations (Shoemaker *et* al. 2013).

The 1994 recovery plan also indicated approximately 10 adult *G. agassizii* per mi^2 should be sufficient to avoid most demographic stochasticity events in large populations, such as random variations in sex ratios, age distributions, and birth and death rates (USFWS 1994a). However, given the high densities documented locally and smaller population sizes more subject to stochastic events (McLuckie *et al.* 2020), local experts determined that densities greater than 39 adult *G. agassizii* per mi^2 may represent realistic local density targets. While upper density limits (carrying capacity) for each AU are unknown, it is recognized that at some level densities would become unsustainable. Workshop participants indicated that managing for these abundance and density targets, or establishing targets for smaller AUs to connect and support larger AUs, should be sufficient to prevent functional extirpation and genetic deterioration over the next 50 years (two *G. agassizii* generations) (USFWS 2019a).

2.3.1.1 Population Viability Analyses and Densities

A population viability analysis (PVA) is a predictive tool that can be used to estimate population growth rates and evaluate the likely persistence of populations given environmental change and demographics. Previous PVAs for *G. agassizii* populations were based on populations with dissimilar ecology to the Red Cliffs Desert Reserve, using data collected primarily from California and Nevada (USFWS 1994a). However, until other modeling is available, these PVAs represent our best available information. Using population viability analyses, the FWS determined in 1994 that (1) reserves should be large enough to contain at least 20,000 individuals to buffer the population adequately from extinction vulnerability due to small size and (2) populations must be managed to prevent lambdas from falling below 1.0 on average; otherwise the populations become extremely vulnerable to extinction. When populations are well above minimum viable density (e.g., 30 or more *G. agassizii* per square mile – in 2017, the Red Cliffs Desert Reserve supported 44.5 *G. agassizii* per square mile) and lambdas can be maintained, on average, at 1.0 or greater through elimination of extrinsic sources of mortality, reserves greater than 1,000 mi^2 that provide high-quality, secure habitat for 10,000 to 20,000 tortoises should provide adequate persistence probabilities for the species well into the future. In other words, the Reserve density counterbalances the small size, but the lambda < 1, as evidenced by the declining population abundance, indicates intensive management or extrinsic factors that support conservation remain a necessity.

A recent analysis of rangewide *G. agassizii* population growth rates found that populations in nearly all recovery units and conservation areas, including the UVR recovery unit, were declining (Allison and McLuckie 2018). The UVR recovery unit may be declining at 3.2 percent annually (standard error 2.0 percent); however, there are three uncertainties with this decline rate:

1) The decline rate in Red Cliffs Desert Reserve was used to extrapolate the decline rate in the rest of the UVR recovery unit. However, the decline outside the intensively managed Red Cliffs Desert Reserve is likely higher where the species is not actively conserved; and

2) The decline rate is an annual estimate, but most of the loss of individuals that resulted in the decline in population abundance occurred following drought and wildfire stochastic events in the early 2000s. In addition, four recent large wildfires impacted West and East Cottonwood AUs; the impact to *G. agassizii* survival and recruitment is not yet known. It is likely that the new wildfires will continue and result in additional stochastic loss of individuals. Based on this information, it is highly probable that Red Cliffs Desert Reserve, Zone 3 will have another large wildfire again. Population declines and factors that contribute to population recovery or overall population trends should be more closely studied to ensure conservation actions are adequately targeting factors that contribute to viability.

3) Higher precision data increase our ability to detect changes and accurately ascribe trends. The Technical Committee (of the HCP) recently supported decreasing the total number of transects sampled and this decrease in precision will need to be considered when drawing conclusions about trends in the future.

Overall, we conclude that a population with a minimum density of 10 adult G. agassizii per mi^2 would require at least 500 mi^2 to be genetically viable (5,000 adult G. agassizii). Multiple smaller areas may need to be intensively managed in areas unable to support 1,000 mi^2 (such as the UVR recovery unit). If population growth rates (lambdas, proportional change in abundance from one year to the next) are below 98 percent on average, no population size is large enough for persistence to 390 to 500 years (15 to 20 *G. agassizii* generations; USFWS 1994a).

2.4.2 Recruitment

Recruitment is a demographic measure of the amount of individuals being added to an AU through survival of young into the population of reproducing adults or immigration of reproducing adults from nearby populations into the target population. Recruitment of females into a population after the first year ranges from 0.51 to 1.18 (Campbell *et al*. 2015) assuming hatchling survival of 0.3 to 0.7. However, recruitment of older life stages, specifically reproductive *G. agassizii*, is essential to support AU resiliency in order to maintain sufficient number of animals. *Gopherus agassizii* populations may be able to withstand high rates of natural juvenile mortality (up to 99 percent) if annual adults survival does not drop below approximately 98 percent (USFWS 1994). However, if adult survival declines, juvenile mortality would need to be maintained at approximately five percent to ensure recruitment into the breeding population (Congdon *et al*. 1993, USFWS 1994a). In addition, any reduction in adult fecundity also increases a population's reliance on juvenile recruitment. Generally speaking, the rate of recruitment must equal or exceed the rate of mortalities and emigration (Berry and Murphy 2019).

2.4.3 Survivorship

Survivorship is a demographic measure of the number of *G. agassizii* individuals in an AU surviving to adulthood and contributing to the next generation each year. Natural survival rates for *G. agassizii* after they reach adulthood may range from 77 to 99 percent, depending on the location and habitat conditions (Berry and Murphy 2019). Generally, survival rates increase with size, and adult annual survival has the greatest impact on population dynamics and population resiliency (Turner *et al*. 1987). Younger life stages for this species are difficult to detect, and therefore less is known about recruitment and survival rates prior to reaching maturity. If adult survivorship is decreasing or declines cannot be managed or reversed, recruitment of early life-stages becomes increasingly important (Recruitment).

2.4.4 Connectivity

Habitat connectivity between populations is important for *G. agassizii* to maintain healthy distribution, support metapopulation dynamics (e.g., rescue effects), and genetic variability (USFWS 2011, USFWS 2014a). Connecting blocks of *G. agassizii* habitat improves genetic fitness (ability to maintain or increase abundance in succeeding generations) by allowing natural movement that supports the natural evolutionary trajectory of the species including mixing to sustain natural genetic diversity and prevent inbreeding (Forman *et al*. 2003). In an unobstructed desert landscape, home ranges of individual *G. agassizii* overlap such that breeding and other types of social interactions occur, thereby allowing natural movement that provides for genetic and demographic mixing among individuals and their natural distribution among sub-populations (Harless *et al*. 2009). However, roads and urban areas form barriers to movement and distribution and tend to create unnaturally small, isolated sub-populations which are more susceptible to extirpation from stochastic events compared to large, inter-connected populations (Wilcox and Murphy 1985). Demographic and genetic connectivity refers to the ability of individual *G. agassizii* to move within and among (intra- and inter-) AUs, and is measured by suitable habitat availability (including a network of burrows) among and between populations as well as distance between AUs and the presence and porosity of anthropogenic and topographical barriers. If *G. agassizii* can move and disperse freely throughout the UVR recovery unit, gene flow can be maximized among sub-populations in the UVR recovery unit into the future.

Rangewide, *G. agassizii* exhibit a pattern of isolation-by-distance, which means that populations closer to each other are more similar genetically than those farther away due to dispersal limitations of the species (and not due to selective pressures) (USFWS 2011). In the past, this species had access to large areas of inter-connected habitats. Due to this, there was a high level of natural gene flow within and among populations and low levels of genetic differentiation across the range of the species (Dutcher *et al.* 2020). However, recent studies have found evidence of local genetic clustering, likely resulting from population isolation caused by natural (slope, distribution of suitable habitat) and anthropogenic (interstate highways, railways) habitat fragmentation (Latch *et al.* 2011, Dutcher *et al.* 2020). Historically, genetic exchange occurred naturally between the UVR recovery unit and the adjacent NEM recovery unit (Utah, Arizona, and Nevada); currently, it is thought that more studies are needed to determine if animals are moving between these recovery units resulting in genetic exchange (USFWS 2011).

2.4.5 Summary: Analytical Unit Demographic Needs

In order to be demographically resilient, *G. agassizii* AUs need sufficient abundance, recruitment, survivorship, growth (rate), and genetic and demographic connectivity among AUs to support these factors. A decline in abundance can be the result of a decline in recruitment and survivorship causing a low growth rate or can result from reduced or impaired habitat acreage or forage quality available (i.e., carrying capacity). Because *G. agassizii* are long-lived, they may persist in an isolated and small area for a long time and maintain a resource pool for genetic diversity. However, over several generations, abundance, reproduction and recruitment must be sufficient to maintain genetic diversity (i.e., avoiding inbreeding depression and loss of fitness). Low intra- and inter-AU connectivity can affect resiliency by limiting gene flow thereby affecting heterozygosity or increasing the chance of inbreeding. Connectivity within and between AUs can help maintain demographics and genetic diversity; however, habitat condition can also limit carrying capacity thereby negatively affecting population dynamics.

2.4.6 Uncertainties and Assumptions Regarding AU Needs

We currently do not understand the level of dispersal and movement needed to maintain healthy genetic diversity in all AUs. In addition, the analysis that supports calculations of minimum viable population sizes needs to incorporate a level of natural or unnatural stochasticity that results in population fluctuations in light of population parameters such as generations length, reproduction and recruitment. The current methodology should be updated to include these considerations into UDWR's systematic monitoring data. In the six AUs outside the Red Cliffs Desert Reserve, recruitment and survival rates are for the most part unknown.

2.5 Redundancy and Representation Needs in the UVR recovery unit

For this report, we summarize needs within the UVR recovery unit related to ensuring redundancy and representation. Redundancy spreads risk among multiple AUs or areas to minimize the risk due to catastrophes or large-scale, high-impact events. Representation uses diversity as a proxy for adaptive capacity (Smith *et al*. 2018).

The AUs in this recovery unit are distributed in a ring shape around the municipal center of St. George, Utah (Figure 5). The AUs were defined primarily by fragmentation barriers (Connectivity). The 11 AUs in the UVR recovery unit may support some level of redundancy. Having multiple AUs distributed across the UVR recovery unit spreads the risk of a catastrophic event, such as wildfire, affecting multiple AUs. For representation, the ecological, morphological, physiological, behavioral and genetic diversity describe the recovery unit's ability to adapt to novel biological and physical changes in its environment. In general, the UVR recovery unit needs a sufficient number of resilient AUs with ecological and genetic diversity in order to withstand catastrophes and adapt to environmental change. We describe the *G. agassizii*'s needs for redundancy and representation below and summarize the key aspects in Table 8.

Table 8. Redundancy and Representation Needs at the UVR recovery unit level.

Species-Level Needs	Definition	Needs
Redundancy	Resilient AUs distributed across geographical areas reducing the chance that a catastrophic event extirpates the entire recovery unit population	Widespread AUs to ensure all AUs are not exposed to a single or series of catastrophic events
Representation	Having a breadth of genetic and phenotypic diversity distributed across resilient AUs thereby maintaining evolutionary processes	Preserve the breadth of variation in biological traits and genetic diversity; maintain adaptability by ensuring AUs occupy an array of environments.

Individual *G. agassizii* in the UVR recovery unit need sufficient shrubs, forage, and burrows to breed, feed, and shelter (Individual Resource Needs). Individual *G. agassizii* success in breeding, feeding, and sheltering influences the overall size, or number of individuals in each of the 11 AUs within the UVR recovery unit. Therefore, for AUs to have enough resiliency to contribute to overall recovery unit redundancy (spreading risk among multiple resilient populations), they need to exhibit recruitment and survivorship that can maintain a positive or stable growth rate. To ensure an individual catastrophic event is unlikely to affect the entire population in the recovery unit, intra-population connectivity and sufficient numbers of individuals is necessary to avoid local extirpations, inbreeding depression, and reduction in individuals' fitness (USFWS 1994a). In this way, multiple resilient AUs provide redundancy to the recovery unit. Alternatively, multiple connected AUs with improved collective resilience or a range of geographic variation provides increased capacity to adapt to change (representation). We discuss the ability of each AU to contribute to redundancy and representation in the recovery unit in Current Condition: Redundancy and Current Condition: Representation.

Connectivity between recovery units also contributes to the redundancy of the recovery unit to the species rangewide by allowing migration of individuals among recovery units in the event of catastrophic loss in one or more AUs within the UVR recovery unit. Recovery unit or to the extent possible connectivity among conservation areas supports population dynamics and genetic integrity of *G. agassizii* across the range and is an important component of species recovery (Averill-Murray *et al*. 2012).

2.5.1 Uncertainties Regarding Recovery Unit Needs

It is unclear how much geographic and genetic variation between the 11 AUs contributes to the overall representation of the UVR recovery unit (T.C. Esque, USGS, personal communication, December 5, 2019). *Gopherus agassizii* are slow to reproduce and genetic changes are thus slow to present in the population. Recent genetic samples were taken in the UVR recovery unit, but the samples have not been analyzed for results. Currently available genetics data from the UVR recovery unit is not sufficient to evaluate or as an index of isolation. It is unclear how much genetic variation across the 11 AUs would support the population in the UVR Recovery unit to remain on a natural evolutionary trajectory.

Chapter 3: RISK AND CONSERVATION FACTORS

In this chapter, we review the negative and beneficial factors affecting the historical, current, and future conditions of the *G. agassizii* in the UVR recovery unit. Factors that have a negative impact on tortoise individuals are referred to a risk factors (also as stressors); factors that have a beneficial effect are referred to as conservation factors. We end with a summary of our analysis of the impact that these factors are having on *G. agassizii* in the UVR recovery unit.

3.1 Risk Factors

For our assessment of stressors that affect the resiliency of *G. agassizii* AUs, we relied on the available scientific literature, the USFWS's species' recovery plans (USFWS 1994a, USFWS 2011), the most recent information from the *G. agassizii* spatial decision support system (SDSS, Darst *et al*. 2013, Murphy *et al*. 2016), and the regularly updated rangewide Status of the Species report (USFWS 2019b). The SDSS was developed by the USFWS using a conceptual model to provide information on how stressors in an area contribute to population change and how effective recovery actions are expected to be at reducing stress to population change from those threats (Darst *et al*. 2013, Murphy *et al*. 2016). The SDSS identified 90 stressors that negatively affect individual *G. agassizii* (Appendix 2). However, many of these are not relevant to the UVR recovery unit or do not occur at a level to cause a UVR recovery unit-level response or affect the resiliency of any of the AUs. Those not relevant were not carried forward in this analysis.

In 2013, we used the SDSS to rank the biggest threats that affect population change and status of the *G. agassizii* in conservation areas and recovery units (Table 9; USFWS 2013). We then used the SDSS to calculate range-wide and recovery unit priorities for recovery actions based on these rankings (USFWS 2014b). The recovery implementation teams for each recovery unit provided input on other priorities that may be relevant (e.g., addressing the increased threat of wildfires), allowing for adaptive management that responded to shifting threats.

In the Workshop, we presented the local *G. agassizii* experts with stressors from various sources, including the SDSS stressors (full list included in Appendix 2), threats identified in the recovery plans (USFWS 1994a, USFWS 2011; which largely mirrored the SDSS), and other sources. The group individually identified the top ten threats that were the most impactful stressors in the UVR recovery unit (Table 9) and then characterized them in each of the AUs (Current Condition: Resiliency). Figure 10 illustrates how factors relate to *G. agassizii* population resiliency. These factors negatively affect all AUs of the *G. agassizii*; however, the level of effect varies and some factors may be exacerbated in areas with limited habitat or lower *G. agassizii* abundance. In addition, climate projections were conducted after the Workshop and included in this analysis.

Table 9. Ranking of stressors acting on the population of G. agassizii in the UVR recovery unit (USFWS 2013, 2014b and 2019a).

Rank	UVR recovery unit (2013)	Red Cliffs Desert Reserve (2013)	UVR recovery unit Updated in Workshop (2019)
1	Landfills	Non-motorized Recreation	Past Wildfire
2	Human Access	Tourism and recreation areas	Invasive Plants
3	Agriculture	Landfills	Drought
4	Past Fire	Human Access	Predation (Ravens)
5	Tourism and recreation areas	Past Fire	Motorized Recreation
6	Free-roaming Dogs	Drought	Non-motorized Recreation
7	Grazing	Ravens	Disease (Mycoplasm)
8	Non-motorized Recreation	Disease	Urbanization
9	Ravens	Temperature Extremes	Paved Roads
10	Drought	Motor Vehicles on Paved Roads	Human Access (specifically off-leash dogs & illegal trails)

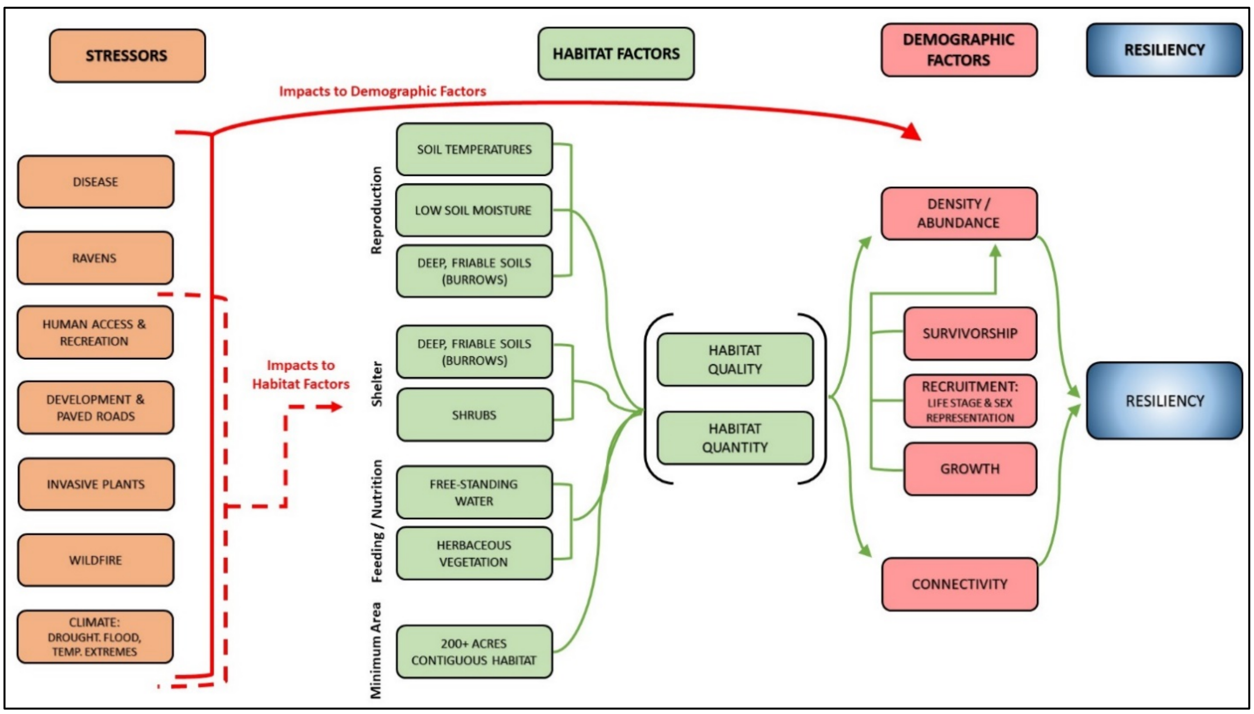

Figure 10. Relationship of primary stressor sources to habitat and demographic factors for G. agassizii in the UVR recovery unit.

3.1.1 Small Isolated Habitat and Abundance

The stressors listed in Table 9 and discussed below are exacerbated by the small size of the isolated AUs in the UVR recovery unit and included in our analysis. Previous rangewide efforts looking at stressors to *G. agassizii* (e.g., USFWS 1994a and 2011, Darst *et al*. 2013) did not include the stressor of small isolated pockets of *G. agassizii*. However, abundance and connectivity within this recovery unit is a key driver to the UVR recovery unit resilience. Natural or human-caused effects limit habitat abundance or distribution in some AUs. Negative effects on population viability, such as reduced reproductive success or loss of genetic variation and diversity, can become more evident as populations decline or become more isolated. When coupled with mortality related to human activity, fluctuations in abundance, and environmental factors, the long-term persistence of small populations in restricted habitat areas is generally unlikely (Traill *et al.* 2010). In addition, if the effective population size becomes too low genetic diversity can be compromised, and the population may be at risk of inbreeding depression (Mills 2012). Inbreeding depression can result in the loss of genotypic and phenotypic expression as well as the potential for deleterious genetic prevalence (Charlesworth and Charlesworth 1987, Lynch *et al.* 1995) and a reduction in the overall genetic fitness of individuals (Kimura and Ohta 1971, Wright 1977). These genetic limitations can result in permanent consequences for an isolated group if deleterious genes become fixed in the population. Loss of genetic variation reduces representation, as well as individual fitness and resilience to environmental stressors.

3.1.2 Wildfire and Invasive Plants

Wildfire frequency, extent, and intensity within the UVR recovery unit and Red Cliffs Desert Reserve has increased as a result of the increase and establishment of non-native invasive annual grasses and forbs as well as access by humans and subsequent activity that causes fires (Figure 11). Recurrent fires can alter habitat structure and plant species composition, including preferred *G. agassizii* forage plants (Brooks and Esque 2002). Impacts to desert tortoises from wildfires can be variable (Esque *et al*. 2003) and include direct burning fatalities or injuries, dehydration, exposure to high temperatures, or smoke inhalation, as well as indirect affects to animal condition that may result from a loss of forage, change in ecotypes and hydrology, and damage to soil and burrows (Esque *et al*. 2003).

In 2005 and 2006, wildfires heavily impacted two of the six *G. agassizii* recovery units, burning approximately 19 percent of *G. agassizii* habitat in the UVR and 10 percent in the NEM. Subsequent UDWR field inventories identified *G. agassizii* mortalities that were directly attributed to the effects of the fires (McLuckie *et al*. 2007). In Red Cliffs Desert Reserve, 65 percent of zone 3) burned between 1993 and 2012 (BLM 2020). Some of the Red Cliffs Desert Reserve's most densely occupied *G. agassizii* habitats adjacent to Cottonwood Springs Road experienced three large fires (2,250, 7,900, and 9,750 acres burned) in that same time period. In Red Cliffs Desert Reserve, zone 3, eight of eighteen documented fires were caused by humans. Proximity to roads can result in non-native invasive plant species introduction and wildfire ignition from the roads themselves or human access (Darst *et al*. 2013). In July 2020, the Turkey Farm Road and Cottonwood Trail fires burned approximately 11,754 acres in the Red Cliffs Desert Reserve, Zone 3. The Cottonwood Trail fire was caused by a blown tire, and the Turkey Farm Road fire was caused by illegal fireworks. In October, the Lava Ridge fire burned another

348 acres (USDOI 2020) and in November the Snow Canyon fire burned 799 acres of habitat– both of these were also caused by human-use activities. Based on this information, it is highly probable that Red Cliffs Desert Reserve will experience large and small wildfires in the future.

Invasive, non-native plants (plants not native to the *G. agassizii* ecosystem) negatively impact G. agassizii habitat, reduce health and growth of *G. agassizii* individuals, and alter the native plant community structure, composition, productivity, nutrient cycling, and hydrology (Vitousek 1990). One hundred sixteen species of non-native plants occur in the Mojave and Colorado Deserts (Brooks and Esque 2002) and are common to areas abundant in G. agassizii. These non-native plants occur primarily in areas of past and ongoing land disturbance (Alston and Richardson 2006). Sahara mustard (*Brassica tournefortii*) and London rocket (*Sisymbrium irio*) are spreading throughout the desert southwest, including the Red Cliffs Desert Reserve and Washington County. A dominance of invasive grasses, which are lower in nutrients than forbs, diminishes the quality of food available for tortoises. For example, juvenile *G. agassizii* that were fed only native forbs or a combination of native forbs with native grasses were healthier (multiple metrics) and had a much higher survival rate than *G. agassizii* fed solely on grasses (invasive or native; Drake *et al*. 2016). *Gopherus agassizii* feeding only on grasses showed losses of fat and muscle mass and increased muscular atrophy. In addition, *G. agassizii* fed only the non-native invasive red brome grass (*Bromus rubens*) showed signs of weakened immune systems, declines in growth, overall body condition, and survival. Symptoms included dehydration and emaciation (recessed eyes, low body mass, and lethargic behavior), anemia, and thinning of the shell (Drake *et al*. 2016). Others have hypothesized that deficiencies in nitrogen and water for *G. agassizii* may be due to a lower water content in non-native invasive plant species (Henen 1997, as cited in USFWS 2011). Additionally, Oftedal et al. (2002) noted that *G. agassizii* bypass plants high in potassium due to the burden of potassium excretion, which is accompanied by a loss of water and nitrogen. Non-native invasive grasses, particularly split grasses (*Schismus barbatus* and *S. arabicus*), are high in potassium, and *G. agassizii* will avoid these species when forbs are abundant (Oftedal *et al*. 2002).

Bromus spp. occupancy mapping from 2001 through 2011 indicates high abundance and density of invasive cool-season annual grasses in the Red Cliffs Desert Reserve with several persistent problem areas, even in years when conditions were not conducive to their growth (USGS 2019). In 2005, approximately 13,000 acres in Red Cliffs Desert Reserve, zone 3 (nearly half the *G. agassizii* habitat in the zone) was mapped as high density *Bromus spp*. Invasive grasses, particularly *Bromus* spp., can out-compete native grasses and forbs in *G. agassizii* habitat, because these grasses require less water than most native plants for germination (USDA 2013). Non-native, invasive plant species often increase wildfire potential compared to native vegetation (Esque *et al*. 2003, Fenstermaker 2012). After a fire, non-native annual vegetation is more likely to dominate the landscape due to the absence and higher resource requirements of slower-growing, native perennial species (Boarman 2002). The proliferation of non-native invasive grasses creates a cycle of fire and decreasing habitat quality (Brown and Minnich 1986, USFWS 1994a, Brooks 1999, Brooks and Esque 2002). Previously burned areas and the resulting non-native invasive plants may support wildfire-return intervals as short as five years in heavily affected areas where wildfire was previously scarce or nearly absent (Hood and Miller 2007).

The climate analysis indicates that the historic number of high fire danger days averaged 73 and that fire danger days may increase to 96 days (range 73 to 114, or 0 to 41 additional fire danger days). Three models projected at least 19 days additional fire danger days, and one model projected no change. Fire danger variability between models appears to be driven by variability in precipitation (Appendix 5).

High fire danger days may increase up to 41 days more than the historic average. This is driven by precipitation and exacerbated by hotter and drier climate conditions. Invasive plant species are projected to expand and increase the fuel load in wet winters and springs (i.e., El Niño conditions; Meyer et al. 2001, Bradley and Mustard 2005, Salo et al. 2005, Germino et al. 2016). Fire risk is greater after these wet periods when dry conditions return. Looking at the climate results holistically, future summer precipitation (monsoons) may be more variable and extreme while wet years may be followed by more frequent droughts. Variability and cycles such as this provide increased opportunities for higher fuel load (during wet years) and higher probability of wildfire (during dry years). Overall, our climate modelling projections indicate that without intervention, invasive plant species will continue to expand and wildfire potential will continue to increase.

In summary, wildfires can have numerous immediate and delayed impacts on *G. agassizii*. Non-native invasive grasses accelerate and exacerbate wildfire frequency and extent. Population resiliency is negatively impacted by the increase in non-native invasive grasses and wildfires.

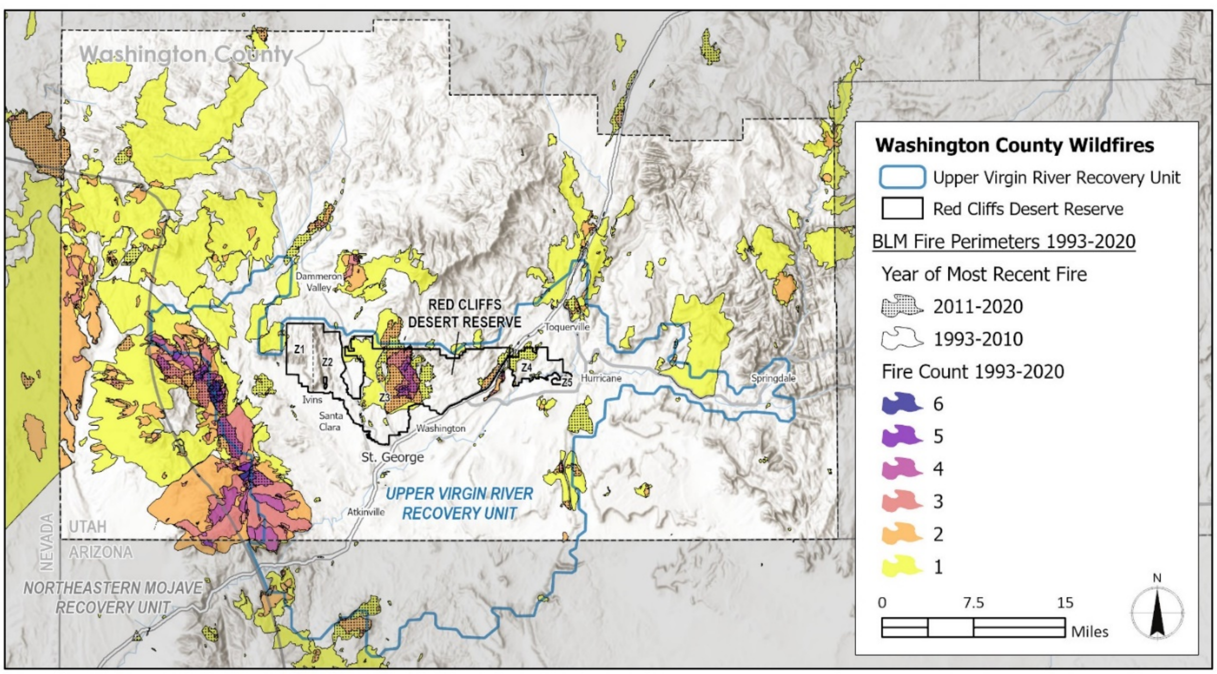

Figure 11. Past wildfire maps in the UVR recovery unit and Red Cliffs Desert Reserve

3.1.3 Drought and Changing Climate Conditions

Droughts are a frequent and natural part of Utah's climate (Frankson *et al*. 2017); however, drought conditions may impact *G. agassizii* and their habitat depending on the severity and duration of the drought. Drought conditions limit spring, summer, and fall forage for *G. agassizii*, and contribute to the establishment of non-native invasive annual grasses (Melgoza *et al*. 1990, USDA 2013). Extended periods of drought can lead to physiological effects to *G. agassizii* including stress, dehydration, malnutrition, starvation, and death, as well as reducing overall activity, limiting opportunities to interact or breed (USFWS 2011). Recurring or long-term droughts may thus have significant impacts on *G. agassizii* population and AU resiliency by reducing survivorship, recruitment, and population sizes (USFWS 2019b). Based on climate projections severe droughts similar to 2002 are expected to occur as frequently as 4 in every 5 years to every 30 years (Appendix 5). It is likely we will see at least one severe drought during the 49 years of the climate analysis, and drought conditions are likely to intensify as temperature increases are predicted to continue throughout the American Southwest and locally (Gonzalez *et al*. 2018, Rangwala 2020).

Because *G. agassizii* are ectotherms, they may be particularly sensitive to changes in ambient temperatures (Barrows 2011, Huey and Berrigan 2001). Increased air temperatures could mean less suitable and shorter above-ground periods of time available for *G. agassizii* to forage. It is unknown if this species has the genetic plasticity or adaptive capacity to shift hibernation periods or suitable forage conditions. Changes in temperature also affect rate of egg development and incubation timing (Rostal *et al*. 1994, Lewis-Winokur and Winokur 1995). Although *G. agassizii* clutch timing seems to be correlated to inter-annual temperature variation, this species can lay two to three clutches a year in the right conditions. This adaptation may ameliorate some temperature impacts to egg development (Lovich *et al*. 2012). In addition, females can nest earlier or later to adjust for slight annual differences in temperature and may select nest sites that are more or less shaded or deeper in their burrows in response to temperature (Refsnider and Janzen 2012, Ennen *et al*. 2012). Precipitation events can also affect clutch health; drought results in reduced clutch frequency while increased rainfall may increase clutch frequency (Lovich *et al*. 1999, Lovich *et al*. 2015).

For *G. agassizii*, higher temperatures influence sex during embryo development; sustained high temperatures could result in all female clutches. Although reptile species with temperature-dependent sex determination have adapted to shifting temperature during natural climatic change (Booth 2006), more rapid rate of change in climate may be limited by adaptive capacity of the *G. agassizii* (USFWS 2011, Lovich *et al*. 2012, Lovich *et al*. 2017). Even with earlier and deeper nesting, warmer temperatures during incubation may still result in skewed sex determination or egg mortality (Spotila *et al*. 1994, Telemeco *et al*. 2013). It is unclear if adaptations in behavior can keep up with environmental change (i.e., behavioral adaptation rate; Telemeco *et al*. 2013). The time frame in the climate analysis is 49 years and was selected due to the difficulties that are encountered from extrapolating beyond 50 years. This time frame, which only spans two *G. agassizii* generations, may not be sufficient for adaptive response on the time of nesting, choice of nest sites, the range occupied, or sex determination in this long-lived and slow-to-recruit species according to Booth (2006).

Climate change that influences vegetation conditions can also impact hatchling survival (Wallis *et al*. 1999) and adult survival (Longshore *et al.* 2003). The species is adapted such that hatchlings emerge when plant and water resources are optimally available (Rostal *et al*. 1994, USFWS 2011, Lovich *et al*. 2012, Gibbons 2013). Native desert plants have specific emergence and timing requirements and may lack adaptive capacity to optimize changed conditions (e.g., changes in soil moisture availability; Meyer 1998, Schwinning and Sala 2004, Hoover *et al.* 2015) which is likely to result in a corresponding shift in vegetation availability and composition. This shift in available forage may impact the health of *G. agassizii*, because it is unclear if nutritionally optimal forage would remain available and non-native plant invasions can increase wildfire frequency (Wildfire and Invasive Plants). Climate changes that result in an increase in droughts could result in little or no plant biomass during foraging seasons, which can cause high mortality rates in relatively short time frames (two years; Longshore *et al.* 2003).

Increased precipitation and changes in vegetative cover can result in increased flooding in desert environments. In future conditions with increased flood events, *G. agassizii* individuals could become entrapped in burrows more frequently, especially during times of the year they are typically hibernating (Lovich *et al.* 2011, USFWS 2011, Berry and Murphy 2019). Increased frequency and severity of flooding may also increase the probability of individuals being washed into culvert debris piles adjacent to roads, because *G. agassizii* frequent washes (Lovich *et al*. 2011). In addition, *G. agassizii*-proof fences are often breached during flood events, resulting in more potential for vehicular collisions (USFWS 2011). Overall, increased flood events have the potential to directly impact *G. agassizii* mortality and injury rates.

In summary, drought, especially if extended in time or severity, may cause individual and population-level effects to *G. agassizii*. These effects may worsen in the future with climate change. Ecosystem changes due to projected future changes in temperature and precipitation from climate change could reduce the ability for individual *G. agassizii* to feed, breed, and shelter. Changes in drought, flood, and wildfire frequency due to future climate change could also reduce the health and survival of *G. agassizii* sub-populations and lower AU sub-population resiliency.

3.1.4 Predation

Gopherus agassizii, particularly hatchlings and juveniles, are prey to several native species of mammals, reptiles, and birds. The common raven (*Corvus corax*) has been the most visible predator of small *G. agassizii* (Boarman 1993, Knight and Kawashima 1993), and coyotes (*Canis latrans*) have caused deaths of adult *G. agassizii*. Human populations can result in increased local predator populations by dumping waste in or near *G. agassizii* habitats or by incidental roadkill which attracts predators (USFWS 2011). Ravens obtain food from garbage in landfills and trash containers, water from sewage ponds and municipal areas, and nesting substrates on billboards, utility towers, bridges, and buildings (Boarman *et al*. 2006). Because ravens tend to follow human populations and have access to resources from humans, an unnatural increase in ravens may result in added predation pressure on *G. agassizii* populations without the typical drop in prey (Boarman 1993). This decoupling of typical predator-prey dynamics is known as hyper-predation (Smith and Quin 1996). While *G. agassizii* populations are generally expected to exhibit low sensitivity to changes in hatchling and juvenile survival (relative to changes in adult survival; Congdon *et al*. 1994), a consistent loss of juvenile recruitment could eventually result in a downward population trend. Raven monitoring in the Red Cliffs Desert Reserve began in 2015. Thus far observations do not indicate high raven occupancy or *G. agassizii* fatality counts compared to other parts of the species' range, although continued monitoring is needed to conclusively identify trends and causal relationships (Schijf and Rognan 2019).

In summary, several native species prey on *G. agassizii*, including domestic dogs. The level of predation is likely increased due to nearby human populations and resources. We do not know if predation by any animal is causing negative, long-term demographic effects to *G. agassizii* in the UVR recovery unit.

3.1.5 Recreation and Human Access

Urban development and highways can affect *G. agassizii* populations through increased human access to *G. agassizii* habitats (LaRue 1993). These may include increased human foot-traffic and recreation, unauthorized off-highway vehicle use, and free-roaming dogs in the surrounding *G. agassizii* habitat.

Non-motorized recreation activities that may impact the species in the AUs include illegal fireworks, camping, hunting, target shooting, rock collecting, hiking, horseback riding, biking, and sightseeing. These human activities can cause loss of habitat from development of recreational facilities, handling and disturbance of *G. agassizii*, increased road kill, deliberate maiming or killing of *G. agassizii*, increased raven predation, degradation of vegetation, and soil compaction (USFWS 1994a, Averill-Murray 2002). Culvert monitoring data using wildlife cameras detected illegal human use including off trail pedestrian and bike use, fence jumping, and illegal collection of an adult *G. agassizii* (McLuckie 2019a).

Illegal collection of *G. agassizii* by collectors and pet owners may play a role in the population decline in the Red Cliffs Desert Reserve (McLuckie *et al*. 2020). Law enforcement officials have documented illegal collecting of *G. agassizii* for food or cultural ceremonies on a few occasions (USFWS 1994a). In the Red Cliffs Desert Reserve, thirty-eight *G. agassizii* have been illegally taken (i.e., moved far distances across barriers or killed; McLuckie 2020). There have been law enforcement investigations where *G. agassizii* were illegally collected or killed directly adjacent to existing roadways that bisect the Red Cliffs Desert Reserve (McLuckie 2020).

Motorized recreation using off-highway vehicles (OHV) can impact native vegetation cover (forage resources) through soil compaction and erosion, and direct removal via the widening of trails and the creation of illegal trails. OHVs may injure or kill *G. agassizii* during collisions, degrade habitat (or injure) via collapsing of burrows, and likely alters their behavior and surface activity (Bury and Marlow 1973, Berry and Nicholson 1984, Bury and Luckenbach 1986, Berry *et al*. 1990).

Human access and proximity also increase domestic and feral free-roaming dogs that may stress, wound, or kill *G. agassizii* (USFWS 2011, Bjurlin and Bissonette 2004, Boarman 2002). *Gopherus agassizii* mortalities caused by pets are higher near human population concentrations (Demmon and Berry 2005, Esque *et al*. 2010) and thus may become exacerbated in the UVR recovery unit as road and residential development increases in Washington County. With the growing number and sizes of cities, towns, and settlements in the Mojave Desert, mortalities and injuries are increasing and are difficult to control rangewide.

3.1.6 Disease

The emergency listing of the *G. agassizii* as a threatened species was prompted, in part, by population declines resulting from an URTD. URTD appears to be a complex disease interacting with other stressors to affect *G. agassizii* (Brown *et al*. 2002, Tracy *et al*. 2004). Two *Mycoplasma* spp., *M. agassizii* and *M. testudineum*, are primary causative agents of *G. agassizii* mycoplasmosis (i.e., URTD) in multiple gopher tortoise species in the United States (e.g., *G. agassizii*, *G. Polyphemus*, and *G. morafkai*) (Jacobson *et al*. 2014). URTD affects the upper respiratory tract of *G. agassizii*, causing lesions in the nasal cavity, excessive nasal discharge, swollen eyelids, and sunken eyes. In its advanced stage it can lead to lethargy and potentially death. URTD can be aggravated by environmental stresses, malnutrition, and immune deficiencies (Jacobson *et al*. 1991). The disease has higher prevalence in relatively dense *G. agassizii* populations, because mycoplasmal infections are dependent upon higher densities of the host (Tracy *et al*. 2004). URTD occurs within the UVR recovery unit, including Red Cliffs Desert Reserve and in 2018, approximately 11 percent of *G. agassizii* within Red Cliffs Desert Reserve showed apparent clinical signs of URTD (McLuckie *et al*. 2018); however, similar clinical signs can also occur from *Bromus* spp. lodged in the nares or eyes of the *G. agassizii* (Drake *et al*. 2016).

Other diseases that can harm *G. agassizii*, such as the herpes virus, *Pasteruella testudinis*, cutaneous dyskeratosis (shell disease), and shell necrosis, are found in *G. agassizii* populations across the species' range (Dickinson *et al*. 2001, Martel *et al*. 2009, USFWS 2011, Berry and Murphy 2019). Less is known about these diseases; however, it has been postulated that certain diseases (e.g., cutaneous dyskeratosis and shell necrosis) can be caused by increased environmental toxins such as heavy metals, mercury, arsenic, and chlorinated hydrocarbons associated with roads (Jacobson *et al*. 1994, Chaffee and Berry 2006).

While disease is a natural phenomenon in wildlife populations, humans and their activities may introduce, spread, or increase susceptibility to harmful pathogens and microbes (e.g., Boarman 2002, Martel *et al*. 2009). Humans can act as a vector for *G. agassizii* diseases through unauthorized release or escape of pet *G. agassizii* to the wild (Johnson *et al*. 2006, Martel *et al*. 2009), and humans activities can potentially compromise immunological health of wild *G. agassizii* through various stressors (e.g., elevated corticosterone from harassment, malnutrition from increased non-native invasive plants related to human-caused ground disturbances; Boarman 2002).

In summary, URTD is the most prevalent disease known to occur in and affect *G. agassizii* populations. The transmission of URTD is likely amplified due to human interactions and reintroductions of previously captive *G. agassizii* into wild populations. Disease can also weaken an already declining population and act synergistically with other stressors to reduce resiliency.

3.1.7 Urbanization and Paved Roads

Commercial and residential development causes the direct permanent modification and fragmentation of *G. agassizii* habitat (USFWS 2011). Studies evaluating effects of development indicate a pattern of reduced *G. agassizii* population sizes as the proportion of development increases, where *G. agassizii* disappear from areas with greater than 10 percent development (Carter *et al*. 2020). This study examined the effect of the project footprint area, not additional effects of linear structures like roads on habitat fragmentation. Habitat loss decreases the carrying capacity of an area, reducing resources that provide for breeding, feeding, and sheltering and connectivity between habitat and populations (USFWS 2011). Thus, habitat loss and fragmentation reduce population resiliency. The activities associated with residential and commercial development include the physical footprint of a structure or building, associated roads, and utilities, parking lots, and vehicle traffic as well as the indirect degradation of the surrounding habitat from related infrastructure, fences, human activities (including pets), altered water runoff patterns, and introduction of non-native invasive plants. Habitat degradation includes the reduction of habitat quality or characteristics on smaller scales, which creates patches of habitat.

Modeled *G. agassizii* habitat depicted directly south of the Red Cliffs Desert Reserve in the UVR recovery unit and extending into Arizona has either been lost to urbanization or was believed to have no or very low occupancy overall (Bury *et al*. 1994, USFWS 1996). While recent surveys have identified more occupancy in some areas than previously expected, these areas were considered difficult to sustain viable *G. agassizii* sub-populations that would support recovery (USFWS 1996). The 1995 HCP (Washington County 1995) allowed, and a proposed 2020 amendment would continue to allow, for continued loss of occupied and potential *G. agassizii* habitat on non-Federal lands south of the Red Cliffs Desert Reserve. The Red Cliffs Desert Reserve was established to offset these ongoing losses and establish a conservation area for the species in perpetuity that supports recovery.

Roads increase mortality rates of *G. agassizii* due to collisions from vehicles, act as barriers to dispersal, and fragment habitats and populations (Andrews *et al*. 2015, Forman and Alexander 1998, Jaeger and Fahrig 2004). Substantial numbers of *G. agassizii* are killed on paved roads (Boarman 2002, USFWS 2011). In the central Mojave Desert (west of the UVR recovery unit), at least one adult *G. agassizii* has been documented as killed per 2.0 miles of road per year along heavily traveled roads (Boarman and Sazaki 1996). Since 2015, 19 *G. agassizii* were killed on fenced roads within and adjacent to Red Cliffs Desert Reserve, despite the installation of *G. agassizii* fencing (McLuckie 2019b). An additional 13 adults were killed on unfenced roads in the Reserve (Snow Canyon Drive and Babylon Road). The numbers of juvenile *G. agassizii* killed on roads is likely underestimated, because of their small size and increased likelihood to be scavenged prior to human detection (Boarman and Sazaki 1996). While some *G. agassizii* continue to be killed on fenced roads (McLuckie 2019b), fencing does minimize injuries and fatalities from vehicular collisions. However, fencing can also results in *G. agassizii* pacing (Peaden *et al*. 2017). Due to high site fidelity, *G. agassizii* will continue to pace a new fence line to access burrows or sites within their home range, sometimes to exhaustion or overheating. Pacing *G. agassizii* can become stressed and may die from heat exposure if temperatures are above 95 °F (USFWS 2009). Fencing needs to be constantly maintained and contributes to habitat fragmentation to *G. agassizii* populations (Boarman and Sazaki 1996, Boarman 2002, Nafus *et al*. 2013, Peaden *et al*. 2017, Sadoti *et al*. 2017). Shade structures can provide refuge from the heat along fencelines. Shade structure guidelines recommend installation at close distances, particularly along new fence lines, to mitigate pacing and associated stress (USFWS 2018b). Reducing habitat fragmentation can be partially addressed by providing sufficiently spaced passage structures under fenced roads in *G. agassizii* habitat.

Roads result in reduced *G. agassizii* densities in a road effect zone extending at least 437 yards from roadways (Boarman and Sazaki 2006, Nafus *et al*. 2013), and as far as 2.8 mi. (Von Seckendorff Hoff and Marlow 1997). High traffic volumes can increase the road effect zone (Boarman and Sazaki 2006). For example, the relative abundance of *G. agassizii* sign and burrows are significantly lower along intermediate (30 to 60 vehicles per day) and high traffic volume (320 to 1100 vehicles per day) roads as compared to low traffic volume roads (<1 vehicle per day; von Seckendorff Hoff and Marlow 2002, Nafus *et al*. 2013). Adult *G. agassizii* located near high traffic roads were at least 30 percent smaller (and below the typical size for sexual maturity) than *G. agassizii* associated with lower traffic volumes or no roads (Nafus *et al*. 2013). Overall, these observations may indicate that habitat near roads used by as few as 300 vehicles per day represents sink habitat for *G. agassizii* (Nafus *et al*. 2013).

The reasons for reduced *G. agassizii* densities and changed demographic structure adjacent to the roads is not known, but highway mortalities likely play a role (Boarman and Sazaki 2006, Nafus *et al*. 2013). However, roads also provide access to remote areas for poachers; create high noise conditions; fragment habitat; facilitate the invasion of non-native and invasive vegetation (Wildfire and Invasive Plants); and attract predators that benefit from roadkill and litter (Boarman 2002, USFWS 2011; Predation). Roads can also increase human-caused wildfires (e.g., catalytic converters, cigarette butts, illegal fireworks, etc.), noise, poaching, litter, and non-native vegetation.

It is not clear if noise from roads negatively affects *G. agassizii*, but many other species display avoidance behavior or decreased reproductive success near roads (Blickley *et al.* 2012). Human activities such as operation of heavy machinery, vehicles, rumble strips on highways, and oil, and gas development can increase noise levels 10 decibels (dBA) or more above ambient conditions. It is unknown if noise at these levels interferes with breeding, feeding, or sheltering of *G. agassizii*. Changes in startle responses and decreases in movements have been observed in some cases, while others seems to show no change in population metrics (Bowles & Eckert 1997, Bowles *et al*. 1999). The physiology of this species tympanic structure suggests hearing comparable to other burrowing turtles (Bramble and Hutchison 2014). Studies on other species have documented that irregular and inconsistent noise may be more detrimental than persistent elevated noise (Blickley *et al.* 2012). Elevated noise levels may also interfere with awareness of predators and *G. agassizii* vocalizations, resulting in potential increases in fatalities and lower reproductive potential.

In summary, urbanization results in the loss and fragmentation of G. agassizii habitat. Residential and commercial development is an ongoing activity in the UVR recovery unit and overlaps with occupied and potential G. agassizii habitat. Roads contribute to *G. agassizii* mortality and stress through habitat loss, fragmentation, and degradation. Fencing, culverts, and underpasses, and attention to human use along roadside habitats may reduce some of the effects of roads (Habitat Connectivity).

3.2 Conservation Factors

In this section, we focus on the actions that can reduce, limit, or avoid AU-level stressors affecting UVR recovery unit viability. Recovery actions include regulatory, preservation, translocation, and restoration measures such as invasive species management to protect and improve the remaining habitat and prevent further decrease in *G. agassizii* numbers, primarily within Red Cliffs (USFWS 2011).

In 2014, the UVR recovery implementation team, using the most up-to-date information from the SDSS, prioritized recovery actions for the recovery unit (USFWS 2014b). This resulted in the following top ten priorities (in order by most importance) for the UVR recovery unit: environmental education, restore habitat, increase law enforcement, install and maintain human barriers (wildland-urban interface), sign and fence protected areas, decrease predator access to human subsidies, remove grazing (close allotments), install and maintain *G. agassizii* barrier fencing, targeted predator control, and control dogs. The subsequent recovery action plan focused on on-the-ground actions rather than policy actions and noted while priorities such as protecting and connecting intact habitat are not in the recovery action plan because the SDSS was unable to model them, protecting and connecting habitat is emphasized in the revised recovery plan (USFWS 2014b). The projects associated with the recovery action plan and other important recovery measures (e.g., land acquisition in Red Cliffs Desert Reserve and restoration projects in burned habitat areas) are prioritized by each recovery implementation teams every year. Adaptively managing recovery actions helps address changes in the areas, such as the increased threat of wildfires and invasive vegetation.

Workshop participants discussed previously identified recovery actions, and experts identified recovery actions that would represent the biggest conservation uplift for *G. agassizii* habitat and demographic factors, as well as for the primary stressors identified earlier in the Workshop (Table 9). Six conservation actions emerged as the most effective for supporting the UVR recovery unit population of *G. agassizii* (Table 10):

1) protecting intact *G. agassizii* habitat,
2) connecting intact *G. agassizii* habitat (within Red Cliffs, between AUs, and between recovery units),
3) restoring habitat (invasive species management pre- and post-wildfire, old roads, illegal trails),
4) ensuring human and *G. agassizii*-fencing is installed and maintained,
5) increasing law enforcement, and
6) environmental education.

Table 10. Ranking of stressors and recovery actions for G. agassizii in the UVR recovery unit (Darst et al. *2013, USFWS 2014b, USFWS 2019a).*

UVR recovery unit Stressors from Workshop (2019)	Recovery Actions (2014)	Recovery Actions identified as high priority in Workshop (2019)
Past Fire	Environmental education, Fire management planning and implementation, increase law enforcement, protect intact *G. agassizii* habitat, restore habitat	Aggressive management of wildfire and breaks, increase connectivity
Invasive Plants	Restore habitat, weed management	Aggressive management of invasive plants and restoration
Drought	Remove grazing to lessen impacts on habitat, restore habitat	NA (later discussed halting translocations)
Predators (Ravens)	Decrease predator access to human subsidies, environmental education, targeted predator control	Predator control plan, reduced subsidies, trash control, increased education
Motorized Recreation	Speed limits, emergency road closure, education, law enforcement, install and maintain human and *G. agassizii* barriers, restore habitat, restore roads, restrict OHV events, sign and fence protected areas, sign designated routes	Manage recreation, education, law enforcement, restore habitat*
Non-motorized Recreation	Education, law enforcement, sign and fence protected areas	Control access, law enforcement, education, signage, management, restore habitat*
Human Access (specifically off-leash dogs & illegal trails)	Designate and close roads, education, law enforcement, install and maintain human barrier, restore roads, sign and fence protected areas, sign designated routes, control dogs, decrease predator access to human subsidies, garbage clean up	Control access, law enforcement, education, signage, management, [restore habitat]
Disease (*Mycoplasma*)	Manage disease in captive population through permitting, manage disease in wild population	Continued implementation (later clarified this includes: monitoring, halting translocation if necessary, improving health through habitat restoration) *G. agassizii* adoption days (to educate current and new adopters)
Urbanization (Development)	Education, land acquisition, protect intact habitat	Fencing, city and county planning, land acquisition, connectivity and expansion
Paved Roads	Connect habitat via culverts and underpasses, install and maintain tortoise fencing, protect intact habitat	Increase connectivity, fencing for roads (with shade structures and passage spacing max distance = local home range), city and county planning, education

*We did not identify restoring habitat from motorized and non-motorized recreation in the Workshop, and we clarified that this was an important priority with our partners.

3.2.1 Long-Term Habitat Protection

The majority of designated critical habitat occurs in the Red Cliffs Desert Reserve, which was set aside as the primary mitigation for the 1995 HCP. The 1995 HCP is a required component associated with Washington County's incidental take permit for *G. agassizii*. The permit allows take of *G. agassizii* resulting from covered activities on suitable habitat outside Red Cliffs Desert Reserve in the UVR recovery unit in Washington County, and a limited amount of take within the Red Cliffs Desert Reserve. The HCP Administration works with Federal and State partners to implement conservation measures associated with the HCP (Washington County 1995). Washington County is currently applying for a new ITP under an Amended HCP.

3.2.1.1 Long-Term Habitat Protection on Private Lands

Protecting intact *G. agassizii* habitat from roads and development continues to be a priority rangewide because habitat is continually fragmented into smaller and more isolated populations (Gray *et al*. 2019, USFWS 2019b, Dutcher *et al*. 2020). Thus, land acquisition from private and School and Institutional Trust Lands Administration (SITLA) owners in Red Cliffs Desert Reserve was established as the primary mitigation for Washington County's 1995 HCP and continues to be a high priority for all stakeholders. Consolidating ownership in Red Cliffs Desert Reserve in conjunction with County regulations within Red Cliffs Desert Reserve has prevented loss and degradation of habitat. The HCP partners will acquire an additional 7,091 acres of private and SITLA lands within Red Cliffs Desert Reserve to fulfill commitments from the 1995 HCP (Washington County 2020).

Protecting habitat areas in perpetuity outside Red Cliffs Desert Reserve would also benefit the UVR recovery unit by creating natural refugia from disease and wildfire, and by preserving genetic and behavioral representation through habitat corridors between AUs and recovery units. For example, the Green Valley AU (including Red Cliffs Desert Reserve, proposed zone 6 of which about half is managed by BLM and the other half managed by SITLA) is occupied by *G. agassizii*. Protecting the proposed zone 6 within this area should include connectivity with other areas to ensure its contribution to UVR recovery unit resiliency. In contrast, the Springdale AU is exceptionally small and connectivity with other AUs may be extremely unlikely. However, we note that protection of habitat in this area could be important to preserve genetic and behavioral variations that may be significant in changing climate conditions.

3.2.1.2 Regulatory Measures on Private Lands

Washington County has developed specific ordinances that include building fees addressing local habitat conservation (Washington County, Utah, Municipal Code § 9-2A). For example, the 1995 HCP includes development impact fees ($250 per acre plat approval, or public utility development and 0.2 percent of building costs on new building permits) that are used to help manage the Red Cliffs Desert Reserve (Washington County 1995). In addition, under the 1995 HCP, *G. agassizii* habitat in known or suspected occupied areas were surveyed and any *G. agassizii* found were translocated to sites within the Red Cliffs Desert Reserve (primarily Babylon AU, Red Cliffs Desert Reserve, zone 4). Washington County engages in numerous efforts to ensure all *G. agassizii* found on private lands are translocated or put into the State's adoption program (worker education program, clearance surveys, and outreach to the community).

Translocations minimize the impacts of development on a species. *Gopherus agassizii* translocation efforts to the Babylon (Red Cliffs Desert Reserve, zone 4) AU survival is based on mark-recapture data from post-translocation monitoring of the population (90 percent, standard error 87 and 92 percent; McLuckie *et al*. 2019). This level of survival is moderately concerning for a long-lived species and below what is considered needed for population viability over several *G. agassizii* generations. We do not have data whether local juvenile annual survival is accommodating for lower adult survival. No *G. agassizii* individuals were found in this AU prior to translocation efforts, and current abundance estimates are approximately 285 (160 to 507) and considered repopulated. Long-term monitoring is needed to evaluate viability. Translocations can also be used to strategically augment demographic and genetic values, although this is not currently a goal or objective occurring in the UVR recovery unit. Recent genetics analysis found that male *G. agassizii* translocated in other recovery units did not contribute to genetic integration after four years, and paternity testing only displayed genetic markers from male resident *G. agassizii*. This observation may be a result of many different variables, including the lack of health assessments prior to translocation and size differences in resident vs translocated males. However, if accurate, this result suggests females may be more influential to translocation efforts. In general, translocation should be considered a last resort, and efforts should be made to emphasize connecting occupied habitat rather than population augmentation or restoring unoccupied habitat.

3.2.1.3 Regulatory Measures on Public Lands

In 2016, the BLM-St. George Field Office finalized the Red Cliffs National Conservation Area Record of Decision and Resource Management Plan (Red Cliffs NCA RMP; BLM 2016) and the St. George Field Office Record of Decision and RMP, as amended 2016 (SGFO RMP; BLM 1999). These plans include measures to address threats to *G. agassizii* habitat on Federal public lands in the UVR recovery unit, especially from wildfire, development, recreation, and grazing. This applies to approximately 45,000 Federal acres of modelled suitable habitat within Red Cliffs Desert Reserve and 106,000 acres of modelled suitable habitat outside of Red Cliffs Desert Reserve. Land management within Red Cliffs Desert Reserve is more restrictive and prescriptive for this species than land management outside Red Cliffs Desert Reserve.

The Red Cliffs Desert Reserve includes 5,678 acres of the Snow Canyon State Park (SCSP). The SCSP implements a Desert Tortoise Management Plan to protect *G. agassizii* and their habitat. This plan addresses management to benefit *G. agassizii* in general and specifically addresses recreation impacts, road mortality, and habitat loss, degradation, and fragmentation.

Distribution of desert tortoise in or near Zion National Park is limited and they do not have a *G. agassizii* specific conservation plan or conservation measures. Up until 2017, Zion National Park was implementing a *G. agassizii* monitoring plan using radio telemetry. Zion National Park no longer surveys for *G. agassizii* but does move them out of harm's way if they are discovered in a construction zone (J. Stroud-Settles, Zion National Park Wildlife Program Manager, personal communication, March 24, 2020).

3.2.2 Habitat Connectivity

Habitat connectivity within and among AUs is a key component to supporting the resilience of the UVR recovery unit (USFWS 2019a) as well as its ability to support population dynamics and to maintain a potential for genetic exchange with the adjacent NEM recovery unit (Figure 5, USFWS 2011). The protection of connection within the UVR recovery unit is a necessary strategic goal to ensure recovery potential, and preserving the potential for natural repopulation of an area impacted by catastrophic stochastic events such as wildfire (USFWS 2011). Climate change is likely to amplify stressors; therefore it becomes important to maintain access to higher elevation (5,000 ft) habitat into which the *G. agassizii* may expand.

Connectivity within AUs can be accomplished by closing unused roads and by providing passage structures across fenced roads in *G. agassizii* habitat (USFWS 2014a). In 2014, the USFWS published a passage spacing guidelines document recommending maximum distances between culverts or underpasses be installed within the distance of one local adult home range (USFWS 2014a). In other parts of the range, culverts appear to be used in some capacity by adult *G. agassizii* (60 percent; K. Holcomb, USFWS, personal communication, March 2, 2020). More information is needed to know the effectiveness of culverts because, data are limited, and sample sizes were quite small. A local multi-year study (2003, 2005, 2014, 2015, and 2016) using wildlife cameras facing nine culvert openings documented four *G. agassizii* using two of the monitored culverts in the UVR recovery unit. The majority of usage was detected as shade or shelter and did not necessarily result in dispersal. No *G. agassizii* have been recaptured on the opposite sides of the five Red Hills Parkway culverts since they were installed (McLuckie 2019a). While the local data did document *G. agassizii* use of culverts for shade or shelter, culverts can become an entrapment risk during flash flood events (Lovich *et al.* 2011, USFWS 2014a) and may draw predators to the crossing points (Little 2003, Van Der Ree *et al*. 2015).

In depth studies have not been conducted to determine whether culverts are sufficient to support demographic dispersal needs (seasonal and life-stage movements verses a genetic exchange which may only require one to two exchanges per generation). Following discussions with several experts, we estimated the effectiveness of improving permeability through a road. Assuming culverts are spaced to local female home range distance and prioritized in washes (naturally used as movement corridors), we estimated maximum demographic effectiveness from culverts to be 5 to 15 percent (McLuckie *et al.* 2005; Dutcher *et al*. 2019; A. McLuckie, UDWR, personal communication, March 19, 2020; K. Holcomb, USFWS, personal communication, March 2, 2020). This effectiveness range is based on expert opinion; given the importance of connectivity to viability, more information is needed to understand and ensure use and effectiveness of passage structures.

Simply based on open areas, viaduct-style designs (open-span, extended stream crossings or bridges over larger washes) are likely to be more effective at providing passage for *G. agassizii* (Lesbarrères and Fahrig 2012). We expect desert tortoises would logically use viaducts (300-ft wide minimum) installed with light and natural vegetative substrate more than culverts. Given associated costs, use and placement of viaducts or spans may be limited. In general, placement should be targeted to washes, which *G. agassizii* use as movement corridors. We recommend spacing at a maximum four female adult home ranges. Under these circumstances, we anticipate maximum effectiveness could achieve 80 to 90 percent, but more research is needed to draw conclusions based on data rather than expert opinion (McLuckie *et al*. 2005; Dutcher *et al*. 2019; A. McLuckie, UDWR, personal communication, March 19, 2020; K. Holcomb, USFWS, personal communication, March 2, 2020).

Permeable corridors facilitate movement of *G. agassizii* within the AU and may be evaluated by the continuity of suitable habitat (based on existing habitat and connectivity models; Gray *et al.* 2019). The USFWS identified connecting blocks of *G. agassizii* habitat such as conservation areas and recovery units as a top recovery action rangewide (Recovery Action 2.11, USFWS 2011). We identified and prioritized potential *G. agassizii* habitat corridors that could be connected within the UVR recovery unit population and with the NEM recovery unit (Figure 12; USFWS 2020). Priority 1 is to restore connectivity within the AUs that occur within the Red Cliffs Desert Reserve (Snow Canyon, West and East Cottonwood, Babylon, and Cinder Knolls). Priority 2 is to connect Snow Canyon AU to Beaver Dam Wash NCA. Priority 3 is a connection between Green Valley AU and Sand Mountain AU. Priority 4 is connectivity of the eastern AU's.

Studies of movement and other factors are needed to validate these areas as movement corridors and to determine *G. agassizii* use. In our habitat connectivity analysis between the UVR and NEM recovery units, we included elevations up to 5,000 ft within and between the two recovery units using the Gray *et al.* (2019) model (Figure 12, USFWS 2020). Mountain ranges were previously thought to act as dispersal barriers to *G. agassizii* (Hagerty *et al*., 2011), but more recently genetic studies have observed more connectivity across these topographic features than previously thought (Dutcher *et al*. 2020). While higher elevation habitats within and around the UVR recovery unit may now be or become suitable for the *G. agassizii* in the near-future as a result of climate change, plant community composition will likely lag (Alexander *et al*. 2018), which limits the use by *G. agassizii*.

Establishment of protected habitat corridors between the UVR and NEM recovery units, and habitat connectivity between Snow Canyon and Far West or Green Valley AUs will depend on close partnerships and coordination with the Shivwits Band of the Paiute Tribe, because the UVR and NEM recovery unit connectivity areas pass through Tribal lands (Figure 3 and Figure 12). Outside of Tribal lands, most of the remaining habitat connectivity areas identified are owned and managed by the BLM. Efforts continue for improving habitats and protections for *G. agassizii* within these areas with support from HCP partners (Figure 12). However, additional land protections will be necessary for long-term protection. Other AUs are unlikely be effectively reconnected due to distance, current land use conflicts, landownership, and on-going development (e.g., Springdale or Urban Interface AUs).

Several uncertainties regarding local intra- and inter-AU connectivity remain. We recommend future studies looking specifically at *G. agassizii* movement data throughout the UVR recovery unit to better clarify obstacles and opportunities to promote connectivity. Movement data can be used to evaluate the distribution of home ranges, analyze the distribution of suitable habitat (Manly *et al*. 2007), and identify dispersal corridors (Kranstauber *et al*. 2012, Zeller *et al*. 2016). This information could be used to inform the placement of passage structures or to target key habitat restoration that would promote use and movement.

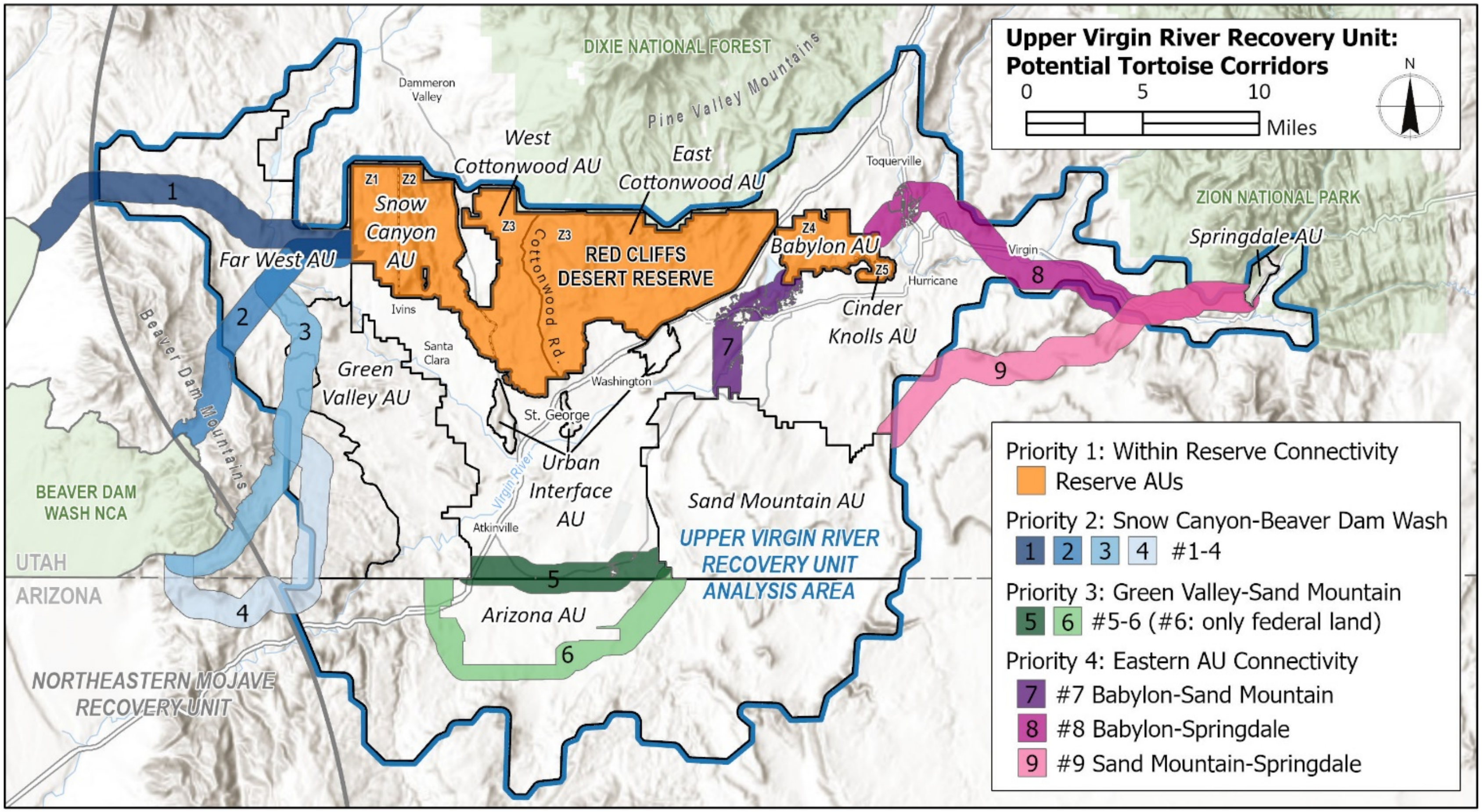

Figure 12. Potential habitat connectivity corridors linking G. agassizii National Conservation Areas in UVR recovery unit and the Northeastern Mojave recovery unit (USFWS 2020).

3.2.3 Habitat Restoration

Wildfires have been increasing in frequency, intensity, and severity throughout the southwest. Restoring habitat before non-native, invasive vegetation is dominant is essential in the UVR recovery unit to minimize threats associated with stochastic events *G. agassizii* resiliency. The BLM and UDWR have been partnering with the University of Nevada-Las Vegas and Song Dog Nursery in Lake Mead, Nevada to restore burned habitat areas within Red Cliffs Desert Reserve (USFWS 2014b). Thus far, transplanting with herbivory prevention cages has been promising, and plantings continue annually. Some of these plantings survived the July 2020 Turkey Farm Road wildfire in East Cottonwood AU. In addition, the HCP partners are experimenting on small scale study plots in Red Cliffs Desert Reserve using a new root-inhibiting herbicide, Esplanade® (Indaziflam). This herbicide shows promise to prevent the establishment of non-native plants in areas that have burned multiple times, but more data is needed on this herbicide and potential ecological impacts in desert environments. Transplanting efforts should be prioritized until other methods have been proven effective. It is possible these techniques may be used in phased approaches in future studies (i.e., herbicide followed by transplanting).

In addition, in response to the large wildfires in the early 2000s, the HCP partners have committed to support aggressive wildfire prevention and suppression in Red Cliffs Desert Reserve (Habitat and Fire Management Guidelines; Washington County 2019). The two primary goals are to protect unburned habitat and restore burned habitat areas with native vegetation. This plan is adaptively managed to include new information, and actions are prioritized each year. Priorities include: treating roadsides and maintaining firebreaks adjacent to roadsides; controlling non-native invasive species with herbicide application; experimental restoration that evaluates effectiveness of islands of vegetation for stabilizing soils; monitoring of treated areas; and maintaining communication between fire response and land management agencies and with the public. The Amended HCP includes commitments from Washington County and HCP Partners to seek grants for restoration (e.g., Watershed Restoration Initiative through the State) and to maintain a contingency fund for emergencies (Washington County 2020).

3.2.4 Fencing Installation and Maintenance

Properly installed and maintained *G. agassizii* fencing effectively prevents injuries and fatalities from vehicular collisions. Effective fence design and specifications require burying the bottom of the fence line due to this species' ability to dig under fences (USFWS 2009). Fences require diligent maintenance, especially in problem areas such as washes and due to flash floods, vandalism, and normal wear and tear. It is difficult to effectively fence washes, which is also where *G. agassizii* may concentrate. In Red Cliffs Desert Reserve, the HCP partners have worked together to devise a promising wash-specific fence design that floats during flood events (K. Comella, SCSP, personal communication, October 26, 2018). Logs are secured to the bottom of the fence. Fencing is then bent inward for 12 inches and the bent section is covered in rock and dirt. This method should be monitored to evaluate *G. agassizii* passage and maintenance; studies are needed to evaluate the effectiveness of any new fencing methods that deviate from the USFWS guidelines.

3.2.5 Increasing Law Enforcement

Washington County has paid for law enforcement presence in Red Cliffs Desert Reserve and has committed to support continued law enforcement on non-Federal lands in the Red Cliffs Desert Reserve. Officers enforce regulations related to leashing of dog, camping, and other human uses in Red Cliffs Desert Reserve. Most law enforcement patrols occur in rural areas and trailheads with occasional patrols on more heavily used trails (BLM 2016). Additional enforcement is present during tourist season or for special events that draw large numbers. The HCP partners receive a law enforcement report annually. Law enforcement officers from the UDWR work closely with Federal, State and local officers to enforce regulations that protect the natural resources within the Red Cliffs Desert Reserve as well as surrounding areas within Washington County. Washington County has also implemented a Trails Steward program. Volunteer stewards engage with and educate visitors to the Red Cliffs Desert Reserve while hiking trails. Stewards also document and report violations and other noteworthy observations.

Human population growth is rapidly increasing in St. George, Utah and adjacent cities (U.S. Census Bureau 2018), thereby increasing human use pressures in Red Cliffs Desert Reserve (Washington County 2020). Visitation to nearby Zion National Park is often redirected to SCSP and Red Cliffs Desert Reserve (and the Red Cliffs NCA) for recreation. Research conducted by the Kem C. Gardner Policy Institute at the University of Utah estimated 50,000 daily transient or short-term visitors to Washington County. The Greater Zion Convention and Tourism office (operated by Washington County) actively works to disperse visitors throughout Washington County which adds to visitation pressure on SCSP and Red Cliffs Desert Reserve. SCSP reported > 500,000 visitors in 2019 (K. Comella, SCSP, personal communication, November 15, 2019); visitation to the park has increased an average of 12% annually over the past decade. Utah State Park law enforcement officers intermittently patrol the canyon, as do officers from the Washington County Sheriff's Department. Law enforcement consists primarily of enforcement of posted speed limits and parking regulations. Trail patrols and enforcement of leash and designated trail laws occur at irregular intervals primarily during the spring and fall. In SCSP, Conservation Officers primarily enforce posted speed limits and parking regulations. The SCSP Desert Tortoise Management Plan identifies maintaining the existing level of Law Enforcement (Goal 2), however, a full-time law enforcement position was eliminated in 2014. Management partners continually cite the critical need for the presence of at least one dedicated, full-time boots-on-the-ground officer and additional support during busier times of the year (Washington County 2019). It is unclear if funding available through the NCA, UDWR, and the County will be sufficient to meet this growing need.

From October 1, 2018 to September 30, 2019, the BLM recorded 220,725 visitors to the Red Cliffs NCA (K. Voyles 2020, BLM, personal communication, 2020). While SGFO RMP (BLM 1999) decisions prioritize BLM law enforcement to collaborate with other appropriate law enforcement agencies to implement enforcement actions needed to accomplish the objectives of the Red Cliffs Desert Reserve, it is unclear to what extent law enforcement is able to protect *G. agassizii* from persistent challenges, such as illegal OHV use, which occurs across the vast public lands outside of the Red Cliffs Desert Reserve.

3.2.6 Environmental Education

As mentioned above, human use and access is a major concern in Red Cliffs Desert Reserve and in most of the AUs. *G. agassizii* habitat overlaps with areas identified for development or used for recreation. Community education on wildlife is an important aspect of managing desert tortoise in heavily used areas. Ensuring the community knows what to do if they encounter a *G. agassizii* (e.g., moving a *G. agassizii* out of harm's way on a road) can make a difference. Educating the community about disposition of domestic, captive turtles, understanding the importance of staying on trails (reducing habitat degradation and stress responses) and keeping their dogs on leash, or supporting measures to minimize impacts from local landfills can add up to measurable population level benefits.

The HCP partners prioritize community education on desert tortoise. Washington County leads several environmental education efforts including signage, visiting schools, worker education training for projects on private lands in *G. agassizii* habitat, managing a visitor center, producing maps and brochures, and coordinating a trail steward program. The SCSP highlights education as a *G. agassizii* management goal, providing materials and guided hikes for visitors to understand the ecosystem, including the *G. agassizii*, and managing a Trail Steward program (UDWR 1998, Goal 3). The UDWR educates the public about native *G. agassizii* and reptile diversity through regular contacts with the general public, local nonprofit organizations, scout groups, and wildlife students from local school districts and higher education institutions (A, McLuckie, UDWR, personal communication, July 9, 2020). The UDWR has worked closely with Zion National Park and the City of Springdale, maintaining an information booth to increase appreciation of the native *G. agassizii* and educate the public about its natural history. The UDWR also works with community volunteers to assist with habitat restoration projects including planting, building and maintaining plant cages, weeding, and providing supplemental water to containerized plants.

Since the Red Cliffs NCA designation, the BLM has embarked on several education initiatives. These include creating maps, a visitors' guide (that highlights NCA trails, trailheads, NCA boundaries, and wilderness boundaries), informative kiosks, portal signs, brochures, new trailhead construction, trail monitoring/maintenance, social trail eradication/rehabilitation, protective fencing construction/maintenance, biological monitoring (including federally listed threatened and endangered species), a scientific research program with universities, archaeological site monitoring (including conservation/protection), a volunteer-professional site steward program, implementing large-scale habitat restoration projects in fire-affected *G. agassizii* habitat, non-native invasive plant monitoring/control, hazardous fuels reduction, coordinated fire suppressions, and a host of other actions that promote and conserve NCA resources and values.

The BLM has also partnered with: (1) The Southern Utah National Conservation Lands Friends (SUNCLF), a 501 (c) (3) non-profit "friends" group for the NCA, to support the BLM's mission, and to assist BLM with volunteer stewardship programs, environmental education outreach, and recruiting volunteers to assist with special projects (including habitat restoration research in the NCA); and (2) The Dixie-Arizona Strip Interpretive Association (DASIA), also a 501(c)(3) nonprofit, to recruit and train volunteers who assist with public contacts in the interagency Public Lands Information Center in St. George, Utah and with special projects.

Chapter 4: CURRENT CONDITION

In this chapter, we describe our analysis of the current condition of *G. agassizii* in the UVR recovery unit.

4.1 Resiliency

G. agassizii require habitat of sufficient quality and quantity and should maintain a population abundance and growth rate sufficient to be resilient to threats. The AUs that retain these attributes are at lower risk of extinction from stochastic events. For the UVR recovery unit population to retain the potential for recovery, a sufficient number of resilient AUs distributed across the UVR recovery unit reduce the risk of loss from catastrophic events that may affect multiple AUs, and increase the potential to maintain genetic and ecological diversity, or representation.

Methods

At the Workshop, we developed condition categories (Table 11) to evaluate and assign values for habitat and demographic factors in each AU (Appendix 3; Analytical Unit Summaries). Considering the stressors and conservation efforts influencing each AU, we then assigned values for each habitat and demographic factor, to each of the 11 AUs. Most factors were equally weighted (e.g., habitat quantity), with the exception of abundance and intra- or inter-AU connectivity which were triple weighted to account for their biological significance to *G. agassizii* resiliency in this recovery unit. When summing the overall condition of an AU, experts recommended adding extra weight or value to some factors (triple-weighting abundance, intra- and inter- habitat connectivity) based on the ecological importance of those factors within an AU to support the long-term persistence of *G. agassizii* in each AU or the entire recovery unit (see Appendix 3 and USFWS 2019a for more information). We used the current condition values with the contribution of each AU to the recovery unit (Appendix 4) to calculate the current condition of the UVR recovery unit as a whole.

We used four habitat factors in this analysis 1) native herbaceous vegetation, 2) diversity and cover of shrubs, 3) availability of burrows, and 4) habitat quantity. We determined that some of the factors identified in the Workshop could be dropped; soils were redundant as a habitat factor because it measured similar attributes to burrows and free water and precipitation are relatively consistent across the AUs (Table 11).

Biologists identified eight demographic factors important for characterizing Adult *G. agassizii*: 1) adult abundance, 2) adult density, 3) adult annual survival, 4) life stages (recruitment and growth rate), 5) sex ratio (recruitment), 6) inter-AU connectivity, 7) intra-AU connectivity, and 8) genetics. Due to the long life span of *G. agassizii* and the limited data in the AUs, genetics information was not included (Table 11; T.C. Esque, USGS, personal communication, December 5, 2019; USFWS 2019a).

Table 11 outlines four levels of resilience for *G. agassizii* AUs (Good, Moderate, Poor, and Critical), with corresponding condition values for the demographic and habitat factors identified for AUs. This valuation is considered a relative assessment of overall resiliency of sub-populations within each AU. For each metric, an AU was given a score of 0 to 3, with 3 being high quality or Good condition, and 0 being non-existent or Critically impaired condition. The overall rank is an average of these scores.

AUs in a high resiliency category are considered to be at low risk of loss from stochastic events, and more likely to persist over time. The AUs in high resilience category have a high density, high *G. agassizii* abundance, and retain ecological connectivity with other AUs, as well as expansive habitat. Conversely, AUs in the low category are considered to be at a higher risk of loss due to stochastic events and less likely to persist over time. AUs in a critical condition category are considered to be at a high risk of extirpation, or functioning as ecologically extirpated. The critical condition category was added after the Workshop in order to accurately depict AUs that may not contribute to the overall recovery potential of the UVR recovery unit.

We recognize in this report that the condition of the entire UVR recovery unit is not equally divided among the AUs. The contribution of an AU to the UVR recovery unit's overall resiliency is important to understand. For example, the Springdale AU is a very small and highly isolated sub-population and the West Cottonwood AU supports the highest abundance of *G. agassizii* and is centrally located (Table 2 and Figure 5). In addition, the relative values can allow comparisons for effectiveness of conservation actions in each AU (e.g., habitat restoration in Springdale compared to West Cottonwood). We characterized past condition of the 11 AUs using the oldest population data estimates available that can be use contemporary methods. We used expert knowledge to describe connectivity between AUs in the past. Past data (20 years) are considered to depict conditions prior to the effects of impacts under recent rates of human-use growth and development. In evaluating past conditions, we considered available data and what we could reasonably include based on habitat and demographic condition categories. We briefly describe these metrics below and include more detail in Appendix 4. We described habitat quantity using the modelled suitable habitat acreage for current conditions (Nussear *et al.* 2009). We did not ascribe a value for past habitat quality, although generally agreed that stressors to habitat have likely worsened over time, especially in areas without active conservation management. For demographic factors, we estimate abundance and density in each area using data from 1999 survey reports, but we lack information to quantitatively describe or compare past survival, life stages, or sex ratios. Finally, we describe connectivity based on our understanding of anthropogenic barriers in existence in 1999.

Line distance sampling has occurred within the Red Cliffs Desert Reserve and portions of the proposed Zone 6. In these areas, estimates are considered relatively accurate for abundance compared to areas that were not surveyed. The Far West AU and Arizona AU abundance estimate has the least amount of available survey data and local knowledge to inform abundance estimates. We normalized AU scores to add to 100 percent, to represent AU contribution to UVR recovery unit resiliency. Our final step was to scale all areas to West Cottonwood as the most important AU (based on abundance and proximity to other known abundant AUs), which allows managers to identify or compare the benefit from conservation projects (e.g., habitat restoration) to preserving or recovering the potential contribution of an area to the UVR recovery unit resiliency relative to another area.

The contribution of each AU to the UVR recovery unit current condition appears relatively robust at each layer of human decision points; for example, if we only apply the estimated recovery unit abundance without consideration of protected areas or connectivity, the contribution of each area to the UVR recovery unit condition remains similar (Appendix 4).

The effectiveness of conservation actions in each AU to improve the UVR recovery unit condition was similarly robust through each human decision point in the ranking process (e.g., connectivity value). The only exceptions to this were the Arizona AU and Far West AU; accounting for uncertainty from lack of formal survey data decreased the effectiveness of conservation actions in these two AUs to support the UVR recovery unit relative to other AUs.

4.1.1 Habitat Quantity

For habitat quantity, we used a linear model equation to estimate habitat needed to support the projected adult population targets. Our habitat quantity estimate essentially compared the actual available habitat to the *G. agassizii* population target abundance and density, which was based on the PVA (USFWS 1994a) and adjusted for realistic objectives during management timeframes. We determined the amount of habitat needed to support a target number of adults as identified in the Workshop and divided this by the estimated density in the AU (relationship of adults to acres of habitat). We used the 2009 peer-reviewed *G. agassizii* habitat model (Nussear *et al*. 2009) to estimate total acres of potential habitat in each AU after removing areas representing human development and water bodies (non-habitat land cover; Jacobs *et al*. 2019). We then compared those results to these metrics. We note that the Nussear *et al.* 2009 model resolution is at 0.39 mi^2 and could be updated and refined with more recent spatial layers and local ground-truthing efforts.

4.1.2 Habitat Quality

We assessed the general habitat quality of the AUs by referring to the final designated critical habitat rule as described in Chapter 2. However, it should be noted that we do not have information or data to assign a threshold or target for attributes that provide sufficient biological and physical needs for this species (e.g., preferred shrub height) (USFWS 1994a and 2011). We referenced the Landscape Conservation Forecasting for Washington County’s National Conservation Areas report (Provencher *et al*. 2011) to identify species metrics, and we refined these numbers in discussions with modelling and local area experts (T.C. Esque, USGS, personal communication, December 5, 2019). The Landscape Conservation Forecasting report describes habitat in the Red Cliffs Desert Reserve only so we could not apply the quantitative results from the report and compare habitat quality between all AUs. Instead, we relied on expert elicitation of the species, habitat and on-the-ground knowledge and satellite modeling to describe native vegetation and shrub cover and diversity and availability of burrows in each AU (Miller 2018; USFWS 2019a; USGS 2019; T.C. Esque, USGS, personal communication, December 5, 2019).

Table 11. Condition category table used to evaluate resiliency.

CONDITION CATEGORIES USED TO EVALUATE ANALYTICAL UNIT RESILIENCE												
	Habitat Quality Factors			**Habitat Quantity**	**Demographic Factors**							**Overall Condition Score**
Resiliency Condition Categories	**Native herbaceous vegetation**	**Shrubs**	**Burrow**	**Suitable habitat (acres)** to support target abundance	**Adult abundance (x3)** to avoid extirpation during management timeframe	**Adult density** per mi^2	**Adult annual survival** over 5 years	**Sex Ratio**	**Life Stages**	Genetics & Population Recovery: **Inter-Analytical Unit (AU) and recovery unit (RU) Connectivity (x3)**	Genetics & Population Recovery: **Intra-Analytical Unit (AU) Connectivity (x3)**	
Good (healthy) 3	> 80%	High diversity and cover (≥ 10 species)	Abundant and diverse burrows available (including rodent burrows for juveniles)	49,421 acres	> 3,000	≥ 38.9	≥ 95%	1:1 or slight female preference	All life stages present	Adjacent to 2 or more AUs > 80% of all AU:AU and RU:RU boundaries (by length) unimpeded by human development or natural barriers. Recent DT records within 1 home range (diameter ≤ 1,667 ft) of the AU boundary)	All *G. agassizii* clusters are likely connected through interbreeding. All *G. agassizii* clusters are connected with permeable corridors. No human development barriers to safe movement. Outer boundary of *G. agassizii* clusters within 2 home ranges of each other (≤ 3,333 ft).	2.34 to 3.00
Moderate (moderately healthy) 2	41 to 79%	Low diversity and low cover of shrubs, but shrubs are abundant (3 to 10)	Moderate availability and diversity of burrows	24,711 to 49,420 acres	501 to 2,999	10.36 to 38.8	90 to 94%	Slightly skewed ratio toward males (1:1.3)	Adult and large juvenile are present.	Adjacent to 2 or more AUs 50-80% of all AU:AU and RU:RU boundaries unimpeded by barriers OR Adjacent to 1 AU with > 80 % of boundary unimpeded. Recent DT records within 2 home ranges (≤ 3,333 ft)	Interbreeding among functionally important *G. agassizii* clusters occurs, but some clusters may be isolated. > 50% of *G. agassizii* clusters are connected through permeable corridors 1 or more human development barriers. *G. agassizii* clusters are within 4 home ranges of each other (≤ 6,667 ft) Infrequent interaction.	1.67 to 2.33
Poor (poor health) 1	20 to 40%	Low diversity of shrubs (1 to 2 species) Shrubs rare and cover is very low.	Low diversity and availability of burrows	1,676 to 24,711 acres	< 500	< 10.36	85 to 90%	Moderately skewed ratio toward males (1:2)	Adults present and very few large juveniles present.	< 50 % of boundaries are unimpeded or no adjacent AUs that could be connected. No recent DT records within 2 home range (≤ 3,333 ft).	Important *G. agassizii* clusters are reproductively isolated. < 50% of *G. agassizii* clusters are connected with permeable corridors Heavily fragmented by manmade barriers (e.g., major fenced roads, debris basins, etc.). *G. agassizii* clusters are highly isolated and more than four home ranges apart (> 6,667 ft). Infrequent to no interaction.	1 to 1.66
Critical (functionally extirpated or close) 0	0 to 20%	Shrubs very rare, if present.	Only rock supported burrows are available.	< 1,675 acres	< 100	< 3.4	< 85%	Heavily skewed ratio toward males (1:3+)	Only adults are present.	No functional connectivity with other AUs or RUs in the absence of human intervention.	No functional connectivity within the AU in the absence of human intervention.	< 1

In the Workshop, experts identified parameters for the quality of native herbaceous vegetation based on the Landscape Forecasting report. After the Workshop, we added a Critical condition as described to accurately depict AUs contribution to the overall condition of the UVR recovery unit. We added a Critical condition for each habitat and demographic factor and for Habitat Quality this included where only rock supported burrows are available; shrubs are very rare, soil conditions have been significantly degraded to either be less friable or not strong enough to support the burrow from collapsing, and rodent populations are low (Table 11).

4.1.3 Abundance, Density, and Survival

We are using the sub-population target of 3,000 adult desert tortoise for the time frame that we analyzed (49 years), but acknowledge that the 5,000 to 10,000 *G. agassizii* are recommended for long-term viability (USFWS 1994a). Workshop participants determined that achieving 3,000 adult *G. agassizii* over 49 years may be a more reasonable management target given the similarity in order of magnitude (multiple thousands), generation length, and timeframe of the analysis.

Because desert tortoise densities are not known to be bound by an upper limit (carrying capacity that limits densities), abundance and density are evaluated together. AUs that are too small to support 3,000 *G. agassizii* primarily provide redundancy and representation value to the UVR recovery unit and may not be self-sustaining or retain numbers sufficient to prevent genetic loss unless they can be connected to other occupied areas. For this biological report and analysis of current conditions, we compared estimated abundance and density for each *G. agassizii* AU to the estimated AU targets from the Workshop (Table 11). Targets were not changed for individual AUs as the low abundance or low density in any AU is indicative of its short or long-term contributions to the resilience of the UVR recovery unit. We defined Good condition related to demographic factors to be the target abundance and density, 3,000 adult *G. agassizii* and 39 adult *G. agassizii* per mi^2 (Table 11). Moderate condition describes abundance and densities where it could be reasonable to work toward the target through habitat improvements (501 to 2,999 adult *G. agassizii* and 10.4 to 38.8 adult *G. agassizii* per mi^2). Poor condition describes abundance and densities that are increasingly difficult to manage without population augmentation (< 500 adult *G. agassizii* and < 10.38 adult *G. agassizii* per mi^2). After the Workshop, we added a Critical condition that describes areas that are considered close to or already functionally extirpated without human intervention (<500 adult *G. agassizii* and < 10.8 adult *G. agassizii* per mi^2) (Table 11).

Workshop experts suggested that 98 percent annual survival of adult *G. agassizii* may be impracticable given adjacency of habitats to urban environments, human access, and roads. Participants suggested greater than 95 percent annual adult individual survival (averaged over five years) may represent Good condition, 90 to 95 percent survival represented a Moderate Condition, and less than 90 percent was considered Poor condition (Table 11). We later added a Critical category and speculated that less than 85 percent survival represents a critical condition for any AU (Table 11). We assumed that an area with resident *G. agassizii* and high quality habitat should theoretically support high adult survival (> 95 percent). Survival analysis has only occurred in the Babylon AU and the reported survival rate was applied in this one instance. In other AUs, we also considered that factors such as high disease prevalence in an area (e.g., Cinder Knolls) or high off-highway vehicle use (e.g., Sand Mountain) would likely reduce survival. We recommend further research within each AU to better understand population recruitment and survival and to validate these assumptions.

4.1.4 Life Stages and Sex Ratios

We have information in some AUs regarding life stages and sex ratios but note high uncertainty in all AUs for life stage ratios because juveniles are difficult to detect. The UDWR has collected data on sex ratios and documents juveniles within Red Cliffs Desert Reserve (McLuckie *et al*. 2018) and these data were included in our analysis. Workshop experts discussed life stage condition as either all life stages present or all life stages not present. After the Workshop, we refined this demographic factor to include all condition categories and to include a metric to reflect change in rate of recruitment (Table 11).

4.1.5 Connectivity

The UVR recovery unit, at the edge of the species' northeastern range, has natural boundaries to the north and east of the recovery unit (Figure 2 and Figure 3; Table 12). Barriers to connectivity throughout the UVR recovery unit include roads, fences, developed areas, rivers, mountain ranges, agricultural areas, or any intervening stretches of unsuitable habitat large enough to deter *G. agassizii* dispersal between AUs. The city of St. George, Utah is positioned near the center of the UVR recovery unit, with many of the AUs proximally located around the periphery of the city (Figure 5). There is little to no possibility for connectivity across the centrally located urban area AU of the UVR recovery unit due to residential and commercial development. Thus, functional connectivity may require that AUs be connected in a ring-like pattern around the urban areas (Figure 5). At present, a number of the AU boundaries are defined by human-made and natural barriers (e.g., development, roads, and rivers; Table 12). Some of the AUs are further subdivided to reflect existing and proposed roads or based on poor condition or unsuitable habitat within the AUs.

Our resiliency values are ranked into categories for inter- and intra-AU connectivity based on the goal of achieving demographic and genetic connectivity among and within AUs of the UVR recovery unit. Connectivity metrics were discussed qualitatively in the Workshop and recognized as key components to resiliency of the recovery unit. After the Workshop, we refined the qualitative metrics with expert input into a quantitative metrics to represent a range of values (Table 11). Our metrics for evaluating inter-AU connectivity include characteristic adjacency to other AUs, boundary porosity (free of human made impediments to dispersal), and recent records of *G. agassizii* within one home range (200 acres per male) from the AU boundary. Adjacency of two or more AUs to each other provides geographic proximity for connectivity to occur among AUs. Boundary porosity allows for *G. agassizii* to freely cross between adjacent AUs. *Gopherus agassizii* records near the AU boundary are an indicator that individuals could interact with adjacent or nearby AUs.

With many of the AUs being divided by barriers, intra-AU breeding is also important for maintaining short-term AU viability. Intra-AU connectivity enhances the effective abundance of *G. agassizii* within an AU and allows for intra-AU rescue effects to occur after disturbances, such as wildfire. Furthermore, intra-AU connectivity acts synergistically with inter-AU

Table 12. Major Topographical and Anthropogenic Barriers within and Between AUs, west to east, in the UVR recovery unit.

Analytical Unit Name	Topographical and Anthropogenic Barriers
Far West	Southeast: Interstate-15 (I-15). West: Beaver Dam Mountains. Within: Unfenced roads (fence refers to *G. agassizii*-fencing throughout).
Arizona	North: Residential development is increasing on the Arizona Strip. Northwest: I-15.
Green Valley	Northeast: Santa Clara River and Old Highway 91. East: High density residential development. Southeast: I-15. Within: Unfenced roads and Off-highway vehicle use.
Snow Canyon (*Zone 1 and 2*)	East: State Route-18 (SR-18). South: Low density residential development. Within: Tuacahn Drive (fenced) and Snow Canyon Drive (mostly unfenced).
Urban Interface	All directions: Three sub-units, each surrounded by high density residential developments. Within: Some residential barriers within as well.
West Cottonwood (*Zone 3*)	North: unsuitable habitat. East: Cottonwood Springs Road. South: High density residential developments. West: SR-18 and residential developments. Within: Red Hills Parkway, fenced on both sides with 5 culverts (low use)
East Cottonwood (*Zone 3*)	North: unsuitable habitat. East: I-15. South: High density residential and commercial developments. West: Cottonwood Springs Road. Within: Electrical substation and expansion
Sand Mountain	North: High density residential development and roads. West: Southern Parkway and I-15
Babylon (*Zone 4*)	North and East: High density residential development. South: the Virgin River. West: Quail Creek Reservoir and I-15. Within: Babylon Road, unfenced
Cinder Knolls (*Zone 5*)	North: the Virgin River. East, South, and West: High density residential development and roads (600 North).
Springdale	North and West: unsuitable habitat. East and South: State Route 9 (entrance road to Zion National Park), Virgin River, and residential development. West: Virgin River and residential and agricultural development.

connectivity to maximize benefits with gene-flow between AUs. Intra-AU connectivity differs from inter-AU connectivity in that we are primarily focusing on connectivity between *G. agassizii* clusters instead of between *G. agassizii* sub-populations and the boundaries are thus less defined. Our metrics for evaluating intra-AU connectivity include the presence of permeable corridors between *G. agassizii* clusters within each AU (i.e., low landscape resistance), absence of anthropogenic barriers, and overlapping or nearby *G. agassizii* home ranges.

Unassigned areas comprise potential habitat areas not included in the 11 AUs and are those areas that are white and not colored within the analysis area in Figure 13. Unassigned areas are large areas of modeled suitable habitat with developed areas removed (78,813 acres; Table 3). These unassigned areas are scattered throughout the UVR recovery unit, making it difficult to describe habitat and demographic conditions. Current conditions in unassigned areas are expected to be similar to the adjacent AUs, but, in contrast to assigned areas, they are not managed for *G. agassizii* conservation, and *G. agassizii* are anticipated to be moved out of these areas when development or other conflicts occur. Throughout this analysis, in areas where we have limited data but suspect occupancy, we have applied the density estimate from the nearby NEM Recovery Unit (3.4 *G. agassizii* per mi^2). These unassigned areas may support up to 415 *G. agassizii* based on this density, or 10 percent of the total *G. agassizii* abundance in the recovery unit (Table 3). These areas may be important because they may be important, for connectivity between AUs (e.g., between Snow Canyon and Green Valley AUs). Additional on-the-ground research will be necessary to identify the specific topographical and anthropogenic barriers that may be present. Given the land ownership, management, and current barriers, we do not describe these areas in greater detail in this document, other than to state the estimated abundance.

Results

In Table 13 and Figure 13, we summarize our resiliency evaluation of current condition for each of the 11 AUs in the UVR recovery unit. Currently, UVR recovery unit resiliency is rated to be in Moderate Condition overall (Table 13). Figure 13 depicts the 11 AUs of *G. agassizii* in the UVR recovery unit with each AU box color-coded to indicate its overall condition. No AUs are in Critical condition. Habitat quality factors overall were rated to be in Good Condition; however, acres of habitat in each AU, abundance, and connectivity (within and between AUs) are consistently in Poor or Moderate Condition (Table 13). Inter-AU connectivity is the metric with the poorest condition value of the UVR recovery unit.

Table 4-3 in Appendix 4 summarizes the potential of each area to contribute to resilience from Table 4-2 in Appendix 4, combined with the current condition score from Table 13. Assessing these together provides a proportional resiliency status for each of the AUs in the UVR recovery unit. For example, West Cottonwood and East Cottonwood AUs (which make up zone 3 of Red Cliffs Desert Reserve) represent 30 to 40 percent of the resiliency of the recovery unit, thus indicating that this percentage of the UVR recovery unit has a Moderate current condition (Table 15). If the resiliency contribution of all AUs are combined using current condition, AUs with Poor and Good current condition contribute to approximately 15 to 20 percent of the resiliency of the recovery unit, and AUs with Moderate resiliency scores contribute to approximately 80 to 85 percent of the resiliency of the recovery unit. Overall, the recovery unit is in Moderate Condition (Table 13).

Table 13. Evaluation of current G. agassizii AU resiliency (listed west to east), based on the Condition Category Table (Table 11). Overall Score for the UVR recovery unit was multiplied by the value the AU can contribute to recovery unit resiliency from Table 4-2in Appendix 4, with uncertainty. <1 = Critical condition, 1 to 1.66 = Poor Condition, 1.67 to 2.33 = Moderate Condition, 2.34 to 3 = Good Condition.

	Habitat Factors				**Demographic Factors**							
Analytical Unit Name	**Native Herbaceous Vegetation**	**Shrubs**	**Burrows**	**Acres of Suitable Habitat (Space)**	**Sex Ratio**	**Life Stage**	**Estimated Annual Survival**	**Density of DTs**	**Abundance 3x**	**Intra-AU Connectivity 3x**	**Inter-AU Connectivity 3x**	**Overall Score**
Far West	Poor (1)	Poor (1)	Moderate (2)	Moderate (2)	Unknown	Unknown	Poor (1)	Poor (1)	Poor (1)	Poor to Moderate (1.6)	Moderate (2)	**Poor (1.5)**
Arizona	Moderate (2)	Moderate (2)	Poor (1)	Good (3)	Unknown	Unknown	Unknown	Poor (1)	Poor (1)	Moderate (2)	Moderate (2)	**Moderate (1.7)**
Green Valley	Good (3)	Moderate (2)	Good (3)	Moderate (2)	Unknown	Good (3)	Moderate (2)	Moderate (2)	Moderate (2)	Good (3)	Moderate (2)	Good (3)
Snow Canyon (*Zone 1 and 2*)	Good (3)	Good (3)	Good (3)	Poor (1)	Good (3)	Good (3)	Good (3)	Good (3)	Poor (1)	Poor to Moderate (1.6)	Poor to Moderate (1.6)	**Moderate (2.0)**
Urban Interface—3 subunits	Moderate (2)	Good (3)	Good (3)	Poor (1)	Unknown	Good (3)	Poor (1)	Unknown	Critical (0)	Poor (1)	Critical (0)	**Poor (1.1)**
West Cottonwood (*Zone 3*)	Moderate (2)	Moderate (2)	Good (3)	Poor (1)	Good (3)	Good (3)	Moderate (2)	Good (3)	Moderate (2)	Moderate (2)	Critical (0.5)	**Moderate (1.9)**
East Cottonwood (*Zone 3*)	Moderate (2)	Moderate (2)	Good (3)	Poor (1)	Good (3)	Good (3)	Moderate (2)	Moderate (2)	Poor (1)	Good (3)	Critical (0.5)	**Moderate (1.9)**
Sand Mountain	Moderate (2)	Moderate (2)	Moderate (2)	Moderate (2)	Unknown	Unknown	Poor (1)	Poor (1)	Poor (1)	Good (3)	Poor (1.5)	**Moderate (1.9)**
Babylon (*Zone 4*)	Good (3)	Good (3)	Good (3)	Poor (1)	Good (3)	Good (3)	Moderate (2)	Moderate (2)	Poor (1)	Moderate to Good (2.3)	Critical (0.5)	**Moderate (1.8)**
Cinder Knolls (*Zone 5*)	Good (3)	Good (3)	Good (3)	Critical (0)	Good (3)	Good (3)	Moderate (2)	Good (3)	Critical (0)	Good (3)	Critical (0.5)	**Moderate (1.8)**
Springdale	Good (3)	Good (3)	Moderate (2)	Critical (0)	Poor (1)	Good (3)	Moderate (2)	Poor (1)	Critical (0)	Moderate (2)	Critical (0.5)	**Poor to Moderate (1.6)**
Unassigned areas	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
UVR recovery unit Weighted	Moderate (2.2)	Moderate (2.2)	Good (2.7)	Poor (1.2)	Moderate (2.2)	Good (2.5)	Moderate (1.8)	Moderate (2.2)	Poor (1.3)	Moderate (2.2)	Critical (0.9)	**Moderate (1.8)***

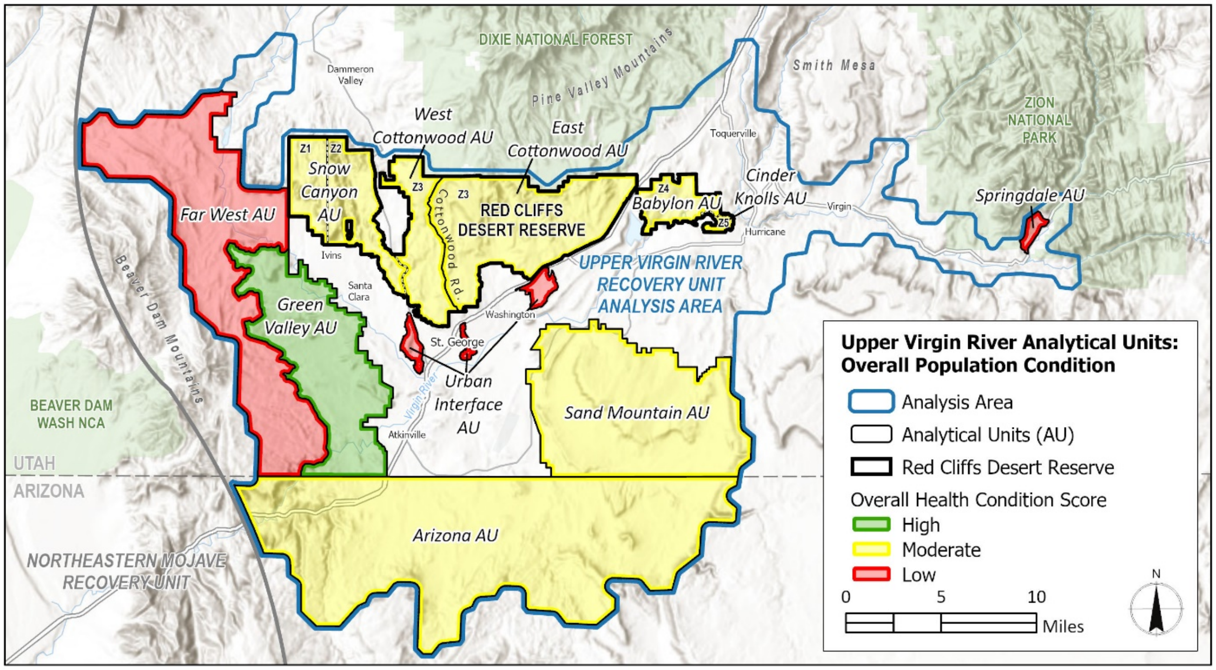

Figure 13. Current condition scores of the 11 analytical units in the UVR recovery unit.

In summary, the abundance in each AU is assessed to be below viability in the absence of connectivity with other AUs or the NEM recovery unit (Table 3, Table 13). Connectivity was recognized as key component to resiliency of the recovery unit (USFWS 2019a). The recovery unit-wide effects of drought coupled with other stochastic events (e.g., wildfire) and the negative effects of anthropogenic stressors (e.g. development) have the potential to reduce resiliency of individual AUs, and thus the overall resiliency of the UVR recovery unit is Moderate Condition and declining.

4.2 Redundancy

A recovery unit with a greater number of resilient AUs that are more widely distributed is generally at lower risk to catastrophic events than a recovery unit with fewer AUs that are closely distributed. Additionally, having multiple resilient AUs distributed across the recovery unit is likely to better preserve the genetic range of adaptive capacity in the UVR recovery unit, and hence, the evolutionary flexibility of the species (representation). The significant determinants of redundancy for the UVR recovery unit are: 1) the number of resilient AUs needed to buffer against catastrophic losses and 2) a sufficient distribution of resilient AUs across the recovery unit to reduce the risk of a catastrophic event causing significant population level impacts. These redundancy factors for *G. agassizii* have changed between the past and current conditions due to urbanization and associated fragmentation.

The past redundancy of *G. agassizii* in the UVR recovery unit area was likely high due to the species inter-connected and wide distribution throughout the recovery unit and because catastrophic wildfires and non-native plant invasion were not an issue. It is probable that wildfire and flooding had a small effect on *G. agassizii* within localized areas of the recovery unit but invasive grasses have undoubtedly increased the risk of and threats from wildfire. Although drought is part of a desert ecosystem and likely impacted the UVR recovery unit area periodically in the past, the species was adapted to the desert environment. The compounded effects of invasive plant species, wildfire, and fragmentation exacerbate the impacts of drought that under more natural conditions, were likely overcome.

Methods

We identified the following catastrophic events that have the potential to affect *G. agassizii* AUs in the UVR recovery unit: (1) drought, (2) wildfire, (3) flooding, and (4) non-native plant invasion. Three of these catastrophic events (drought, natural wildfire, and flooding) would be considered naturally occurring, and non-native plant invasion and human-caused changes to wildfire regimes would be considered anthropogenic disturbances. We qualitatively evaluated and summarized each catastrophic event in terms of frequency of occurrence, recovery unit-level impact, and spatial extent (Table 14).

Results

The UVR recovery unit has 10 AUs in southwestern Utah and 1 AU in northwestern Arizona (Figure 5). The 11 AUs help provide redundancy that reduces risk from catastrophic events like wildfire, flooding, and invasive non-native plant species. However, the 11 sub-populations are distributed relatively narrowly in a small corner of southwestern Utah and in an even smaller part of Arizona. This puts the species at greater risk to catastrophic events like severe or extended drought conditions. In addition, the AUs in this recovery unit are distributed in a ring configuration (Figure 5) and connectivity between AUs across the recovery unit is low (Table 12 and Table 13). One AU out of 11 exhibits Good Condition overall (Table 13 and Figure 13) and Red Cliffs Desert Reserve provides the majority of the resiliency of the recovery unit (Table 4-2 and Table 4-3 in Appendix 4). Stochastic events, such as wildfire, flooding, and non-native plant invasion, are likely to occur in each AU, and likely multiple times, over the next 49 years. These repeating events would have long term effects to the AU and the UVR recovery unit.

Recent localized catastrophic events (drought and wildfire) have reduced the resiliency of redundant sub-populations in the UVR recovery unit (McLuckie *et al*. 2018). Drought is the one catastrophic event that has the potential to impact all AU populations at the same time within the recovery unit. The ability of the AUs to retain redundancy and reduce the risk of catastrophic events is likely dependent upon maintaining high quality, intact, and inter-connected habitat conditions that provide the necessary nutritional forage and life-history resources to enable the *G. agassizii* to persist under extreme weather events. In addition, the small degree of spatial and habitat heterogeneity across the UVR recovery unit area should be maintained to reduce the chances of all sub-populations failing concurrently due to poor environmental conditions. Habitat heterogeneity provides a range of options under varying conditions.

Table 14. Catastrophic events: Frequency and impacts to the UVR recovery unit.

Catastrophic Event	**Historic Occurrence**	**Present Occurrence**	**Recovery Unit-Level Impact(s)**
Drought	Periodic (decadal)	Periodic (decadal)	• Reduction in recovery unit abundance. • Strength of impact dependent upon the timing, length and severity of drought conditions. Impact to species would be greater during summer months. • Spatial occurrence of drought is recovery unit wide. Same impact across all AUs. Strength of impact depends on length and severity.
Wildfire	Infrequent (25 – 100 years)	Periodic (decadal)	• Reduction in AU abundance. • Strength of impact dependent upon fire severity. The impact to the recovery unit would likely be low based on localized occurrence of fires. • Spatial occurrence of wildfire is localized. Unlikely to impact more than 1 AU per wildfire event.
Flooding	Periodic (decadal)	Periodic (decadal)	• Reduction in AU abundance. • Possible reduction in available habitat. • Strength of impact dependent upon the length and severity of precipitation event. • Spatial occurrence of flooding is localized and dependent on topographic features, though large events may impact many or all AUs simultaneously. Unlikely to impact more than 1 AU per event.
Non-native plant invasion	None	Periodic (decadal)	• Reduction in AU population size. • Reduction in available habitat. • Strength of impact dependent upon the extent and severity of the invasion within the AU. • Spatial occurrence is of non-native plant invasion is localized. Unlikely to impact more than 1 AU per invasion, but are often present in all AUs.

In summary, the low abundance in each AU requires connectivity with other AUs or the NEM recovery unit in order for the population to be robust to extirpation. Stochastic events coupled with negative effects of anthropogenic stressors (e.g. development) further reduce resiliency of individual AUs, and thus the UVR recovery unit lacks redundancy that is considered sufficient without a connection between AUs or to the NEM recovery unit.

4.3 Representation

Healthy representation for *G. agassizii* is characterized by genetic diversity, behavioral and ecological heterogeneity in occupied habitat, and sufficient abundance or a level of inter-connectivity with other areas that can avoid demographic related collapses, inbreeding depression, and other deleterious genetic outcomes that could otherwise result from small, isolated sub-populations. *Gopherus agassizii* in the 11 AUs of the UVR recovery unit occupy a diversity of environmental conditions, ranging from caliche burrows and Mojave desert ecotype (Far West and Green Valley AUs) to sandstone and basalt soils (Red Cliffs), creosote flats (Arizona AU), and even some areas with juniper trees and clay soils intermixed with creosote and sandstone (Springdale AU). Occupation of these diverse environmental conditions range-wide indicates that the *G. agassizii* likely retains plasticity and adaptive potential to respond to some ecological variation, given sufficient forage and burrow sites. Heterogeneity between the AU populations reduce the risk of loss associated with potential catastrophes, such as widespread drought, and help reduce risk associated with novel, environmental change, such as long-term climatic changes.

Genetic diversity is not well understood in the UVR recovery unit, but the genetic structure of the desert tortoises in the UVR recovery unit has likely been influenced by socially-driven human relocations and movements (e.g., pets, illegal releases of captives, or concerned individuals moving an animal from one side of the road to the other side of a road). Moving *G. agassizii* to new areas can compromise genetic adaptations to a local environment or unintentionally reduce fitness through outbreeding depression (Murphy *et al.* 2007) though outbreeding depression responses may take 500 years or more to present (Averill-Murray and Hagerty 2014). Moving *G. agassizii* to new areas can also preserve genetic diversity when conducted through specifically informed translocations, though this should only be conducted in controlled trials. In recent decades, education efforts have increased and illegal releases are considered infrequent and less likely to occur than in the past, though still occurs (McLuckie 2020). While natural genetic diversity may be influenced by the lack of connectivity between AUs, natural genetic divergence (the natural genetic shift apart between sub-populations) may be low given this species slow reproduction rates (Latch *et al*. 2011).

Although not currently known to be at risk, if the UVRRU lacks genetic diversity or if it is at risk of deleterious genetic outcomes due to an unremedied small, isolated condition, the entire recovery unit could be at greater risk from environmental and demographic stresses, such as mortality from disease, malnutrition, or low hatching success. The UVR recovery unit population as a whole has been documented as experiencing declining abundance of adult animals and the UVR recovery unit is likely to always have relatively small overall population numbers due to its small size compared to other recovery units. However, density estimates in some areas are above the population-level target densities. We note that we have lower certainty about densities and abundance of desert tortoise in the UVR recovery unit outside the Red Cliffs Desert Reserve. In addition, the AUs are distributed widely across the recovery unit, and abundance is below targets within individual AUs. However, as an inter-connected unit among some AUs, the recovery unit population size may be sufficient. Only three AUs of the 11 have been documented with densities that are considered to meet recovery targets for the sampled area

(Snow Canyon, West Cottonwood, and Cinder Knolls). Overall, small size of the AUs could result in deleterious genetic outcomes over several generation-times.

Connectivity between most AUs is limited to some degree and distances between some AUs can be > 15 miles apart, often with human development restricting movement potential. The long distances between AUs reduces the likelihood of *G. agassizii* dispersing between those AUs, which increases the risk of decreased genetic diversity and lower fitness over an evolutionary time scale. We have very little evidence of how *G. agassizii* currently move between sub-populations, but it is unlikely that *G. agassizii* outside Red Cliffs Desert Reserve would repopulate some extirpated areas on their own due to low estimated abundances and densities and limited connectivity. However, the successful translocations that occurred in the Babylon AU since 1996 and the evidence of reproduction following translocations indicates translocating *G. agassizii* may be an effective way to supplement populations below 10.1 adult *G. agassizii* per mi^2 (minimum viable density; USFWS 1994a). With a focused effort on the sub-populations that are most likely to continue to support the demographic and habitat needs of *G. agassizii*, translocations are considered to be a promising recovery action that could improve the population abundance and overall representation of the UVR recovery unit.

We note that it remains unknown but is not anticipated that there are genetic or behavioral differences between sub-populations in the UVR recovery unit given the relatively short time they have been isolated or fragmented. It is also unknown whether any adaptive advantage exists among or within the UVR recovery unit. Whether desert tortoise retains the evolutionary plasticity or adaptive capacity for adaptations that would result in a natural selection of individuals that would be better adapted to local environmental conditions or recent changes, such as the ability to thrive in higher elevations would require extensive research. Some natural genetic material or population structure could have been altered as a result of people moving desert tortoises for non-scientific or conservation purposes. Genetic shifts resulting from small populations are a risk, but natural selection can also act on a population that favors positive phenotypes. Overall, these dynamics occur over evolutionary timeframes and are not likely to be detected over 1 generation-time (25 years). More research is needed to understand the genetic population and individual composition and the species evolutionary plasticity and adaptive capacity to determine positive or negative changes that may have or are likely to occur in the UVR recovery unit.

Results

G. agassizii in this recovery unit occupies a diversity of habitats. However, relatively low abundance within AUs and high fragmentation levels between AUs can lead to demographic and genetic deterioration over time (Table 3, Table 2, Table 13). Human-assisted movement or translocation programs may address some of the concern if cautiously undertaken (Murphy *et al.* 2007). We investigate the potential effects of ongoing, additional, and reduced translocations in Chapter 5 Future Condition. More importantly for management timeframes, the recovery unit-wide effects of habitat fragmentation and degradation limit resilience in individual AUs and have the potential to reduce healthy representation among AUs and thus the overall representation health of the UVR recovery unit.

4.4 Synopsis

The priority population-level need to promote persistence and recovery of the UVR recovery unit is to maintain multiple AUs in Good Condition, and maintain healthy resiliency, representation, and redundancy by improving inter- and intra-AU connectivity. In Chapter 2 we described the condition of these needs which highlighted the importance of maintaining and improving conditions in West and East Cottonwood AUs. Currently, UVR recovery unit resiliency, redundancy, and representation is in Moderate Condition (Table 13 and Figure 13), primarily driven by the current condition in West and East Cottonwood AUs and small size, low abundance, and limited connectivity of all the AUs (Table 13 and Tables 4-2 and 4-3 in Appendix 4). Overall the recovery unit is in Moderate Condition because AUs with Poor current condition (resiliency) provide < 10 percent of the resiliency of the recovery unit, and AUs with Moderate current condition provide 89 percent of the resiliency of the recovery unit.

The Red Cliffs Desert Reserve is estimated to support approximately 2,300 adult *G. agassizii* and more than 50 percent of the UVR recovery unit population, including Arizona AU (Table 3). West and East Cottonwood AUs support 75 percent of the Red Cliffs Desert Reserve population (1,749) and these core AUs support 40 to 50 percent of the UVR recovery unit's resiliency value (Appendix 4). These two AUs have greater influence on resiliency than the other nine because of their ability (in densities and abundance) to support a multi-generational sub-population with recruitment and all life-stages of *G. agassizii*. These AUs would be more effective if reconnected across Cottonwood Springs Road, thus improving access to suitable habitat and movement. Their central location in the recovery unit makes them integral to redundancy and representation through restoring inter-AU demographic connectivity and gene flow. This combination of population density, large area, and central location have made these AUs the focus of most recovery efforts and management over the past 25 years. The Moderate and Poor conditions of most other AUs, mainly due to limited size, low density, fragmentation, or isolation put these AUs at greater risk for loss or extirpation, and further reduce their contributions of representation and redundancy to the resiliency of the UVR recovery unit. That said, moderate condition AUs remain critical to the long-term recovery, and their condition could be improved through connectivity. This is also true for AUs that have the potential to connect westward to the NEM recovery unit such as Green Valley AU which is contiguous with the species range to the west. Sustaining population numbers in West and East Cottonwood AUs and promoting resilience to stochastic events continues to be a conservation effort priority as well as promoting connectivity among other larger AUs. Abundance and density values in each AU may indicate where habitat connectivity or population augmentation is warranted. The current condition of the UVR recovery unit remains reliant on intensive management, especially in the West and East Cottonwood AUs and in the Reserve in general. Improving connectivity throughout the recovery unit is critical to long-term recovery.

Chapter 5: FUTURE CONDITION

In this chapter, we describe our analysis of the future condition of *G. agassizii*. Specifically, we forecast the AU's likely to persist over time and use this information to infer the future distribution of the *G. agassizii* within the UVR recovery unit over the next 49 years (2020-2069).

We forecasted scenarios to 2069 because this time period includes the range of available, localized climate models within a reasonable range of certainty, projections about human population growth, response of desert ecosystems to those changes, and is biologically relevant to the *G. agassizii*, representing two *G. agassizii* generation lengths. Future environmental projections, slow and rapid environmental change, were developed to evaluate the likely future condition of the species. We also developed three conservation management scenarios to explore the potential impact of conservation actions on the species' future condition. With these scenarios, our evaluation of future condition presents a plausible range of expected species responses into the future, using the results of our Current Conditions (Chapter 4) as the baseline.

Methods

5.1 Environmental Scenarios (Slow or Rapid Change)

We selected four plausible future climate projections representing four global climate model simulations that capture the range of likely future changes in temperature and precipitation for the UVR recovery unit over the next 49 years (Appendix 5; Rangwala 2020). We used the average from the upper range in changes and the average from the lower range in changes from these four projections in our two environmental scenarios, slow and rapid change. These plausible projections (slow and rapid environmental change) for Washington County, Utah capture the range of future anthropogenic influences, and they are based on the range of climate projections and anticipated environmental response. The two projections include a slow environmental change projection and a rapid environmental change projection. Table 5-1 in Appendix 5 provides a summary of the changes in variables between the slow and rapid environmental change.

We then evaluated the plausible range of future changes in stressors to 2069 (Table 15). The slow environmental change projection assumes that growth and associated conditions will continue to worsen conditions for the *G. agassizii* but at less rapid rates. The rapid environmental change projection is a logical worsening of all conditions for the *G. agassizii* in the UVR recovery unit. The primary anthropogenic influences on *G. agassizii* in this recovery unit and their habitat that were used to evaluate the projections include residential development, associated infrastructure and roads, and recreation. The U.S. Census Bureau reported 165,662 people in Washington County in 2017 (U.S. Census Bureau 2018) and population projections estimate 356,000 people will live in Washington County by 2045, a more than doubling of the human population (Perlich *et al*. 2017, U.S. Census Bureau 2018). We anticipate this growth will continue through and beyond 2069. Thus, we also anticipate continued residential and commercial development, infrastructure, road development, utility development, trail development, and recreation associated with the increased population growth.

Table 15. Plausible range of future changes in stressors to 2069 identified in the Workshop with local G. agassizii experts.

Source of Stressor	Slow Environmental Change	Rapid Environmental Change
Wildfire	Frequency of fire risk days increases slightly (Table 18)	Frequency of fire risk days increases substantially (Table 18)
Invasive Plants	Moderate conversion to invasive plants	Complete conversion
Drought and Climate	Lower range of change in Table 18. Overall, hotter and more precipitation	Upper range of change in Table 18. Much hotter and longer droughts, precipitation variable
Predators (Subsidized)	Does not increase enough to influence *G. agassizii* population dynamics	Increase in predators influences *G. agassizii* population dynamics
Motorized Recreation	Slight increase	Significant increase in motorized recreation
Non-motorized recreation: Biking, hiking, horse-back riding	Slight to Moderate increase	Significant increase
Disease (esp. *Mycoplasma*)	Slight to Moderate increase in *Mycoplasma*, increased presence of other diseases	Significant increase in *Mycoplasma* and other diseases
Urbanization	Slight to Moderate increase	Large increase
Roads (Direct and Indirect Impacts)	Slight to Moderate increase	Large increase

5.2 Conservation Management Scenarios (Continued, Improved, Reduced)

Workshop experts identified a suite of conservation actions that could be implemented to address *G. agassizii* stressors. We then identified which actions we predicted would be most likely under three different groupings of conservation management actions: continued, improved, and reduced (Table 16). Management actions in each grouping are not mutually exclusive (i.e., a combination of actions will likely be used); the groupings are intended to capture the range of variation in *G. agassizii* responses to management actions. A "continued" set of actions assumes no change in conservation management from current levels. The current regulatory mechanisms remain the same, with no improvement in wildfire or non-native invasive species management or planning. An improved, or heightened conservation management set of actions assumes more and improved conservation and planning, with a focus on connectivity and developing goals for each AU. A reduced, or decreased conservation management set of actions assumes reduced conservation, with a major reduction in resources from local governments and organizations.

Table 16. Range of future G. agassizii conservation management scenarios.

Influence	Continued, no change in conservation management from current	Improved conservation management (Focus on Connectivity)	Reduced conservation management
Regulatory Mechanisms and Residential Development	The County and HCP partners implement the HCP which includes a translocation plan with limited money available for adaptive management and limited connectivity or restoration efforts. Clearance surveys are primarily conducted within the Red Cliffs Desert Reserve and 1995 incidental take areas. Fencing is monitored and maintained with a limited source of funding.	The County, local, and Federal governments have a plan for *G. agassizii* in each AU, which improve habitat quality and connectivity. Each municipality would enforce trash control plans. Clearance surveys are conducted in all modeled suitable habitat or strong justification is provided that the area is not habitat. Fencing is monitored and maintained with sufficient funding.	The Federal and State governments implement *G. agassizii* conservation (fencing, law enforcement, education, monitoring) without the County finances or facilitation. Clearance surveys are not managed by the County most areas outside the Red Cliffs Desert Reserve are not surveyed. Fencing is not monitored or maintained regularly.
Wildfire	Invasive plant species and wildfire continue without effective management or restoration solutions. No increase in law enforcement, and human-caused wildfires increase. No connectivity between AUs to allow demographic recovery.	Aggressive management of wildfire and fuel breaks. Increased law enforcement on-the-ground and provide education to help prevent human-caused wildfires. Increased connectivity between AUs allows demographic recovery following wildfires, protect intact habitat, restore habitat.	Relies on limited funding from Federal and State partners and mitigation from piecemeal projects. Law enforcement is reduced and human-caused wildfires increase.
Invasive plant species	Invasive plant species continue to expand without effective management solutions, although efforts (ROW herbicide and small scale projects) are on-going.	Aggressive management of invasive plants and habitat restoration (scaling up and incorporating innovation).	Management solutions do not receive continued funding and innovations cannot be attempted.
Drought	Drought is not planned for in habitat restoration seed mixes. Translocations of *G. agassizii* are temporarily halted during the drought and any capacity concerns would be adaptively managed by the HCP Partners.	Remove grazing, restore habitat prior to droughts, maintain cleared *G. agassizii* in a holding facility and rapidly expand and adapt if it appears the holding capacity may reach capacity.	Translocations needs are not met quickly while growth continues unabated; there is nowhere to hold cleared *G. agassizii* until the drought subsides. Habitat restoration is not occurring in non-drought years.

Influence	Continued, no change in conservation management from current	Improved conservation management (Focus on Connectivity)	Reduced conservation management
Subsidized predators (esp. Ravens)	No monitoring plan, no coordinated control possible, no discussions with cities about trash control ordinances or educational campaigns.	Decrease predator access to human subsidies in and adjacent to habitat, Predator monitoring and control plan, environmental education.	Trash increases in and adjacent to habitat with no funding to control, ravens multiply with no monitoring or control, *G. agassizii* recruitment severely impaired.
Motorized recreation	No limits on motorized recreation in *G. agassizii* habitat outside Red Cliffs Desert Reserve. Law enforcement is not dedicated full-time on-the-ground.	Restrict motorized recreation in habitat connectivity areas. Speed limits in habitat in all AUs, emergency road closure, education, at least one dedicated full-time on-the-ground law enforcement, install and maintain human and *G. agassizii* barriers, restore habitat, restore roads, restrict OHV events, sign and fence protected areas, sign designated routes.	Increase in OHV events with a focus on areas that overlap important *G. agassizii* habitat connectivity areas. Law enforcement is not available at a level to enforce compliance.
Non-motorized recreation	Signage maintained in Red Cliffs Desert Reserve to alert recreation users to the presence of *G. agassizii*. Minimal management for *G. agassizii* elsewhere. Law enforcement is not dedicated full-time on-the-ground.	Sign and fence protected areas and AUs, at least one dedicated full-time on-the-ground law enforcement, education, restore habitat.	No new signs and signage is not maintained. Law enforcement is not available at a level to enforce compliance.
Disease	Monitoring blood of translocated individuals and symptoms of individuals encountered in Red Cliffs Desert Reserve surveys. No habitat improvements experiments are conducted to target or study disease.	Monitoring using updated protocols adapted for site-specific considerations (e.g., density of translocation site), halting translocations of *G. agassizii* if a risk assessment is moderate, improving health through habitat restoration of areas heavily invaded by *Bromus* spp.	All monitoring ceases, disease is spread through translocations, no habitat restoration occurs.
Urbanization	Surveys and translocations at HCP administrator discretion.	Surveys and translocations in all potentially suitable habitat (unless the habitat is not suitable), fencing, City and County planning, land acquisition and habitat protection in areas that	No surveys or translocations in any potentially suitable habitat. Fencing would not be maintained and no additional habitat would be protected.

		could meaningfully connect habitat or improve resilience, facilitate connectivity passage structures, and education.	
Influence	**Continued, no change in conservation management from current**	**Improved conservation management (Focus on Connectivity)**	**Reduced conservation management**
Paved Roads	Additional roads are constructed at the edge of the Red Cliffs Desert Reserve zones and connectivity areas (west of proposed zone 6).	No new roads in Red Cliffs Desert Reserve. Increase connectivity on existing roads through underpasses, install and maintain tortoise fencing (with shade structures and passage), protect intact habitat, City and County planning, speed limits posted and enforced, public educated about what to if they encounter a *G. agassizii* and the impacts of litter.	All planned roads are constructed in and adjacent to Red Cliffs Desert Reserve: e.g., Northern Corridor, Cottonwood Springs Road improvements, Western Corridor, proposed zone 6 link roads, Red Cliffs Desert Reserve, zone 4 and 5 roads.
Human access (esp. Off-leash dogs & illegal trails)	Law enforcement is not dedicated full-time on-the-ground. Trail stewards continue. Signage and fencing maintained. Education campaigns. Natural regeneration of dispersed trails occurs by blocking with rocks or other minimal trail control. Minimal litter control.	Designate and close roads, dedicated full-time on-the-ground law enforcement, education, install and maintain human barriers, restore roads, signed and fenced protected areas and designated routes, control dogs, decrease predator access, litter control, restore habitat.	Law enforcement is not available at a level to enforce compliance. Signage and fencing is not maintained. No educational resources, trail stewards disband. Habitat continues to degrade. *Gopherus agassizii* killed or injured through interactions with off-leash dogs.

5.3 Results: Future Scenarios to 2069 (49 years)

Using the two environmental change scenarios (Slow or Rapid Environmental Change) and three conservation management scenarios (Continued, Improved or Reduced), we evaluated the future condition for each AU out to the year 2069 using the same methodology we used to evaluate the current condition in Chapter 4 (Table 17). We used the conditions category table (Table 11) to evaluate the future condition for each habitat and demographic factor and calculated an overall resiliency score for each AU and the recovery unit as a whole (Tables 18 to 23).

Table 17. Future Scenarios: slow or rapid environmental change and continued, improved, or reduced conservation management.

Slow Climate & Environmental Change (slow increase in temperatures, invasive plants, and wildfires)			Rapid Climate & Environmental Change (rapid increase in temperatures, invasive plants, and wildfire)		
Conservation Management Scenario			Conservation Management Scenario		
Continued	Improved	Reduced	Continued	Improved	Reduced

5.3.1 Continued Conservation Management

5.3.1.1. Scenario 1 – Continued Conservation Management and Slow Environmental Change

Maintaining the current level of conservation action is unlikely to be slow or halt decline rates of *G. agassizii* across the UVR recovery unit. This is primarily due to the fragmented nature of this recovery unit with each AU and because many AUs are likely too small or supporting low densities or abundance (Table 13). Despite management at current levels, abundance in the AUs continue to decline due to continued pressures from stochastic events such as wildfires and droughts (Table 18). Impacts relating to human access are likely to continue to increase, thereby exacerbating natural stochastic events in the absence of an increase or change to management (i.e. increasing law enforcement and protective measures, connecting habitat).

Under the slower climate change projections, it is unlikely that temperatures would increase rapidly enough to impact *G. agassizii* sex ratios in this most northeastern part of the species' range (Appendix 5, Climate Projections). Spring, summer, and fall temperatures may be the most important to consider for future sex ratio considerations. Projections for average spring temperatures are 60 to 63°F, summer temperatures 83 to 86°F, and fall temperatures are 64 to 67°F. Number of days where air temperatures are projected to be over 100°F may increase from an average of 5 days a year historically, to 16 to 33 days a year. Air temperatures and soil temperatures are highly correlated in the Mojave Desert and soil temperatures are typically warmer than air temperatures (Bai *et al.* 2014). Thus, spring-laid eggs may be impacted by the projected increase of days above the optimal sex ratio temperature (> 88°F produce all females) and optimal survival (83 to 91°F); however, desert tortoise may also respond through adaptive behavioral changes to adjust. We note that increased precipitation also decreased soil temperatures (Bai *et al.* 2014) which may also alleviate temperature concerns in some years.

Increased frequency of droughts and wildfires would likely contribute to the vegetation community shift to *Bromus* spp., further accelerating the local impacts to *G. agassizii* (Abundance, Density, and Survival and Risk Factors). However, the slow change projection considers drought frequency every 15 to 30 years and a zero to slight increase in wildfire risk days. This slower change may provide time for science and management strategies to be developed that improve post-fire native plant restoration and result in effective tools for managing non-native invasive plant species and improving forage. Under continued management, we would expect to see some continued research and efforts toward restoration and invasive species management, particularly within Red Cliffs Desert Reserve.

Under this scenario, we anticipate ten existing AUs would be maintained or slightly decline in condition throughout the recovery unit, which is similar to current conditions (Table 13 and Table 18). One AU is likely to be in Critical Condition (Urban Interface AU). For that AU, we anticipate continued decline given the past development impacts to its value to the recovery unit and the continued loss of habitat even under the slow environmental change scenario (Table 4-3, Appendix 4). Despite the reduction in value of the Urban Interface AU, the recovery unit overall will retain a high number of AUs distributed across diverse habitat types and among varying topographic features thereby providing resilience to withstand more localized catastrophic events (wildfire, disease), and to some extent, range-wide catastrophic events (drought). However, because conservation management is neither improved nor reduced under the scenario, we expect healthy representation (genetic and behavioral diversity) to decrease without human intervention, due to lack of connectivity between the existing AUs, thereby increasing the risk of genetic deleterious changes such as inbreeding depression in the small and isolated AUs over several generation-times. The predicted distribution and connectivity conditions would likely be similarly impacted compared to the current distributions with no change or worsening likely for fragmentation influencing demographics and genetic diversity within and among AUs.

Under the continued level of conservation and management and slowly worsening climate and stochastic events, the decline rate of *G. agassizii* leads to a high likelihood of extirpation in one AU. All variables scored in Poorer condition under the scenario, except for connectivity, which generally stayed the same. However, in some AUs, no management change also results in continued increased fragmentation, which would add further risk to the viability of this recovery unit. The overall condition worsens from Moderate to Poor under this scenario (Table 13 and Table 18).

5.3.1.2. Scenario 2 – Continued Conservation Management and Rapid Environmental Change

Similar to projections under less severe environmental conditions, management at current levels may be insufficient to support *G. agassizii* viability over time if the current *G. agassizii* decline continues unchecked (Table 19 and Scenario 1 Continued Conservation Management and Slow Environmental Change). Under this scenario, impacts relating to human access are likely to increase without increased management or law enforcement.

*Table 18. Scenario 1 – Continued conservation management and slow environmental change. *These sums include zeros in the unknown columns that correct for uncertainty.*

			Habitat Factors				Demographic Factors						
Analytical Unit Name	**Value to Recovery Unit with uncertainty**	**Overall Score**	**Native Vegetation**	**Shrubs**	**Burrows**	**Habitat Quantity**	**Adult Annual Survival**		**Life Stage**	**Density**	**Abundance 3x**	**Inter-AU Connectivity 3x**	**Intra-AU Connectivity 3x**
Far West	**6%**	**1.2**	1	1	1	2	1	Unknown	Unknown	0.5	1	1	1.6
Arizona	**7%**	**1.7**	2	2	1	3	Unknown	Unknown	Unknown	0.5	1	2	2
Green Valley	**6%**	**1.9**	2	2	3	2	2	Unknown	2	2	1	2	2
Snow Canyon (*Zone 1 and 2*)	**12%**	**1.8**	2	2	3	1	2	3	2	3	1	1.6	1.6
Urban Interface	**4%**	**0.7**	1	2	3	0.5	1	Unknown	2	Unknown	0	0	0.5
West Cottonwood (*Zone 3*)	**31%**	**1.7**	2	2	3	1	2	3	2	3	2	0.5	1
East Cottonwood (*Zone 3*)	**18%**	**1.6**	2	2	3	1	2	3	2	2	1	0.5	2
Sand Mountain	**3%**	**1.6**	2	2	2	2	1	Unknown	Unknown	0.5	1	1.6	2
Babylon (*Zone 4*)	**8%**	**1.6**	2	2	3	1	2	2	2	2	1	0.5	2
Cinder Knolls (*Zone 5*)	**3%**	**1.6**	2	2	3	0	2	3	2	3	0	0.5	3
Springdale	**0%**	**1.1**	2	2	2	0	2	1	2	0.5	0	0.5	2
Unassigned Areas	**2%**	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
Recovery Unit Total	**100%**	**1.6**	**1.9**	**1.9**	**2.7**	**1.2**	**1.7***	**2.1***	**1.6***	**2.1***	**1.2**	**0.9**	**1.5**

*Table 19. Scenario 2 – Continued conservation management and rapid environmental change. *These sums include zeros in the unknown columns that correct for uncertainty.*

			Habitat Factors				**Demographic Factors**						
Analytical Unit Name	**Value to Recovery Unit**	**Overall Score**	**Native Vegetation**	**Shrubs**	**Burrows**	**Habitat Quantity**	**Adult Annual Survival**	**Sex Ratio**	**Life Stage**	**Density**	**Abundance 3x**	**Inter-AU Connectivity 3x**	**Intra-AU Connectivity 3x**
Far West	**6%**	**1.0**	0.5	0.5	0.5	2	0.5	Unknown	Unknown	0	1	1	1.6
Arizona	**7%**	**1.6**	2	2	0.5	3	Unknown	Unknown	Unknown	0	1	2	2
Green Valley	**6%**	**1.8**	2	2	2	2	2	Unknown	2	1	1	2	2
Snow Canyon (*Zone 1 and 2*)	**12%**	**1.7**	2	2	2	1	2	3	2	2	1	1.6	1.6
Urban Interface	**4%**	**0.6**	1	1	2	0.5	1	Unknown	2	Unknown	0	0	0.5
West Cottonwood (*Zone 3*)	**31%**	**1.6**	2	2	2	1	2	3	2	2	2	0.5	1
East Cottonwood (*Zone 3*)	**18%**	**1.5**	2	2	2	1	2	3	2	1	1	0.5	2
Sand Mountain	**3%**	**1.4**	2	2	2	2	1	Unknown	Unknown	0	1	1	2
Babylon (*Zone 4*)	**8%**	**1.3**	2	2	2	1	2	2	2	2	1	0.5	1
Cinder Knolls (*Zone 5*)	**3%**	**1.5**	2	2	2	0	2	3	2	2	0	0.5	3
Springdale	**0%**	**1.1**	2	2	2	0	2	1	2	0	0	0.5	2
Unassigned Areas	**2%**	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
Recovery Unit Total	**100%**	**1.4**	**1.8**	**1.8**	**1.8**	**1.2**	**1.7***	**2.1***	**1.6***	**1.3***	**1.2**	**0.8**	**1.5**

Under rapid climate change projections, the faster change in temperatures may be more likely to result in an impact to *G. agassizii* egg survival and sex ratios over time. Eggs laid later in the spring are more likely to be subjected to hotter temperatures that can skew sex ratios compared to the slow change projection. Thus, spring-laid eggs that hatch in the summer may be impacted by the projected increase of days above the optimal sex ratio temperature (> 88°F produces all females) and optimal survival (83 to 91°F). Average summer air temperatures are projected to increase 6 to 10 degrees to 87 to 91°F (skewing sex ratios toward females and potentially producing all females) while summer daytime air temperature maximums are projected to be greater than optimal egg survival temperatures in the summer (101 to 116°F) and may be concerning in the spring of (80 to 83°F). While soil temperatures are typically hotter than air temperatures in the Mojave Desert (Bai *et al*. 2014), *G. agassizii* have displayed the ability to modify their nesting behavior and it is unclear if sex ratios and egg survival would be impacted under rapidly changing conditions.

In the rapid environmental change projections, frequency of droughts may occur every year or every other year and wildfire danger days may increase by 30 to 40 days. These projections would accelerate the shift in the vegetation community to *Bromus* spp. and thus accelerate the local decline rate of *G. agassizii* (Table 19; Abundance, Density, and Survival and Wildfires and Invasive Plants). It may be more difficult for science and management to develop information sufficient to respond under the rapid change scenario. Under continued management, we would expect to see continued research and efforts toward restoration and invasive species management particularly within Red Cliffs Desert Reserve. However, we have high uncertainty about restoration success under drought conditions and it is unclear if management would be successful at limiting drought and wildfire impacts in this scenario.

Under this scenario, we anticipate the maintenance and possible decline of ten existing AUs throughout the recovery unit and a change to Critical Condition in one AU (Urban Interface AU). Also, the Far West AU continues to worsen and near Critical Condition under this scenario, due primarily to worsening habitat quality factors (Table 19). Overall, the UVR recovery unit will likely continue to have a high number of AUs (nine to ten) distributed across a range of habitat types and on different topographic features which may support the species' ability to withstand more localized catastrophic events (e.g., wildfire, disease) and may provide a limited ability to withstand range-wide catastrophic events (drought).

Because conservation management is not increased or reduced, we expect the same connectivity scenario as (Scenario 1 – Continued Conservation Management and Slow Environmental Change). Representation (behavioral and genetic diversity) will decrease due to lack of connectivity between AUs and could increase the risk of inbreeding depression in the absence of management intervention in the small and isolated AUs. The distribution and connectivity options would likely be reduced under similar management compared to the current distributions with similar or worse barriers influencing demographics and genetic diversity within and among AUs. The increasing decline toward Poor Condition of the Far West AU further impacts possibilities for genetic exchange with the adjacent NEM recovery unit (Table 19, Figure 5, and Figure 12).

When managing these lands under the same management scenario but with rapidly worsening environmental conditions, all variables scored in Poor conditions except for connectivity, which generally stayed the same. However, in some AUs, no management change also results in increased fragmentation, which would further risk the viability of this recovery unit. The overall condition worsens from Moderate to Poor under this scenario (Table 19).

5.3.2 Improved Conservation Management

5.3.2.1 Scenario 3 – Improved Conservation Management and Slow Environmental Change

If land managers act collaboratively and quickly, *G. agassizii* connectivity could be restored and protected and habitat restoration can be scaled up and prioritized. Human impacts could be controlled through increased on-the-ground law enforcement and education. Litter management can positively influence recruitment rates. New translocation sites can be identified and population augmentation targeted.

As expected under this scenario, with a slow change to the environment and climate, conditions improve slightly in almost all AUs (Table 13 and Table 20). The resiliency of six AUs (Snow Canyon, Green Valley, West Cottonwood, East Cottonwood, Sand Mountain, and Arizona) would be in Good condition and the overall condition is improved and nearly in Good condition (Table 20). For some AUs, we do not anticipate change given the low value of those AUs and the continued loss of habitat even in slow environmental change scenario (e.g., 2 of the 3 Urban Interface subunits). However, through continued translocations of *G. agassizii* and because desert tortoise is a long-lived species ample time may exist for land managers to respond with sufficient action to preserve representation value.

Under this scenario, we anticipate the maintenance of all 11 existing AUs throughout the UVR recovery unit. The AUs would remain distributed across the habitat types and on different topographic features which may provide the ability to withstand more localized catastrophic events (wildfire, disease), and may provide a limited ability to withstand range-wide catastrophic events (drought). We expect representation to stay remain near current conditions or improve due to improved connectivity between AUs, which would also reduce concerns relating to in-breeding depression in the small and isolated AUs. The predicted distribution and connectivity conditions would likely improve under increased management compared to the current distributions with improved human-made passages and protected habitat corridors that can influence genetic diversity through connectivity within and among AUs.

Overall, an increased conservation approach with a focus on connectivity, restoration, human access, and population augmentation would proactively address stressors before they are compounded in the future. Resiliency would improve in five AUs from Moderate to Good condition and the overall condition would improve, nearing Good condition (Table 20).

*Table 20. Scenario 3 – Improved conservation management and slow environmental change. *These sums include zeros in the unknown columns that correct for uncertainty.*

			Habitat Factors				**Demographic Factors**						
Analytical Unit Name	**Value to Recovery Unit**	**Overall Score**	**Native Vegetation**	**Shrubs**	**Burrows**	**Habitat Quantity**	**Adult Annual Survival**	**Sex Ratio**	**Life Stage**	**Density**	**Abundance 3x**	**Inter-AU Connectivity 3x**	**Intra-AU Connectivity 3x**
Far West	**6%**	**2.2**	2	2	2	2	2	Unknown	Unknown	1	2	3	2.3
Arizona	**7%**	**2.4**	3	3	2	3	Unknown	Unknown	Unknown	1	2	3	2
Green Valley	**6%**	**2.6**	3	3	3	2	3	Unknown	2	2	2	3	3
Snow Canyon (*Zone 1 and 2*)	**12%**	**2.4**	3	3	3	1	3	3	3	3	2	2	2
Urban Interface	**4%**	**0.9**	2	2	3	1	1	Unknown	2	Unknown	0	0	1
West Cottonwood (*Zone 3*)	**31%**	**2.6**	3	3	3	2	3	3	3	3	3	2	2
East Cottonwood (*Zone 3*)	**18%**	**2.5**	3	3	3	2	3	3	3	2	2	2	3
Sand Mountain	**3%**	**2.4**	3	3	3	3	2	Unknown	Unknown	1	2	2	3
Babylon (*Zone 4*)	**8%**	**2.2**	3	3	3	1	3	3	3	3	2	1	2
Cinder Knolls (*Zone 5*)	**3%**	**2.2**	3	3	3	1	3	3	3	3	1	1	3
Springdale	**0%**	**1.8**	3	3	3	1	3	2	3	1	1	1	2
Unassigned Areas	**2%**	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
Recovery Unit Total	**100%**	**2.3**	**2.8**	**2.8**	**2.8**	**1.8**	**2.6***	**2.2***	**2.4***	**2.3***	**2.2**	**2.0**	**2.2**

5.3.2.2 Scenario 4 – Improved Conservation Management and Rapid Environmental Change

If land managers collaborate and act quickly, many actions can occur similar to those described in Scenario 3 Improved Conservation Management and Slow Environmental Change. Connectivity areas for *G. agassizii* could be protected and habitat restoration could be scaled up and prioritized. Human access could be controlled through increased on-the-ground law enforcement and education. Litter management could positively influence recruitment rates. New translocation sites could be identified and population augmentation targeted.

However, under the more rapid environmental and climate changes projected in this scenario, it is unclear how quickly managers, habitat, and *G. agassizii* can respond. More rapid change in temperatures may be more likely to result in an impact to *G. agassizii* sex ratios and egg survival as described in Scenario 2 Continued Conservation Management and Rapid Environmental Change. Increased drought and wildfire frequency may result in high *G. agassizii* mortality rates. However, we project that improved conservation management (including identifying techniques that restore habitat post-plant invasion or wildfire) would result in slight improvement of conditions in almost all AUs (Table 21).

Given the location of this recovery unit in the most northeastern part of the species' range, *G. agassizii* may be able to adapt to increased temperatures if the habitat quality continues to provide resources for feeding and breeding, though our uncertainty is high. Improved conservation management could also result in population augmentation efforts in key locations that address local abundance and density declines. For some AUs, we do not anticipate change given the low value of those AUs and continued loss of habitat even under the slow environmental change scenario (e.g., 2 of the 3 Urban Interface subunits). However, continued translocations and the long life spans of *G. agassizii* should provide ample time for land managers to preserve representation value, if not small pockets of redundant habitat.

Under this scenario, we anticipate the maintenance of 11 existing AUs throughout the recovery unit. The resiliency of five AUs (Green Valley, West Cottonwood, East Cottonwood, Sand Mountain, and Arizona) would be in Good condition and the overall condition would be improved and nearly in Good condition (Table 21). The recovery unit will continue to have a high number of AUs distributed across diverse habitat types including different topographic features which could provide the ability to withstand more localized catastrophic events (wildfire, disease), and could provide a limited ability to withstand range-wide catastrophic events (drought). We expect representation would remain similar to current conditions or improve due to improved connectivity between AUs, which would minimize risks relating to in-breeding depression in the small and isolated AUs. The distribution and connectivity options would likely be improved under increased management compared to the current distributions, with improved passages and corridors influencing genetic diversity and connectivity within and among AUs.

*Table 21. Scenario 4 – Improved conservation management and rapid environmental change. *These sums include zeros in the unknown columns that correct for uncertainty.*

Analytical Unit Name	Value to Recovery Unit	Overall Score	Native Vegetation	Shrubs	Burrows	Habitat Quantity	Adult Annual Survival	Sex Ratio	Life Stage	Density	Abundance 3x	Inter-AU Connectivity 3x	Intra-AU Connectivity 3x
Far West	**6%**	**2.2**	2	2	2	2	2	Unknown	Unknown	1	2	3	2.3
Arizona	**7%**	**2.4**	3	3	2	3	Unknown	Unknown	Unknown	1	2	3	2
Green Valley	**6%**	**2.6**	3	3	3	2	2	Unknown	2	2	2	3	3
Snow Canyon (*Zone 1 and 2*)	**12%**	**2.3**	3	3	3	1	2	3	3	3	2	2	2
Urban Interface	**4%**	**0.9**	2	2	3	1	1	Unknown	2	Unknown	0	0	1
West Cottonwood (*Zone 3*)	**31%**	**2.5**	3	3	3	2	2	3	3	3	3	2	2
East Cottonwood (*Zone 3*)	**18%**	**2.5**	3	3	3	2	2	3	3	2	2	2	3
Sand Mountain	**3%**	**2.4**	3	3	3	3	2	Unknown	Unknown	1	2	2	3
Babylon (*Zone 4*)	**8%**	**2.1**	3	3	3	1	2	3	3	3	2	1	2
Cinder Knolls (*Zone 5*)	**3%**	**2.1**	3	3	3	1	2	3	3	3	1	1	3
Springdale	**0%**	**1.8**	3	3	3	1	2	2	3	1	1	1	2
Unassigned Areas	**2%**	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
Recovery Unit Total	**100%**	**2.3**	**2.8**	**2.8**	**2.8**	**1.8**	**1.8***	**2.2***	**2.4***	**2.3***	**2.2**	**2.0**	**2.2**

Overall, under more rapid environmental changes the decline rate would increase more rapidly and, unchecked, could lead to eventual extirpation of *G. agassizii* in each AU. However, proactive and increased conservation could improve the resiliency of four AUs (West Cottonwood, East Cottonwood, Sand Mountain, and Arizona) from Moderate to Good condition and the overall condition could be improved and nearly in Good condition (Table 21).

5.3.3 Reduced Conservation Management

5.3.3.1 Scenario 5 – Reduced Conservation Management and Slow Environmental Change

A reduced level of conservation management could result in Critical to Poor Condition for the UVR recovery unit (Table 22). While temperatures may be sustainable under slower change scenarios, reduced conservation will accelerate the loss of habitat and *G. agassizii*, and lead to increases in habitat fragmentation, human access, invasive species, wildfires, and ravens. Increased drought would exacerbate many stressors, worsening conditions. Each AU would exhibit Poor or Critical conditions and *G. agassizii* decline rates would likely be accelerating rapidly through mortality and reproduction rates (Table 22). This decline rate acceleration would be primarily caused by the fragmented nature of this recovery unit, with each AU already stressed and many AUs too small or supporting low densities or abundance (Table 13).

Reduced conservation management also considers that new significant impacts would impact the UVR recovery unit population. Some AUs are more valuable to the resiliency of the recovery unit than others (Table 4-3, Appendix 4)). New impacts may include habitat loss, *G. agassizii* injuries and fatalities, habitat degradation, loss of genetic exchange, reduction in demographic rescue effects, and others (Darst *et al*. 2013 and Murphy *et al.* 2016). Because some AUs are more valuable to the resiliency of the recovery unit than others (Table 4-3, Appendix 4), the location of new habitat loss, degradation, or fragmentation is important to understanding the impact to the resiliency of the recovery unit (Recreation and Human Access, Urbanization and Paved Roads). Loss of habitat in the Urban Interface AU, for example, would not be as consequential to the UVR recovery unit population resiliency as loss of habitat in the West Cottonwood AU. Additional habitat loss or fragmentation impacts in protected areas, abundant areas, or areas important for connectivity can pose significant risks to the UVR recovery unit population (Recreation and Human Access, Urbanization and Paved Roads) and also represent rapid environmental change (Scenario 6).

Under this scenario, we anticipate six AUs throughout the recovery unit could be maintained, though would likely be in a declining condition (Table 22). Five AUs would likely be in critical condition or functionally extirpated, losing their redundancy value. The UVR recovery unit would have a moderate number of AUs spread across the habitat types and on different topographic features—however, the Poor condition of these AUs would limit the ability of the sub-population to withstand localized catastrophic events (wildfire, disease) or range-wide catastrophic events (drought). We also expect healthy representation would decrease due to lack of connectivity between AUs, which would lead to in-breeding depression in the small and isolated AUs. The predicted distribution and connectivity options would likely be reduced under reduced management compared to the current distributions with similar or worse barriers influencing genetic diversity and connectivity within and among AUs.

*Table 22. Scenario 5 – Reduced conservation management and slow environmental change. *These sums include zeros in the unknown columns that correct for uncertainty.*

Analytical Unit Name	**Value to Recovery Unit**	**Overall Score**	**Native Vegetation**	**Shrubs**	**Burrows**	**Habitat Quantity**	**Adult Annual Survival**	**Sex Ratio**	**Life Stage**	**Density**	**Abundance 3x**	**Inter-AU Connectivity 3x**	**Intra-AU Connectivity 3x**
Far West	**6%**	**0.5**	0.5	0.5	0.5	1	0.5	Unknown	Unknown	0	0	0.5	1
Arizona	**7%**	**0.9**	1	1	0.5	2	Unknown	Unknown	Unknown	0	0.5	1	1
Green Valley	**6%**	**1.0**	1	1	2	2	1	Unknown	0	1	1	1	0.5
Snow Canyon *(Zone 1 and 2)*	**12%**	**1.1**	1	1	2	0.5	1	3	1	2	0.5	1	1
Urban Interface	**4%**	**0.0**	0	0	0	0	0	Unknown	0	Unknown	0	0	0
West Cottonwood *(Zone 3)*	**31%**	**1.1**	1	1	2	1	1	3	1	2	1	0.5	0.5
East Cottonwood *(Zone 3)*	**18%**	**1.0**	1	1	2	1	1	3	1	1	0.5	0.5	1
Sand Mountain	**3%**	**1.1**	1	1	2	1	0.5	Unknown	Unknown	0	0.5	1	2
Babylon *(Zone 4)*	**8%**	**0.9**	1	1	2	0.5	1	1	1	2	0.5	0.5	1
Cinder Knolls *(Zone 5)*	**3%**	**1.1**	1	1	2	0	1	3	1	2	0	0.5	2
Springdale	**0%**	**0.7**	1	1	2	0	1	1	1	0	0	0.5	1
Unassigned Areas	**2%**	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
Recovery Unit Total	**100%**	**0.9**	**0.9**	**0.9**	**1.7**	**0.9**	**0.8***	**2.0***	**0.7***	**1.3***	**0.6**	**0.6**	**0.8**

Overall, under reduced management the decline rate would increase more rapidly and lead to eventual extirpation in nearly half the AUs. All AUs in this scenario would be in poor or critical condition and the overall condition of the recovery unit would be in critical condition (Table 22).

5.3.3.2 Scenario 6 – Reduced Conservation Management and Rapid Environmental Change

A reduced level of conservation management combined with rapid environmental and climate change could result in a Critical Condition for the recovery unit (Table 23). It is unclear if this species can adapt to rapidly changing conditions (behavioral adaptation rate), and time frames are likely not long enough to allow for genetic adaptation (two *G. agassizii* generations; Appendix 5 Climate Projections). Reduced conservation management would accelerate the loss of *G. agassizii* to habitat loss, habitat fragmentation, human access, invasive species, and ravens (Risk Factors). Increased frequency of droughts and wildfires would exacerbate many stressors. Each AU would exhibit critical overall condition and *G. agassizii* decline rates would likely be accelerating rapidly through mortality and reproduction rates (Table 23). This collapse would primarily be a result of the fragmented nature of the UVR recovery unit, with each AU already stressed and many AUs too small or supporting low densities or abundance (Table 13).

The reduced conservation management scenario also considers that new significant disturbances would impact the recovery unit population, as described in Scenario 5 – Reduced Conservation Management and Slow Environmental Change. The immediate ecosystem and *G. agassizii* responses associated with new impacts represent rapid environmental change. Under this scenario, all AUs would be in critical condition or functionally extirpated and redundancy would be minimal (Table 23). Under just the changes in temperatures and precipitation, the UVR recovery unit would not likely be able to withstand localized catastrophic events (wildfire, disease) or range-wide catastrophic events (drought). We expect healthy representation would decrease due to lack of connectivity between AUs, which could increase the risk of in-breeding over time in the absence of human intervention in the small and isolated AUs. The predicted distribution and connectivity options would likely be reduced under reduced management compared to the current distributions with similar or worse barriers influencing genetic diversity and connectivity within and among AUs.

Overall, under reduced management and rapidly worsening environmental conditions, the population decline rate would increase more rapidly and could lead to eventual extirpation in all the AUs. All AUs in this scenario would be in critical condition and the overall condition would be critical (Table 23).

Table 23. *Scenario 6 – Reduced conservation management and rapid environmental change. *These sums include zeros in the unknown columns that correct for uncertainty.*

			Habitat Factors				Demographic Factors						
Analytical Unit Name	**Value to Recovery Unit**	**Overall Score**	**Native Vegetation**	**Shrubs**	**Burrows**	**Habitat Quantity**	**Adult Annual Survival**	**Sex Ratio**	**Life Stage**	**Density**	**Abundance 3x**	**Inter-AU Connectivity 3x**	**Intra-AU Connectivity 3x**
Far West	**6%**	**0.4**	0	0	0.5	1	0	Unknown	Unknown	0	0	0.5	1
Arizona	**7%**	**0.6**	0.5	0.5	0	2	Unknown	Unknown	Unknown	0	0	1	1
Green Valley	**6%**	**0.7**	0.5	0.5	2	1	0.5	Unknown	0	0.5	0.5	1	0.5
Snow Canyon *(Zone 1 and 2)*	**12%**	**0.9**	0.5	0.5	2	0.5	1	2	1	1	0	1	1
Urban Interface	**4%**	**0.0**	0	0	0	0	0	Unknown	0	Unknown	0	0	0
West Cottonwood *(Zone 3)*	**31%**	**0.8**	0.5	0.5	2	1	0.5	2	1	1	0.5	0.5	0.5
East Cottonwood *(Zone 3)*	**18%**	**0.7**	0.5	0.5	2	1	0.5	2	1	0.5	0	0.5	1
Sand Mountain	**3%**	**0.7**	0.5	0.5	1	1	0.5	Unknown	Unknown	0	0	0.5	2
Babylon *(Zone 4)*	**8%**	**0.7**	0.5	0.5	2	0.5	0.5	1	1	1	0	0.5	1
Cinder Knolls *(Zone 5)*	**3%**	**0.9**	0.5	0.5	2	0	0.5	2	1	1	0	0.5	2
Springdale	**0%**	**0.5**	0.5	0.5	1	0	0.5	0.5	1	0	0	0.5	1
Unassigned Areas	**2%**	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
Recovery Unit Total	**100%**	**0.7**	**0.4**	**0.4**	**1.6**	**0.9**	**0.5***	**1.4***	**0.7***	**0.7***	**0.2**	**0.6**	**0.8**

5.4 Synopsis

The abundance of *G. agassizii* in the UVR recovery unit is forecasted to decline over time under the continued and reduced conservation management scenarios. We found that conservation management, specifically facilitating connectivity and improving habitat restoration and invasive species management efforts, are the primary drivers of condition for *G. agassizii* in the UVR recovery unit and strategic translocation to areas important for recovery can provide added conservation benefit. Unless habitat connectivity can be improved and protected, effective solutions discovered and implemented for non-native invasive plant species and habitat restoration, and dedicating full-time law enforcement on-the-ground (i.e., Scenario 3 or 4, improved conservation management), future conditions are likely to impart added stresses on this already fragile and declining recovery unit.

Under both slow and rapid environmental change, if conservation management is improved we likely would only risk extirpation in the Poor condition Urban Interface AU by 2069 (due largely to ongoing development) and persistence in all other AUs (Table 24). Persistence in the other AUs would be primarily a result of the species' life history and long life-span. Under continued conservation scenario, the recovery unit may persist, but in Poor condition; six AUs (Far West, East Cottonwood, Sand Mountain, Babylon, Cinder Knolls, and Springdale) would be in Poor condition and the Urban Interface AU may become functionally extirpated. Given the recent *G. agassizii* decline rates in the area (3.2 percent), impaired recruitment in all AUs, increased vulnerability to stochastic and catastrophic events, and decreased annual survival, managing the UVR recovery unit with reduced conservation management approaches in any likely future environmental scenario could reasonably result in the functional extirpation in all AUs (Table 24). However, total extirpation may be unlikely over the 49 years and two *G. agassizii* generation times projected. An increased conservation approach with a focus on connectivity, pre- and post-wildfire restoration, human access, and augmentation could proactively address the primary stressors identified in this report before they compound in the future (Table 24).

The UVR recovery unit *G. agassizii* population may experience more risk to long-term viability under continued or reduced conservation management scenarios (Scenarios 1, 2, 5, and 6), though extirpation is unlikely over the two *G. agassizii* generation times (49 years) projected (Table 24). However, recovering the species would be more difficult to achieve if the population is further impacted as projected in these scenarios. Poor future condition would primarily result from inadequate connectivity within and between AUs, continued vulnerability of habitats to fire, and the negative effects of human access and recreation. The UVR recovery unit population relies heavily on the Red Cliffs Desert Reserve AUs, especially West and East Cottonwood AUs (Table 4-3 in Appendix 4), which are already fragmented by two existing roads (Red Hills Parkway and Cottonwood Springs Road).

In addition, the West and East Cottonwood AUs currently support less than the 5,000 adult *G. agassizii* which is the target set by the DTRO for an effective genetic population size (USFWS 1994a) and supports less than the AU management target of 3,000 individuals (USFWS 2019a). New habitat fragmentation impacts from ongoing development would likely pose additional risks to the recovery unit population, especially when occurring in protected areas, abundant areas, or areas important for connectivity even with current conservation measures.

We found that unless habitat connectivity can be significantly improved and protected, effective solutions discovered and implemented for invasive plant species and habitat restoration, and dedicating full-time law enforcement on-the-ground, future conditions are likely to impart significant stresses on this already fragile and declining recovery unit (Table 24). Connectivity would not be improved under the continued or reduced conservation management scenarios, yet connectivity is important to maintain resiliency under slow and rapid environmental change scenarios. Managers should consider connectivity key for establishing good future conditions.

If some AUs are managed in the future to provide redundancy to the recovery unit, they would require improved habitat conditions and connectivity to contribute to the overall resiliency value in this fragmented and small recovery unit. In addition, to achieve sufficient healthy future representation, sub-populations would need to be actively managed across the recovery unit to minimize risk of genetic loss and demographic collapse in the small, isolated AUs.

Overall, the future viability of the recovery unit is questionable and declining under continued or reduced conservation management scenarios, regardless of the speed of environmental change (Table 24). The UVR recovery unit requires aggressive and intensive conservation management to remain viable into the future, with a focus on connectivity and habitat restoration.

Table 24. Summary of future UVR recovery unit population conditions to 2069. This table shows the overall score for each AU and the recovery unit in each environmental scenario with each conservation scenario.

Analytical Unit Name	**Current Value to RU**	**Current Overall Score**	Slow Climate & Environmental Change (slow increase in temperatures, invasive plants, and wildfires)			Rapid Climate & Environmental Change (Rapid increase in temperatures, invasive plants and wildfire)		
			Conservation Scenario			Conservation Scenario		
			Continued	Improved	Reduced	Continued	Improved	Reduced
Far West	**6%**	1.5	**1.2**	**2.2**	**0.5**	**1.0**	**2.2**	**0.4**
Arizona	**7%**	1.7	**1.7**	**2.4**	**0.9**	**1.6**	**2.4**	**0.6**
Green Valley	**6%**	2.4	**1.9**	**2.7**	**1.0**	**1.8**	**2.6**	**0.8**
Snow Canyon (*Zone 1 and 2*)	**12%**	2.0	**1.8**	**2.4**	**1.1**	**1.7**	**2.3**	**0.9**
Urban Interface	**4%**	1.1	**0.7**	**0.9**	**0.0**	**0.6**	**0.9**	**0.0**
West Cottonwood (*Zone 3*)	**31%**	1.9	**1.7**	**2.6**	**1.1**	**1.6**	**2.5**	**0.8**
East Cottonwood (*Zone 3*)	**18%**	1.9	**1.6**	**2.5**	**1.0**	**1.5**	**2.5**	**0.7**
Sand Mountain	**3%**	1.8	**1.6**	**2.4**	**1.1**	**1.4**	**2.4**	**0.7**
Babylon (*Zone 4*)	**8%**	1.8	**1.6**	**2.2**	**1.0**	**1.4**	**2.1**	**0.7**
Cinder Knolls (*Zone 5*)	**3%**	1.8	**1.6**	**2.2**	**1.1**	**1.5**	**2.1**	**0.9**
Springdale	**0%**	1.3	**1.1**	**1.8**	**0.7**	**1.1**	**1.8**	**0.5**
Unassigned Areas	**2%**	NA	NA	NA	NA	NA	NA	NA
Recovery Unit TOTAL	**100%**	**1.80**	**1.6**	2.3	0.9	**1.5**	**2.3**	0.7

Chapter 6: SYNTHESIS

This chapter summarizes the results from our current and future analyses and discusses the future viability of the UVR recovery unit. We assessed the viability of G. agassizii in the UVR recovery unit by evaluating the ability of the species to maintain a sufficient number and distribution of healthy populations to withstand stochasticity (resiliency), catastrophes (redundancy), and changes in its environment (representation).

Our analyses indicate that the viability of *G. agassizii* in the UVR recovery unit is likely declining due to stress from increased wildfires, and this decline is expected to continue under the current and reduced management scenarios (Table ES-1). The magnitude and implications of reduction in resiliency, representation, and redundancy are discussed below.

Resiliency - *G. agassizii* need habitats of sufficient quality and quantity and have sufficient abundance and growth rate to be resilient. The UVR recovery unit population has a declining been documented to be declining in abundance of adult desert tortoises, likely due to episodic losses from stochastic events of fire and drought. The recovery unit is currently in Moderate Condition because AUs with Poor current condition provide < 10 percent of the resiliency of the recovery unit, and AUs with Moderate current condition provide 89 percent of the resiliency of the recovery unit. The abundance of *G. agassizii* in the UVR recovery unit is forecasted to have a higher likelihood of decline over time under the continued and reduced conservation management scenarios. This trend may improve under an improved conservation scenario.

Redundancy - *G. agassizii* need resilient AUs to buffer against catastrophic losses, and a sufficient distribution of resilient AUs across the recovery unit to reduce the risk of a catastrophic event causing significant species level impacts. Stochastic events coupled with negative effects of anthropogenic stressors (e.g. development) further reduce resiliency of individual AUs, and thus the UVR recovery unit lacks effective redundancy. Under the reduced and current management scenario, it is likely that as *G. agassizii* numbers decrease in the UVR recovery unit, the chance of catastrophic events such as wildfires causing extirpation within AUs and ultimately the entire recovery unit increases.

Representation - *G. agassizii* in this recovery unit occupies a diversity of habitats. However, the low abundance within AUs and high fragmentation levels between AUs result in potential demographic and genetic deterioration that may lower overall fitness. The recovery unit-wide effects of habitat fragmentation and degradation limit resilience in individual AUs and have the potential to reduce healthy representation among AUs and thus the overall representation health of the UVR recovery unit. The loss of AUs as predicted by our analysis for the reduced or continued management scenarios suggests that adaptive capacity could be at higher risk of loss unless we pursue the improved management scenario.

To increase G. *agassizi* viability in the UVR recovery unit, it is necessary to pursue to the improved management scenario and:

1. Permanently protect habitat in the AUs and corridors connecting the AUs.
2. Improve habitat connectivity within and between most AUs.
3. Restore habitat within each of the AUs. A focus should be on those areas affected by wildfires and non-native invasive plant species.
4. Provide effective law enforcement to ensure human impacts are minimized.

KEY UNCERTAINTIES

Distribution **–**Due to lack of surveys, our distributional knowledge in more than half (six) of the AUs are low, thus some uncertainty about the population distribution remains. Future viability could be under or overestimated.

***Abundance Estimates* -** Lack of formal surveys result in high uncertainty about this estimate. Three sources of abundance and density uncertainty are that systematic surveys have not been conducted in each AU, captive or captured *G. agassizii* may be released by members of the public in unknown areas, and population estimates are imperfect. The 1994 PVA has not been updated and detection of immature *G. agassizii* is difficult. As the Revised Recovery Plan notes (USFWS 2011), updating the PVA and associated population targets could help us understand what the habitat is capable of supporting, how stochasticity impacts the species, and which AUs need the most intensive management (e.g., habitat improvements). Future viability could be under or overestimated.

***Decline Rate* -** the decline rate is likely underestimated outside Red Cliffs Desert Reserve due to limited data. In addition, the decline rate remains an area of uncertainty within Red Cliffs Desert Reserve because the *G. agassizii* is a long-lived species. Declining trends may be affecting distribution, though our uncertainty is high in unsurveyed areas. Future viability could be under or overestimated.

***Life Stages and Sex Ratios* -**We have limited information in some AUs regarding life stages and sex ratios, but note high uncertainty in all AUS for life stage ratios because juveniles are difficult to detect, even by the most seasoned of *G. agassizii* biologists. Future viability could be under or overestimated.

***Adaptation to climate change* -**Given the location of this recovery unit in the most northeastern part of the species' range, *G. agassizii* may be able to adapt to increased temperatures however direct effects spatially and temporally are unknown. Future viability could be under or overestimated.

Wildfire or Invasive Species – The dominance of invasive plants and the frequency of fire may increase in the future. Fire frequency is affected by drought and climate change. The regional impact of these invasive grasses on fire regimes remains unclear, however, wildlife frequency is increasing in recent years. Future viability could be underestimated.

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APPENDIX 1. Peer review comments

Following peer and partner review of the report in April 2020, we made changes to this biological report. Main topics of concern among most reviewers were (1) that the contribution to resiliency section in the draft was unclear and confusing, (2) how to estimate *G. agassizii* outside of areas that have been formally surveyed with line distance sampling, (3) non-native invasive plant species management, and (4) the human-assisted movements and how that may influence genetic structure. We also responded to a variety of comments on local biology, management and other inputs. Below, we summarize the changes and the resulting modifications, if applicable:

(1) The condition of the entire UVR recovery unit is not equally divided among the AUs. The contribution of an area to overall resiliency is important to understand the stressors that contribute to the current condition. The table in the draft was developed to help us more accurately describe the overall condition of the recovery unit, given the unequal contribution from different AUs. However, several reviewers had questions about the specific inputs that were used in this table. We worked with the Desert Tortoise Recovery office to substantially revise the table from the draft, which is now in Appendix 4). We addressed concerns about how inputs were calculated by clearly stepping through each input, human decision point, and including all columns before human decision points. For example, two reviewers commented on whether critical habitat was an appropriate metric to include; the updated table removes reference to critical habitat and reports percentages with and without considering the protected population. However, we also note that the relative values of different areas are very similar between all human decision points in the evaluation (protected, connectivity, uncertainty). This Table allows us to evaluate the overall condition of the recovery unit and allows us to scale these resiliency values to each other to help understand the relative effectiveness of future conservation actions in each AU.

(2) We discussed *G. agassizii* abundance estimates with the Desert Tortoise Recovery Office and the UDWR. We determined that it was most appropriate to apply the same density estimate throughout all areas where line distance sampling surveys have not been conducted, while noting that this estimate comes with a high degree of uncertainty. In the absence of line distance surveys, this approach balances potential overestimates in some areas with potential underestimates in other areas and addresses the comments received on this draft report. We applied the Beaver Dam Slope estimate of 1.3 adult *G. agassizii* per square mile (mi^2) as the closest line distance sampling outside the Red Cliffs Desert Reserve.

Some reviewers recommended including historical 1991 sign surveys. We chose not to use these historical estimates because they used a different survey technique. In addition, these surveys were designed to give a coarse sense of *G. agassizii* presence across large areas. Individual sign in low-density populations (e.g., 3.4 adult *G. agassizii* per mi^2) is more likely to be missed in such coarse surveys. The best we can do at this time considering the best available science is to caveat the estimate with our high uncertainty. We recognize that the use of 3.4 adult *G. agassizii* per mi^2 implies potential occupancy throughout the recovery unit and, as with any point estimate, some places will be overestimated and others underestimated.

We also received comments recommending we use the McLuckie et al. 2020 instead of McLuckie et al. 2018. We discussed with the UDWR biologist (and author of these papers) that we used her 2018 report so we could reliably compare the UDWR 2017 data with survey data in a new area (the proposed Zone 6; Rognan et al. 2017). This provided consistent estimates in the same sampling year within the Red Cliffs Desert Reserve, within the proposed Zone 6 surveyed areas, and within the Beaver Dam Slope. However, we do reference the 2020 report where possible.

(3) One reviewer recommended expanding discussion and emphasis on the importance of non-native invasive plant species management. Generally this report considers habitat restoration to include non-native invasive plant management. However, to address this comment we have added text to relevant sections that further highlight the importance of non-native invasive plant management and on-going efforts targeting prevention and management.

(4) One reviewer commented that human-assisted movements may have influenced genetic structure in the past and will likely continue to influence genetic structure in the future. We added language that translocations can be used to strategically augment population’s genetic and demographic structure, though this is not currently a goal or objective in the UVR recovery unit. We note that human-assisted migrations should be a last resort, with primary focus on connecting habitat and individuals so that they are self-sustaining.

(5) Abundance and Density – Reviewers questioned the use of the 3,000 target (Table 11) in our analysis. We are using the 3,000 target for the time frame that we analyzed (49 years) but acknowledge that the 5,000 to 10,000 *G. agassizii* are recommended for long-term viability (USFWS 1994). Workshop experts determined that achieving 3,000 adult *G. agassizii* over 49 years may be a more reasonable management target over the analysis time frame. Participants indicated that managing for this target should be sufficient for this long-lived species to prevent functional extirpation and genetic deterioration over the next 25 to 50 years in each AU. The group recognized that smaller areas that are likely unable to support 3,000 *G. agassizii* will mostly provide representation and redundancy if they are connected to larger areas that can support resilient target populations of 3,000 adult *G. agassizii*.

APPENDIX 2. Spatial Decision Support stressors identified for the species rangewide (2014).

STRESSOR NAME	STRESSOR DESCRIPTION	CARRIED FORWARD
Military Operations	Military installations, training, and range exercises using explosives, military vehicles, urban simulation, etc.	No. Population-level response not expected.
Urbanization	Urban and suburban development and associated infrastructure.	Carried forward in preceding biological report (Urbanization).
Agriculture	Farming of annual and perennial crops; hay, pasture, and cultivated crops.	No. Population-level response not expected.
Oil and Gas Development	Development and production of oil and gas; wells and pipelines.	No. Population-level response not expected.
Mineral Development	Exploring for, developing, and producing minerals and rocks, including ancillary facilities, leachate ponds, and mine tailings; metals, semi-metals, minerals, sand and gravel, coal etc.	No. Population-level response not expected.
Grazing	Utilizing natural habitats for forage to support domestic livestock (i.e., cattle and sheep); typically use on public lands is authorized by allotments, animal unit months (cow and calf for cattle), forage availability, and season of use according to established Standards and Guidelines and allotment-specific objectives.	No. Population-level response not expected.
Temperature Extremes	Periods in which temperatures exceed or go below the normal range of variation, including heat waves and cold spells. Temperature Extremes are a natural process, but one that can be exacerbated by human activities that influence climate change.	Carried forward in preceding biological report (Appendix 5 Climate and Environmental Projections)
Wild Horse & Burros	Unbranded and unclaimed horses and burros on public lands protected under the Wild Free-roaming Horses and Burros Act of 1071 (PL 92-195); herd management areas are generally established as a means of maintaining healthy, genetically viable populations and determining appropriate management levels within a given area or range of the herd.	No. Population-level response not expected.
Human Access	Permission, liberty, or ability to enter, approach, or pass to and from a place from various points that facilitates both authorized and unauthorized land uses	Carried forward in text.
Motor Vehicles on Paved Roads	Self-propelled, wheeled vehicles on paved roads, including cars, trucks, jeeps, motorcycles, and all-terrain vehicles (ATVs).	Carried forward in text.
Landfills (i.e. Predation)	Authorized sites to take in household and industrial garbage and solid waste.	Carried forward in preceding biological report (Predation.
Non-motorized Recreation	Outdoor activities that do not involve the use of motorized vehicles, such as primitive camping, hunting, target practice, hiking, picnicking, horseback riding, and biking.	Carried forward in preceding biological report (Recreation and Human Access).
Motor Vehicles Off Route	Impacts from off-highway vehicle use include mortality of tortoises on the surface and below ground.	Carried forward in preceding biological report (Recreation and Human Access).

Motor Vehicles on Unpaved Roads	Self-propelled, wheeled vehicles on unpaved roads which are open and legal for motorized travel, including cars, trucks, jeeps, motorcycles, and all-terrain vehicles (ATVs).	Carried forward in preceding biological report (Recreation and Human Access).
Utility Lines and Corridors	Utility corridors and lines including transmission and power lines and poles, and oil and gas pipelines.	Carried forward in preceding biological report (Urbanization).
Air pollution	Increased levels of atmospheric pollution and nitrogen deposition related to increased human presence and combustion of fossil fuels resulting in increased particulate matter in the air and increase levels of soil nitrogen.	No. Population-level response not expected.
Garbage and Dumping	Refuse resulting from unauthorized dumping and littering or wind-blown accumulation.	Carried forward in preceding biological report (Predation and Recreation and Human Access).
Paved Roads	Linear corridors that have been finished with asphalt or concrete, typically impervious, to support vehicular or other travel.	Carried forward in preceding biological report (Paved Roads).
Surface disturbance	Disruption or removal of surface soil and vegetation.	Carried forward in preceding biological report (Wildfire and Invasive Plants and Urbanization).
Drought	Periods in which rainfall falls below the normal range of variation, which can result in desertification and limited water availability. Drought is a natural process, but one that can be exacerbated by human activities that influence climate change.	Carried forward in preceding biological report (Appendix 5 Climate and Environmental Projections).
Tourism and recreation areas	Small-scale, dispersed developments such as golf courses, campgrounds, visitor's centers, RV parks, and rest stops.	Carried forward in preceding biological report (Urbanization)
Unpaved Roads	Dirt or gravel secondary or tertiary roads, often labeled as accessible to 4-wheel drive vehicles only (includes BLM's open OHV routes).	Carried forward in preceding biological report (Recreation and Human Access).
Railroads	Transportation mode of vehicles or cars on corridors of parallel steel tracks.	No. Not relevant in the area.
Storms and Flooding	Extreme precipitation or wind events or major shifts in seasonality of storms. Storms and Flooding are a natural process, but one that can be exacerbated by human activities that influence climate change.	Carried forward in preceding biological report (Appendix 5 Climate and Environmental Projections).
Captive Release or Escape	Release of captive-reared or wild-caught tortoises that have been in captivity.	No. Population-level response not expected.
Fugitive Dust	Airborne particulate matter containing toxicants released from anthropogenic sites such as mines, roads, construction, and other disturbances.	Carried forward in preceding biological report (Recreation and Human Access, Urbanization, and Paved Roads).

Toxicants	Air- and water-borne toxic substances from mine tailings, illegal dumping of hazardous wastes, garbage and litter, and toxic spills.	No. Population-level response not expected.
Invasive Plants	Plants species not native to the ecosystem; < 115 non-native plant species have been documented in the Mojave and Sonoran deserts, many are of Eurasian origin and have become common to abundant in the *G. agassizii* habitats due to past and ongoing land disturbance.	Carried forward in preceding biological report (Wildfire and Invasive Plants).
Shift in Habitat Composition and Location	Potential changes in climate may cause or have already caused changes in species composition in *G. agassizii* habitats and shifts in habitat availability and usage. Shift in habitat composition and locations is a natural process, but one that can be exacerbated by human activities that influence climate change.	Carried forward in preceding biological report (Appendix 5 Climate and Environmental Projections).
Altered hydrology	Modification of the occurrence, distribution, and movement of water, such that natural water transportation, storage and evaporation processes are affected.	Carried forward in preceding biological report (Urbanization and Paved Roads)
Disease	Harmful pathogens and other microbes that may or may not be endemic to the ecosystem or region but that are directly or indirectly introduced, spread, or susceptibility is increased by humans and human activities. Upper respiratory tract disease as caused by Mycoplasma spp. is the best known disease pertinent to the *G. agassizii*; others include herpesvirus and Pasteruella testudinis.	Carried forward in preceding biological report (Disease)
Coyotes & Feral Dogs	Coyotes and feral dogs are subsidized by human activities; the elevated levels of predation are a stress on *G. agassizii* populations.	Carried forward in preceding biological report (Predation)
Ravens	Ravens are a human-subsidized predator of mostly hatchling and juvenile *G. agassizii*.	Carried forward in preceding biological report (Predation)
Solar Energy Development	Development and production of solar energy; solar farms and ancillary facilities.	No. Not relevant in the area.
Wind Energy Development	Development and production of wind energy; wind farms and ancillary facilities	No. Not relevant in the area.
Geothermal Energy Development	Development and production of geothermal energy	No. Not relevant in the area.
Aqueducts	Channel or conduit constructed to convey water, typically a system of ditches, canals, and tunnels.	Carried forward in preceding biological report (Connectivity, Urbanization and Paved Roads)
Open OHV area use	Open-use public land where off-highway vehicles can be ridden anywhere, includes travel on both open routes and cross-country travel within the designated open area.	Carried forward in preceding biological report (Recreation and Human Access).
Fire Potential	Potential for human or naturally caused fire in *G. agassizii* habitats.	Carried forward in preceding biological report (Wildfire and Invasive Plants and Recreation and Human Access).
Past Fire	Past human or naturally caused fire in *G. agassizii* habitats.	Carried forward in preceding biological report (Wildfire and

		Invasive Plants and Recreation and Human Access).

APPENDIX 3. Resiliency – Analytical Units Summaries

Far West AU

The Far West AU is 52,773 acres and includes 45,300 acres of modelled *G. agassizii* habitat (up to 4,500 ft; Table 2). Far West is the westernmost AU, and supports connectivity between the western boundary of the UVR recovery unit and the northeastern boundary of the NEM recovery unit (Figure 5 and Figure 13). This north-south strip is remote with infrequent recreation and low demand for resources or development. The area is primarily owned and managed by the BLM (32,001 acres); however, part of the Shivwits Band of the Paiute Tribe Reservation is within this AU (17,995 acres) (Figure 3). The area also includes small SITLA (2,776) and private land (40 acres) parcels interspersed throughout. This AU also includes two BLM ACECs comprising 2,111 acres of this AU. ACECs confer conservation protections and management for other listed or sensitive species (BLM 2016).

Workshop experts identified the Far West AU as a higher elevation area with diverse soils, geology (including limestone), abundant washes, and caliche burrows. Several datasets confirm local ecological knowledge that this area is heavily impacted by wildfires and non-native invasive grasses (e.g., *Bromus* spp.; BLM 2020, USGS invasive grass spatial imagery and modelling 2011, USGS 2019). The majority of the Far West AU is likely marginal habitat and experts accordingly rated the native herbaceous vegetation and shrubs as Poor Condition (Table 10 and Table 14). Because of the loss of shrubs, burrows are diminished, though caliche burrows and other soil structures remain. The extent and impacts from invasive plant and wildfire impacted lands was used to delineate the boundary between Green Valley and Far West AUs.

The Far West AU area contains modelled suitable habitat (>45,000 acres) to support *G. agassizii* however, because the habitat conditions are poor overall, and were considered low occupancy prior to fires, the Far West AU likely supports low *G. agassizii* densities and abundances (Table 3). The Far West AU exists on the margins of what is predicted to be suitable habitat (Nussear *et al*. 2009), and thus is believed to have supported low *G. agassizii* densities and abundances even prior to non-native grass invasion and wildfire driven habitat degradation; however, line distance surveys have not been conducted in this area. Informal surveys on BLM lands near the Shivwits Reservation have shown very little *G. agassizii* sign (A. McLuckie, UDWR, personal communication March 5, 2020). In addition, *G. agassizii* translocated to this same area continued to display elevated movement distances after three years compared to *G. agassizii* translocated to other areas (Nussear *et al*. 2012). This behavior response may indicate continued movement of *G. agassizii* to find more preferable habitat (Rittenhouse *et al*. 2008, Nussear *et al*. 2012). Both abundance and density in Far West AU were in Poor Condition (Table 14).

Sex ratios and life stage data are unavailable in this AU (Table 14). However, we can speculate survival probability based on the individual resource needs. Poor habitat quality in this AU impacts feeding, breeding, and sheltering for this species through poor nutrition, lower reproductive success, and reduced availability of seasonal shrubs for protection from predators and weather. Survival is therefore likely to be in Poor Condition in the Far West (Table 14).

Other stressors were identified as concerns in the UVR recovery unit, but are either not present at concerning levels in this area or their status is unknown (Table 12 and Appendix 2). Drought likely affects habitat and demographics in this area similarly to other areas while disease prevalence is unknown. Stressors associated with human access are all relatively low in this AU, including ravens, recreation, urbanization, paved roads, off-leash dogs, and illegal trails.

We determined Far West AU connectivity with adjacent AUs (inter-AU) and the NEM recovery unit units is in Moderate Condition because only one boundary exhibited Good Condition, the Far West—Green Valley AU boundary (Table 14). Far West AU connectivity with adjacent AUs includes the following:

- ❖ The Far West—Snow Canyon AU boundary is one of the most important boundaries for the UVR recovery unit, and represents possible linkage to individuals within the protected Red Cliffs Desert Reserve (Figure 5, Figure 12, and 13). The Far West AU is adjacent to Snow Canyon's western border, which is not fenced. We have little data in this area, but there have been several observations in the Kayenta development and historic observations on Shivwits lands. At least one recorded *G. agassizii* observation is within one home range distance of the border. However, the urban matrix to the south includes low density housing in this area and the developable lands make up about 80 percent (0.75 of 0.97 miles) of the modelled habitat along the south border. Given the porosity of the west boundary we determined the overall connectivity is Moderate to Good.

- ❖ The Far West—Green Valley AU boundary is also important, as the Green Valley population may not support a viable population without connectivity with other AUs (Table 3). The boundary between these two AUs was delineated using ecological features (wildfire and invasive annual grass cover) rather than human or topographical barriers (Figure 5 and Figure 13). While it is unclear how much suitable habitat remains in the burned areas, porosity from physical barriers is in Good Condition.

- ❖ The Far West—Arizona AU boundary is political (i.e., the state line) rather than ecologically drawn; the Virgin River Gorge would otherwise be the natural boundary between the two units (Figure 5 and Figure 13). The connectivity model (Gray *et al.* 2019) does show some small, potential corridors. However, I-15 isolates most of the Arizona AU from the Far West AU. I-15 is not fenced in this area and, although there are a few large culverts under the highway that could be used by some *G. agassizii*, I-15 likely acts as a mortality sink for *G. agassizii* and a major impediment to habitat and AU connectivity. Arizona Department of Transportation, in coordination with USFWS, may fence this stretch of highway in the future (C. Rognan, Washington County HCP Administrator, personal communication, May 5, 2020). Due to these human and topographical barriers, connectivity between these AUs is Poor.

- ❖ The areas connecting the Far West AU—NEM recovery unit are fundamental to natural connectivity (non-human assisted) between the UVR and NEM recovery units (Figure 5, Figure 12, and Figure 13). All four habitat corridors identified between the recovery units traverse the Far West AU. The primary barrier to connectivity between the Far West AU and NEM recovery unit is the Beaver Dam Mountains (see Dutcher *et al*. 2020 on the value of mountain passes as potential *G. agassizii* connectivity corridors). Roads are present, but are not fenced. Habitat quality may also deter some movement, but no studies have been conducted in this area. Overall, the connectivity between the Far West AU and the NEM recovery unit is Poor to Moderate (50 percent or less unimpeded by anthropogenic and topographical barriers).

We determined that connectivity within the Far West AU (intra-AU) is in Poor to Moderate Condition (Table 14). This was based on two potential habitat areas, one in the north and linking the north and the south, where connectivity may be meaningful to the recovery unit. Connectivity within the Far West AU includes the following:

- ❖ In upper Far West AU, the most important population clusters to connect would be those on the west and east sides of the Santa Clara River and Old Highway 91 (no *G. agassizii*-proof fencing). If *G. agassizii* clusters are present, they are poorly connected (< 50 percent) due to the presence of a river that would only provide infrequent crossing opportunities. It is unlikely there will be regular natural movement without human intervention (bridges or translocations). We lack sufficient data to determine where *G. agassizii* clusters are and whether they are within 1 to 2 home ranges of each other. Overall, intra-AU connectivity in this area of Far West AU is Poor. Notably, this area consistently maps out as the most likely habitat connectivity area between the UVR and NEM (NEM) recovery units, and thus connectivity throughout the upper Far West AU landscape remains a high priority for future evaluation and conservation planning.

- ❖ Connectivity between presumed *G. agassizii* clusters in the northern and southern extents of the Far West AU may be geographically constrained (about 50 percent) by habitat quality (e.g., *Bromus* spp.) and topographical barriers (e.g., cliffs and elevation, though see Dutcher *et al*. 2020). If such features constrain connectivity within the Far West AU, it would also limit the genetic benefits of connectivity with the adjacent NEM recovery unit. However, occupancy and use are relatively unknown in this area. Overall, connectivity across the north-south axis in Far West AU is likely Poor to Moderate.

Overall, the current resiliency of the habitat and demographic factors, including connectivity, in the Far West AU is in Poor Condition (Table 14 and Figure 13). This is primarily a result of both habitat and demographic factors exhibiting Poor Condition. This condition is exacerbated by repeat wildfires and non-native plant invasions, though *G. agassizii* occupancy was considered low prior to these events.

Arizona AU

The Arizona AU is 99,537 acres with an estimated 86,894 acres of modelled suitable habitat (Table 2). The Arizona AU is jurisdictionally outside (south) of the original UVR recovery unit boundaries, but at the Workshop, we redrew those boundaries to include adjacent predicted habitat (Nussear *et al*. 2009) that extends continuously south of the Utah-Arizona state line (Figure 5). The continuous predicted habitat extending south and west may provide linkages between Utah and Arizona tortoises in the UVR recovery unit, as well as linkages between the UVR and NEM recovery units (Figure 12). This continuity of populations and potential connectivity across recovery units make the Arizona AU ecologically relevant to the analysis of the UVR recovery unit as a whole. This area is primarily managed by the BLM (84,907 acres) and the Arizona State Land Trust (14,622 acres) (Figure 3).

Information on the *G. agassizii* population in Arizona is limited. However, *G. agassizii* in the Arizona AU face many of the same challenges as those elsewhere in the UVR recovery unit. Development pressure is high on private and state lands throughout the Arizona-Nevada-Utah tri-state area, reducing and fragmenting *G. agassizii* habitat and populations (BLM 2007). Increased development in this area has resulted in an increase in raven densities (BLM 2007). Increases in legal and illegal usage of public lands, including OHV use, *G. agassizii* collection, and intentional shooting of *G. agassizii* is also occurring (BLM 2007). Degradation of *G. agassizii* habitat throughout the Arizona AU is also attributed to intense grazing pressure and spread of non-native invasive grasses and associated wildfires (BLM 2007). These stressors deplete and degrade forage resources and result in direct mortality from promotion of wildfires, all of which are expected to have negative consequences on survival and recruitment (USFWS 1994, USFWS 2011, Berry and Murphy 2019).

Our assessments of current conditions were made by *G. agassizii* experts that had familiarity with the populations in this region (USFWS 2019a; B. Wooldridge, USFWS, personal communication, April 3, 2020). Habitat quality factors, including native herbaceous vegetation and shrub cover were assessed as being in Moderate Condition due to ongoing disturbances related to grazing and non-native invasive grasses (Table 14). Despite ongoing development pressure, sufficient acreage of suitable *G. agassizii* habitat remains in the Arizona AU (Good Condition). Burrow availability is considered Poor Condition, but uncertainty is high due to lack of recent surveys. We lack robust demographic data on sex ratios, life stage distributions, and survival rates within the Arizona AU (Table 14). Based on the most recent surveys that were performed in the early 2000s, densities and abundances are thought to be Poor Condition; *G. agassizii* abundance is approximately 457 individuals (Table 3).

We determined that connectivity between the Arizona AU, adjacent AUs (inter-AU), and the NEM recovery unit is in Moderate Condition based on three boundaries in Poor Condition and one in Good Condition (Table 14). The Arizona AU borders three other AUs: Far West, Green Valley and Sand Mountain and shares a boundary with the NEM recovery unit (Figure 5). Arizona AU connectivity with adjacent AUs includes the following:

- ❖ The Arizona—Far West AU boundary is separated by human and topographical barriers and connectivity between these AUs is Poor (Far West AU).

- ❖ The Arizona—Green Valley AU boundary has I-15 and the Virgin River functioning as ecological boundaries between these two units. Similar to Far West, I-15 is not fenced, and represents a population sink with high resistance to movement. We have very little data in this area, but the connectivity model (Gray *et al*. 2019) does suggest some potential corridors if the highway and river could be overcome. Due to these anthropogenic and natural barriers, connectivity between these AUs is Poor.

- The Arizona—Sand Mountain AU boundary appears relatively unimpeded in the habitat connectivity model (Gray *et al*. 2019). Most of the development along the Arizona Strip occurs west of Sand Mountain AU, and we assume this pattern continues on the Arizona side as well. We have very little information in this area but assume connectivity is in Good Condition.

- The areas connecting the Arizona AU—NEM recovery unit may be important to natural connectivity (non-human assisted) between the UVR and NEM recovery units (Figure 5 and Figure 12). At least one of the habitat corridors identified between the recovery units traverses the Arizona AU. There are confirmed *G. agassizii* populations to the west of the Virgin Mountains. While the habitat connectivity model (Gray *et al*. 2019) identified the Virgin Mountains as a likely barrier to connectivity, others have noted the potential value of mountain passes as corridors for *G. agassizii* (Dutcher *et al*. 2020). There may be opportunities for connectivity with suspected *G. agassizii* populations further south of the Arizona AU, specifically Wolf Hole Valley and Main Street Valley; however occupancy in those areas is not confirmed (Wooldridge 2020). The connectivity model does identify potential corridors between these unconfirmed populations and the NEM recovery unit further to the southwest (Gray *et al*. 2019). Overall, the primary barriers to connectivity between the Arizona AU and NEM recovery unit generally match the barriers between Arizona AU, Far West AU, and Green Valley AU. Barriers in these areas are both anthropogenic and topographical including I-15, the Virgin River Gorge, and the Virgin Mountains. Overall, the connectivity between the Arizona AU and NEM recovery unit is Poor.

We determined that connectivity within the Arizona AU (intra-AU) is in Moderate Condition (Table 14). This is based on two potential population areas where connectivity would be meaningful to the recovery unit, the northwestern corner and east of I-15. Connectivity within the Arizona AU includes the following:

- Information on the distribution of *G. agassizii* within the Arizona AU is limited, but the large tracts of continuous habitat and recent modeling efforts (Gray *et al*. 2019) suggest that connectivity could occur throughout much of the AU. However, there are at least two major barriers within the AU, I-15 and the Virgin River gorge. These barriers likely isolate *G. agassizii* clusters within the northwestern corner of this unit (south of Beaver Dam) from those to the east (south of St. George, Sand Mountain AU). Restoring or improving connectivity and fencing across I-15 could provide an important genetic linkage for tortoises on the western and eastern sides of the recovery unit. In modelling efforts, approximately 15,000 acres were removed from available habitat acres, primarily along I-15.

We have high uncertainty about the habitat and demographic factors in the Arizona AU, but the size of the area, a slower development rate, and assumed moderate connectivity indicate resiliency is in Moderate Condition (Table 14 and Figure 13). However, much is unknown in this AU and surveys assessing these characteristics are highly recommended.

Green Valley AU

The Green Valley AU is 31,433 acres (Table 3) and is on the west side of the UVR recovery unit and east of the Far West AU (Figure 5). It is bounded on the north and east by the urban matrix (residential, agriculture, roads, and other developed land cover) and on the south by the Arizona AU. The Green Valley AU is estimated to support 30,661 acres of modeled suitable habitat and was previously thought to support low levels of *G. agassizii* occupancy. However, recent surveys in parts of Green Valley AU indicate a high density *G. agassizii* cluster (Rognan *et al.* 2017). The Green Valley AU, which includes the Zone 6 area, may support over 600 adult *G. agassizii* (Table 3). Most of the suitable habitat in this AU is managed by the BLM (21,272 acres), with other landowners including Tribal (4,963 acres; approximately half of the Shivwits Reservation), SITLA (4,195), Utah Department of Transportation (70 acres), and at least one private landowner (161 acres) (Figure 3;Table 3). This AU also includes five BLM ACECs comprising 12,927 acres of this AU. The ACECs provide conservation protections and management for other listed or sensitive species such as dwarf bear-poppy (*Arctomecon humilis*), Holmgren milkvetch (*Astragalus holmgreniorum*) and Gierisch mallow (*Sphaeralcea gierischii*) (BLM 2016) that likely also benefit *G. agassizii*.

The Green Valley AU features caliche and limestone geology, diverse soils (including badlands and gypsiferous soils), and cliffs. In addition to the endangered plant species noted above, this area also supports creosote shrubs and barrel cactus and other diverse native vegetation. Overall, the habitat quality factors in this AU are in Good Condition (Table 14). This assessment was largely based on expert assumptions that the biocrust slows the spread of non-native invasive *Bromus* spp., and there is a lack of wildfire history in this AU. Thus, native herbaceous vegetation is in Good Condition. The biocrust may similarly suppress the availability of shrub cover, limiting vegetative shelter (Moderate Condition). However, biocrust stability and friability as well as the availability of caliche burrows in this area likely allow for ample burrows (Good Condition). Acreage of suitable habitat is high enough to support target population abundance and density (Good Condition).

A portion of the Green Valley AU has been proposed for protection as Red Cliffs Desert Reserve, zone 6 (6,818 acres) to help offset impacts from a proposed highway in Red Cliffs Desert Reserve, zone 3 (Figure 5, Washington County 2020). Recent surveys were conducted across 5,150 acres of the proposed zone 6 (Rognan *et al.* 2017), but very little is known about this species west of the Red Cliffs Desert Reserve, proposed zone 6 area. Protecting sensitive biocrusts prevents human access for substantive surveys in some areas; other areas simply have low development and recreation pressure, lack of which decrease the need for surveys. Drone technology is being refined to detect *G. agassizii* using multiple flyovers, but is not yet practicable because the species' is ectothermic (cold-blooded) and therefore does not allow for heat mapping.

Overall, Workshop experts speculated that density and abundance estimates are much lower in areas west of the Red Cliffs Desert Reserve, proposed zone 6. Although this seems to conflict with the high densities reported in the proposed zone 6 area, *G. agassizii* are a clustered species and so it is not unusual that they would be denser in one area and less dense in an adjacent area (Allison and McLuckie 2018). Individuals have also been translocated to proposed zone 6 lands following adjacent development clearance surveys and the densities there may be partially the result of these translocations, though documented translocations may only represent 10 to 20 animals (C. Rognan, Washington County HCP Administrator, personal communication, May 5, 2020). Local experts helped clarify lower *G. agassizii* density estimates west of proposed zone 6 lands (A. McLuckie, UDWR, personal communication March 16, 2020; C. Rognan, Washington County HCP Administrator, personal communication, March 26, 2020) and we determined the Green Valley AU abundance and density are Moderate Condition overall when considering Zone 6 and the rest of the AU together (Table 14).

Sex ratio is unknown (Table 14). The area supports all life stages (likely Good Condition) as evidenced by community science data collected in the east side of the Green Valley AU and reviewed by HCP *G. agassizii* biologists.

We based survival estimates on habitat quality metrics and also considered impacts in the area (overall, Moderate Condition; Table 14). While most of the Green Valley AU has relatively low levels of impacts, the proposed zone 6 area is a popular recreation destination, with recent estimates of 82,775 visitors per year documented on the BLM lands (K. Voyles 2020, BLM, personal communication, 2020; D. Kiel, BLM, personal communication, 2019). Zone 6 has a higher density of recreation use than any other area on public land in the Red Cliffs NCA, and this intensive human use may adversely impact *G. agassizii* and their habitat (Taylor and Knight 2003). Non-motorized recreation activities bring with them threats associated with increased human presence, such as loss of habitat from development of recreational facilities, handling and disturbance of *G. agassizii*, increased road kill and deliberate maiming or killing of *G. agassizii*, increased raven predation, degradation of vegetation, and soil compaction (USFWS 1994a, Averill-Murray 2002). In general, *G. agassizii* in areas with heavy visitor use are vulnerable to collecting and vandalism and road kills (e.g., Berry *et al*. 2008, Hughson and Darby 2013). Trail braiding is extensive on the approximately 3,400 acres of SITLA lands in this area. Human presence is often attributed as a primary factor in *G. agassizii* declines (Berry and Murphy 2019). The impacts of human access on the demographics in the east portion of this AU also likely includes attracting ravens and off-leash dogs. Thus, the habitat quality is lower in Zone 6 than the rest of Green Valley, especially on the SITLA lands (G. Billings, Utah State University, personal communication, March 19, 2020). Other stressors were identified as concerns in the UVR recovery unit, but are either not present at a concerning level in the Green Valley AU or their status is unknown (Appendix 2).

Disease (i.e., URTD) has occurred in the proposed zone 6 area but prevalence is unknown. The size of the proposed zone 6 also indicates inbreeding depression could occur if connectivity decreases in the future from other proposed roads (USFWS 2019a). The small area is unlikely to support target abundance without continued connectivity with Green Valley AU and other populated areas.

We determined Green Valley AU connectivity with adjacent or nearby AUs (inter-AU) is in Moderate Condition because only one of five boundaries exhibited Good Condition, the Green Valley—Far West AU boundary (Table 14). Green Valley AU connectivity with adjacent or nearby AUs includes the following:

- ❖ The Green Valley—Far West AU boundary (Far West AU) is in Good Condition. This boundary is important for connectivity potential with the neighboring recovery unit.

- ❖ The Green Valley—Snow Canyon AU boundary is an important boundary, providing a possible route for *G. agassizii* within Red Cliffs Desert Reserve to connect with populations and recovery units to the west. Unfortunately, this AU is separated from the Snow Canyon AU by the urban matrix, though there may still be some remaining connectivity to the west of the developments in Ivins City. Removing developed areas that are fenced along Red Cliffs Desert Reserve, zone 2, approximately 50 percent of the Red Cliffs Desert Reserve boundary is unimpeded (Moderate Condition). However, the AU map halts the Green Valley AU at Old Highway 91 (unfenced) and the Santa Clara River, which provide infrequent and poor passage opportunities. Overall, this boundary is in Poor to Moderate Condition.

- ❖ Interactions between *G. agassizii* in the Green Valley AU and the Urban Interface AU (three isolated subunits) is not possible without human intervention (e.g., translocations). These three subunits are separated from Green Valley by miles of suburban and urban development.

- ❖ Connectivity across the Green Valley—Sand Mountain AU boundary requires passing I-15 and is unlikely because this stretch of highway is not fenced, though some culverts exist that could be used by *G. agassizii*. Arizona Department of Transportation in coordination with the USFWS may fence this stretch of highway in the future (C. Rognan, Washington County HCP Administrator, personal communication, May 5, 2020). If *G. agassizii* are present, the interstate highway would likely act as a population sink. The area of the urban matrix that is still *G. agassizii* habitat is being rapidly developed. This boundary exhibits high resistance to movement, or Poor Condition.

- ❖ The boundary between the Green Valley—Arizona AUs exhibits poor connectivity due to anthropogenic and natural barriers (Arizona AU).

We determined connectivity within the Green Valley AU (intra-AU) is in Good Condition (Table 14). Connectivity within the Green Valley AU includes the following:

- ❖ The *G. agassizii* clusters in Green Valley AU that are biologically meaningful to connect are those on the east side with potential connectivity areas to the north, west, and south. Movement between *G. agassizii* clusters appears to exhibit low resistance (< 20 percent) based on the connectivity model (Gray *et al*. 2019). Occupancy is relatively well known on the east side of this AU, but less well known on the west side due to sensitive biocrusts preventing surveys and less habitat impacts (resulting in fewer opportunistic surveys or encounters). On the east side where data has been gathered, *G. agassizii* clusters are within 1 to 2 home ranges of each other. On the west side, we lack sufficient data to determine where *G. agassizii* clusters are and whether observations are within 1 to 2 home ranges of each other. While heavy recreational use occurs on approximately 5,150 acres, about half of this is managed on BLM lands. The other 3,000 acres are not managed and would impede connectivity and movement, though not through a hard physical barrier. Connectivity is currently good between Zone 6 and Green Valley AU lands to the northwest, west, and southwest (primarily BLM lands). While the Zone 6 SITLA lands are bordered on the northeast, east, and southeast by residential developments, connectivity can extend west with the rest of Zone 6. Overall, connectivity within Zone 6 and Green Valley AU is relatively unimpeded, or Good condition.

Overall, Green Valley AU habitat factors exhibit Moderate to Good condition, though impacts are heavy in the east portion of the AU. Demographic factors exhibit a mix of Moderate and Good condition scores, and highlight that the AU *G. agassizii* abundance is still well below the target abundance. Connectivity with adjacent or nearby AUs is Moderate but connectivity within the 30,830-acre AU is Good overall. The Green Valley AU resiliency as a whole is in Good condition (Table 14 and Figure 13).

Snow Canyon AU

Snow Canyon AU is the westernmost AU in Red Cliffs Desert Reserve. The AU includes Red Cliffs Desert Reserve, zones 1 and 2, and spans 16,434 acres (Table 2). However, only 6,290 acres are estimated to be suitable *G. agassizii* habitat (Nussear *et al*. 2009), with much of the AU occurring across areas higher than 4,500 ft elevation and other areas made inaccessible by cliffs. In addition, the AU contains a small residential development, a State park, and is crossed by multiple roads.

Red Cliffs Desert Reserve, zone 1 contains a narrow strip of *G. agassizii* habitat (1,374 acres) at the base of the Red Mountains (Figure 5). A small development occupies the area directly south of Red Cliffs Desert Reserve, zone 1 and the Shivwits Indian Reservation encompasses the land below the Red Mountains to the west of the area. The Red Mountains northwest of SCSP were designated as the Red Mountain Wilderness Area about 18,700 acres) in 2009 as part of the Omnibus Public Land Management Act of 2009 – Public law 111-11 (March 30, 2009). There are no OHV trails or roads in Red Cliffs Desert Reserve, zone 1, and only one hiking trail and one equestrian trail are designated in this entire zone. Relative to other AUs and Red Cliffs Desert Reserve, zones, zone 1 may have experienced fewer stressors to *G. agassizii*.

Adjacent to Red Cliffs Desert Reserve, zone 1, the Shivwits Band of the Paiutes Indian Reservation allows cattle and sheep grazing, and neighboring State lands are likely to continue to be developed. This area has been relatively untouched by wildfire; however, a small 30-acre wildfire burned habitat on the northwest border of the area as part of the 2006 Red Hills 2,480 acre fire. The Red Hills fire primarily burned west and north of Red Cliffs Desert Reserve, zone 1. Occupancy mapping of *Bromus* spp. grasses from 2001 through 2011 indicated that Red Cliffs Desert Reserve, zone 1 had the lowest levels of invasion among all of the zones in the Red Cliffs Desert Reserve (USGS 2019). If this remains the case, wildfire expectancy for this area is likely lower than other zones, and this zone may provide a source of native plant propagules to adjacent habitat areas.

In contrast, the Red Cliffs Desert Reserve, zone 2 area supports approximately 5,500 acres of *G. agassizii* habitat north of Ivins City (Figure 5). Roughly one-third of Red Cliffs Desert Reserve, zone 2 is part of the Red Mountains Wilderness Area managed by the BLM. The remaining two-thirds of Red Cliffs Desert Reserve, zone 2 is managed by SCSP. Red Cliffs Desert Reserve, zone 2 is primarily used for non-motorized recreation, and impacts in SCSP are medium to medium-high (K. Comella, SCSP, personal communication, November 15, 2019). SCSP estimates they received 500,000 visitors in 2019 (Washington County 2020). The town of Ivins is directly south of Red Cliffs Desert Reserve, zone 2 and is a low-impact housing community. However, debris basins (areas that capture sediment and debris washed out of canyons during storms) are continually being updated and improved along the interface of the foothills where most *G. agassizii* observations occur, and also between the residences. Housing developments and a golf course border the east side of State Route 18. Raven occupancy appears to be increasing in Red Cliffs Desert Reserve, Zone 2, with associated evidence of juvenile predation (Schijf and Rognan 2019). Wildfires in Red Cliffs Desert Reserve, zone 2 have primarily impacted SCSP. The Park indicated that four wildfires have impacted the area, two caused by lightning and two by humans (K. Comella, SCSP, personal communication, June 6, 2019). SCSP also reported several smaller fires under 50 square (sq.) ft that they were able to extinguish quickly. The BLM fire data indicate two fires occurred near SR-18 in Red Cliffs Desert Reserve, zone 3, one of which was ignited from the road. Occupancy mapping of *Bromus* spp. grasses from 2001 through 2011 indicate fluctuating levels of invasion in this area with a small number of persistent problem areas (USGS 2019).

Habitat conditions within Snow Canyon AU are generally high quality, with herbaceous vegetation, shrub cover, and burrow availability all rated as Good Condition (Table 14). However, the overall habitat area within Snow Canyon AU is insufficient to support a *G. agassizii* population in the long term, and is in Poor Condition (Table 14).

The *G. agassizii* population in the Snow Canyon AU is likely concentrated at lower elevations along the eastern edge and especially the southeastern corner of the AU, with an estimated total abundance of 161 to 252 tortoises (Table 3). Because bi-annual surveys do not include Red Cliffs Desert Reserve, Zone 1, we applied the density of 3.4 adult *G. agassizii* per mi^2 to this area, consistent with other unsurveyed areas (Table 3). Paradise Canyon in the southeast and Padre Canyon and Snow Canyon in the south support high concentrations (McLuckie *et al.* 2020). This small area supports a high density population with representation across sexes and life stages, which may indicate healthy survival rates (Good Condition; Table 14). The small and insular populations, despite high densities, were considered Poor Condition (Table 14).

Snow Canyon AU connectivity with adjacent or nearby AUs (inter-AU) is in Poor to Moderate Condition (Table 14) as only one of three boundaries exhibited Moderate to Good Condition, the Snow Canyon—Far West AU boundary. Snow Canyon AU connectivity with adjacent or nearby AUs includes the following:

- ❖ The boundary between Snow Canyon and the Far West AUs is one of the most important boundaries for the UVR recovery unit, representing the only possible connection to individuals within the protected Red Cliffs Desert Reserve (Figure 12). Overall the connectivity in the south is in Moderate to Good (Far West AU).

a. While not strictly the AU boundary, the western half of the Snow Canyon AU (Red Cliffs Desert Reserve, zone 1) may provide a nexus for gene flow from within the Red Cliffs Desert Reserve to *G. agassizii* outside Red Cliffs Desert Reserve, by providing connectivity with the northern portion of the Far West AU. A least-cost corridor analysis was conducted range-wide for this species based on the species' occupancy habitat model (Averill-Murray *et al.* 2013). We conducted a new analysis in 2020 using the same peer-reviewed habitat model and looking for additional corridor possibilities (Figure 12; USFWS 2020). The 2013 and 2020 analyses determined connectivity between the Red Cliffs NCA (part of the Red Cliffs Desert Reserve) and the Beaver Dam Wash NCA are all directly west from Snow Canyon. *Gopherus agassizii* would need to cross an unfenced road as well as the Santa Clara River, which flows from Gunlock Reservoir (constructed in 1970). *Gopherus agassizii* have been observed on both sides of the river but it is unknown if *G. agassizii* crossed the river pre- or post-Reservoir construction. Reservoir-regulated river flows can sometimes be as low as two cubic ft per second, which may allow intrepid *G. agassizii* to cross, though such events are likely exceptionally rare.

❖ Connecting Snow Canyon—Green Valley AUs could provide a possible route for *G. agassizii* within Red Cliffs Desert Reserve to connect with populations and the NEM recovery unit to the west. Unfortunately, these AUs are separated by the urban matrix (Figure 5). Overall, this boundary is in Poor to Moderate Condition.

❖ The Snow Canyon—West Cottonwood AU boundary is defined by State Route 18 (SR-18). SR-18 is fenced on both sides with *G. agassizii* proof fencing that deters digging under and climbing over the fence and minimizes road injuries and fatalities. SR-18 has one culvert at Twist Hollow, but it is not designed nor maintained for *G. agassizii* passage, and is unlikely to be used by *G. agassizii*. This highway boundary effectively eliminates functional connectivity and is in Critical to Poor Condition.

We determined connectivity within the Snow Canyon AU (intra-AU) is in Poor to Moderate Condition (Table 14). The *G. agassizii* clusters in Snow Canyon that are biologically meaningful to connect are in Red Cliffs Desert Reserve, zone 1, the foothills west of Tuacahn Drive, habitat between Tuacahn Drive and Snow Canyon Drive, and habitat just west of SR-18. Connectivity within the Snow Canyon AU includes the following:

❖ While modelled habitat in Red Cliffs Desert Reserve, zone 1 suggests *G. agassizii* can occupy and travel around developed areas, the connectivity model indicates high resistance to movement within zone 1 (Gray *et al*. 2019). Zone 1 *G. agassizii* are not well connected given development in the foothills where connectivity would be most likely and is in Moderate Condition.

❖ Tuacahn Drive is fenced with *G. agassizii*-proof fencing. Three culverts were installed in the mid-1990s specifically to facilitate *G. agassizii* movement. Two *G. agassizii* crossings were observed on the middle culvert in 2005 (McLuckie 2019a). The other two were constructed using similar techniques and may be similarly effective for genetic flow given the one-migrant-per-generation rule. However, as discussed in Habitat Connectivity, these culverts may be insufficient for demographic flow or population recovery needs and we have very limited research on their effectiveness for genetic flow. We note that some unknown level of human assisted migrations may be occurring as *G. agassizii* are moved by the public out of harm's way. Overall, this connectivity need is currently in Poor to Moderate Condition (demographics and genetics respectively).

- Snow Canyon Drive is a 5-mile paved road with ¼ mile of *G. agassizii*-proof fencing. Pre-fencing, most *G. agassizii* fatalities were along this stretch of road because the adjacent areas are high quality habitat as far as vegetation and topographic features. Fatalities are still the highest on this road than any other fenced road in the Red Cliffs Desert Reserve (McLuckie 2019b); however observations of fatalities may also be higher due to presence of SCSP personnel and recreationists (A. McLuckie, UDWR, personal communication, March 31, 2020). The decision to fence just this stretch was a result of three factors including genetic flow, topographical challenges to fencing in some areas, and topographical impediments to *G. agassizii* movements in other areas. *Gopherus agassizii* mortality rates are likely reduced through speed limits along Snow Canyon Drive, "share the road" signs, outreach messaging (leaflets, brochures), staffed gates with messaging, and speed humps (UDWR 1998). Allowing connectivity in lesser quality habitat areas may allow for sufficient genetic flow (Good Condition) and insufficient demographic flow or population recovery (Poor to Moderate Condition). In non-fenced areas, it is possible the road could act as a population sink. Overall, the connectivity need is in Poor to Moderate Condition.

Overall, Snow Canyon AU habitat factors exhibit Good Condition, though the smaller AU size is a major concern (Table 14 and Figure 13). Demographic factors also reflect the size limitation of this AU, as high densities are not enough to balance low abundance and low intra- and inter-AU connectivity. The Snow Canyon AU as a whole is in Moderate Condition.

Urban Interface AU

The Urban Interface AU is a collection of three *G. agassizii* occupied habitat patches embedded within the urbanized center (i.e., St. George and surrounding communities) of the UVR recovery unit (Figure 5; Table 2). These patches span 3,229 acres and contain an estimated 1,555 acres (2.4 mi^2) of suitable habitat and may be inhabited by as few as 3 to 26 adult *G. agassizii* (Table 3), though local experts believe the abundance is much higher (A. McLuckie, UDWR personal communication, March 31, 2020; C. Rognan, Washington County HCP Administrator, personal communication, May 5, 2020). What remains of *G. agassizii* habitat within this AU appears to be in suitable condition because the subunits contain native herbaceous vegetation (Moderate Condition), shrub coverage (Good Condition), and sufficient burrows (Good Condition) (Table 14). However, there is a severe deficit of suitable habitat area (i.e., space, acreage), far below what is necessary to support an independently viable tortoise population, even in the short term (Critical Condition).

There is representation across all *G. agassizii* life stages within the AU (Good Condition), and based on habitat conditions annual survival is in Moderate Condition (Table 14). Due to the critically small habitat area, this patch supports poor *G. agassizii* abundances (estimated 10 to 18 adults; Poor Condition). We presently lack data on sex ratio and tortoise densities within this AU (Table 14).

The Urban Interface AU is subdivided into three subunits that are entirely isolated by human development. There is no remaining functional connectivity (within subunits or with other AUs) in the absence of human intervention (e.g., translocations). We rated inter-AU connectivity in the Critical Condition (non-existent) (Table 14).

We determined intra-AU connectivity within each of the Urban Interface AU subunits rather than between the sub-units. Overall connectivity to support genetic and demographic integrity is in the Poor Condition primarily due to fragmentation from encroaching residential and commercial development, low numbers, and small size (Table 14). Subunit connectivity includes the following:

- ❖ The West Black Ridge subunit includes the area with the old airport. This area has been preserved as open space, the *G. agassizii* population is protected, and the area includes a popular hiking trail maintained by the City of St. George. Development is low due to steep slopes and hillside ordinances (C. Rognan, Washington County HCP Administrator, personal communication, May 5, 2020). Functional connectivity given the low numbers and small area is in Poor to Moderate Condition for genetic or demographic needs.

- ❖ The Black Ridge subunit continues to be developed in the northern region and steep slopes isolate the habitat patches on the east and west. Developed areas adjacent to this subunit were previously cleared of approximately 200 *G. agassizii* (A. McLuckie, UDWR personal communication, March 31, 2020). A few *G. agassizii* observations were recorded since the clearance surveys and the area is continually being developed and fragmented. This subunit is in Poor Condition due to low numbers, small area, continued removal of *G. agassizii*, and continued habitat loss and fragmentation.

- ❖ The Sleepy Hollow subunit includes several expanding residential and commercial developments. Given the low numbers, small area, continued removal of *G. agassizii*, and continued habitat loss and fragmentation, this subunit is in Poor Condition.

Overall, Urban Interface AU habitat factors exhibit Good Condition, though the size of the subunits are a major concern (Table 14 and Figure 13). Demographic factors of low densities, low abundance, and Critical to Poor connectivity compound on the habitat factors to suggest functional extirpation. Resiliency in the Urban Interface AU as a whole is in Poor Condition.

West Cottonwood AU

Incorporating expert feedback from the Workshop, we determined the core zone of the Red Cliffs Desert Reserve, Zone 3, is segmented into two separate AUs by Cottonwood Springs

Road: West Cottonwood AU and East Cottonwood AU (10,446 and 28,909 acres overall, and 7,489 and 21,669 acres of modelled suitable habitat, respectively; Table 2). Cottonwood Springs Road runs in a north-south direction following the main wash and bisects Zone 3. Cottonwood Springs Road is fenced through *G. agassizii* habitat with *G. agassizii* proof fencing, it is well maintained (although some breaches do occur), and there are no underpasses or overpasses connecting the two AUs for terrestrial wildlife. These two AUs are north of the city of St. George and surrounded on south, east, and west by urban developments and fenced highways. West Cottonwood AU extends from SR-18 to Cottonwood Springs Road. The *G. agassizii* habitat in West Cottonwood is primarily BLM owned and managed (5,952 acres), but other areas are privately (1,030 acres) or State owned (DNR: 265 acres, SITLA: 241 acres; Table 2).

In addition to being bordered on the west by the fenced SR-18 and the east by the fenced Cottonwood Springs Road, a corner of the West Cottonwood AU is also crossed by Red Hills Parkway. There are five culverts in Red Hills Parkway, which enters and exits the southwest corner of zone 3. Two of these culverts were built with concrete boxes to facilitate *G. agassizii* movement and three were built with corrugated steel; over three years of monitoring the five culverts, two *G. agassizii* were observed using one of these culverts (Habitat Connectivity).

West Cottonwood AU was affected by the Plateau Fire, a large wildfire in 2005. Nevertheless, isolated pockets of habitat have not burned and islands of habitat with no or very little non-native invasive plant species persist in this area. The AU is primarily blackbrush-mesic with interspersed patches of desert sand shrub (Provencher *et al*. 2011). In addition, Workshop experts noted that shrubs and native vegetation appear to be coming back, albeit slowly (15 years later). Unfortunately, non-native invasive *Bromus* spp. have increased exponentially throughout the recovery unit and in the West Cottonwood AU due to significant winter, spring, and summer precipitation in 2019. Workshop experts characterized this AU as supporting moderate amounts of native plants, moderate shrub diversity, and an abundance of seasonal *G. agassizii* burrow availability (Table 14). The suitable habitat acres mapped in 2009 were already too few to support the management target of 3,000 *G. agassizii* and the wildfires likely reduced that capacity further. Overall, the current habitat score is in Moderate Condition (Table 14). This is generally consistent with the Landscape Conservation Forecasting report that put ecological departure (from an ideal pristine reference condition) at about 25 percent (Provencher *et al*. 2011).

The UDWR has systematically and rigorously collected over 20 years of data (14 separate survey periods) in Red Cliffs Desert Reserve, focusing most of their effort on zone 3 (McLuckie *et al.* 2020). Although most of our data is across zone 3, separating the zone into two AUs was considered warranted based on the impermeability of Cottonwood Springs Road, which effectively isolates *G. agassizii* on each side. Based on the available monitoring data across zone 3, we can conclude that the *G. agassizii* sex ratio and life stages in West Cottonwood are in Good Condition (Table 14). Potential annual survival based on habitat characteristics is likely in Moderate Condition, especially in the areas still recovering from the 2005 wildfire where nutrition, reproduction, and shelter may be compromised. Clinical presentation of URTD in Red Cliffs Desert Reserve, zone 3 has fluctuated over time from a low of 4 percent in 1998 and 1999 to 16 percent in 2001 and 2005 (McLuckie *et al*. 2018).

Gopherus agassizii density is high in this area, and the West Cottonwood AU may support densities three times higher than East Cottonwood, containing the highest density cluster in zone 3 (Figure 14). In density surveys in the late 1980s and early 1990s, the City Creek area indicated densities may have been as high as 84 to 114 *G. agassizii* per mi^2 (Fridell *et al.* 1988 and 1994) and high densities and abundance were also documented adjacent to the T-Bone Mesa area. Given the high levels of fragmentation throughout the rest of the UVR recovery unit and the importance of the West and East Cottonwood AUs, the cluster in West Cottonwood AU may continue to be the most important high density cluster of *G. agassizii* in the recovery unit (USFWS 2020). This cluster previously extended further north in the West Cottonwood AU, but high fatalities and reduction in range of the cluster resulted from the drought and wildfires in the early 2000s (Figure 14). However, efforts are underway to restore habitats in all of the West Cottonwood AU, and the entire AU remains important for *G. agassizii* recovery (see within AU connectivity below). Abundance remains in Moderate Condition in this area, at just over 500 adult *G. agassizii* and inbreeding depression could be occurring based on the demographics; studies are needed to evaluate if this is a concern.

The UVR recovery unit and Red Cliffs Desert Reserve, zone 3, was impacted by drought prior to the 2006 wildfires, and population declines were likely exacerbated by these two stochastic events occurring relatively close in time. The Red Cliffs Desert Reserve, zone 3 population declined 66 percent, from a high of 3,351 (95% Confidence Interval (CI): 2481 to 4525) to a low of 1,181 tortoises (95% CI: 830 to 1682; McLuckie *et al*. 2019). Surviving *G. agassizii* continue to use the burned areas, though their numbers are diminished.

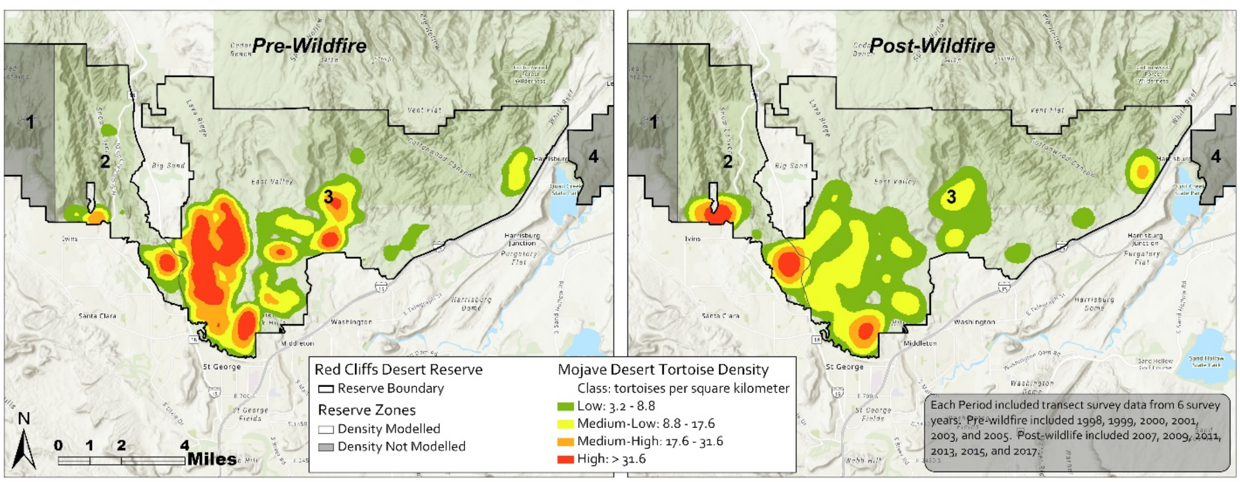

Figure 14. Gopherus agassizii densities before and after droughts and wildfires in the early 2000s. G. agassizii in West Cottonwood AU (west of Cottonwood Springs Road) are approximately three times higher than densities in East Cottonwood Springs Road.

Human access from proximity to urbanization is the primary stress to this AU, impacting both habitat quality and demographics. Total disturbance in Red Cliffs Desert Reserve, zone 3 is estimated from spatial layers at around 432 acres in *G. agassizii* habitat, but this does not include all utility developments that have occurred in Red Cliffs. The Washington County HCP allows small scale utility developments in Red Cliffs Desert Reserve to serve the surrounding cities (Washington County 1995); Washington County estimates 40 to 50 acres have been developed for utilities under the last HCP (2 acres per year), and much, but not all of this occurs in Zone 3.

Thus, total disturbance in Zone 3 may be 432 to 462 acres, or a little more than 1 percent of suitable habitat. Thus far new disturbance related to utilities has not been capped, despite long restoration time lags in desert environments (Nauman *et al*. 2017). However, it has been managed to ensure the intent of small disturbances was implemented (Washington County 2020). The amended HCP requests 50 acres of new development in the Red Cliffs Desert Reserve may be needed over the next 25 years and caps this at 200 acres. While new disturbances in the Red Cliffs Desert Reserve have resulted in at minimum acre to acre boundary realignments and often 6 to 1 mitigation, remaining habitat connected to the Red Cliffs Desert Reserve is diminishing in availability and new utility developments continue to further fragment habitat in Red Cliffs Desert Reserve in important areas. We note that while total disturbance from utilities represents a fraction of the disturbance of suitable habitat compared to wildfire, continued habitat fragmentation and degradation exacerbate invasive plants and wildfire susceptibility. In addition, a disturbance of 50 acres can represent a significant impact depending where it occurs (Figure 14). Adaptive management and review of individual projects in the Red Cliffs Desert Reserve will continue to be an important component of management in the UVR recovery unit.

Humans have ignited 8 of the 18 large wildfires documented in Red Cliffs Desert Reserve, zone 3. Paved roads are present in the area and fenced, though *G. agassizii* injuries and fatalities still occur. Roads overall account for 117 acres of Red Cliffs Desert Reserve, zone 3. Motorized recreation is not an allowed use of Red Cliffs Desert Reserve, but non-motorized recreation is present and growing and becoming more difficult to manage. The Red Cliffs NCA recorded 220,725 visitors in 2018, although other areas receive visitors not included in this estimate (Washington County 2020). HCP staff have previously stated there were 40,000 visitors a year to Red Cliffs Desert Reserve, zone 3 alone. There are 120 acres of trails in Red Cliffs Desert Reserve, zone 3, a very small percentage of which overlap the roads.

The HCP administration and BLM minimize human access to this AU by implementing a public use plan (PUP; Washington County 2000) and the Red Cliffs NCA Resource Management Plan (BLM 2016), respectively. Through these plans, law enforcement issues warnings and citations for illegal uses of Red Cliffs Desert Reserve (e.g., off-leash dogs or illegal camping) and HCP, BLM, and State staff implement public education efforts and install and maintain signage.

We determined West Cottonwood AU connectivity with adjacent AUs (inter-AU) is in Critical to Poor Condition as the two adjacent AUs are fenced with *G. agassizii* barriers installed specifically to eliminate *G. agassizii* movement across roads and reduce *G. agassizii* injuries and fatalities (Table 14; Figure 13). These fences are well maintained, and although breaches occur, *G. agassizii* are typically put back on the same side of the fence. This intentional isolation is a significant issue for the recovery unit, fragmenting the core zone of the Red Cliffs Desert Reserve that has the most abundant *G. agassizii* population. West Cottonwood AU connectivity with adjacent AUs includes the following:

- ❖ The West Cottonwood—Snow Canyon AU boundary is fenced along SR-18 and presents high resistance to *G. agassizii* movement through 100 percent of *G. agassizii* habitat (Snow Canyon AU). Functional connectivity between these AUs without human intervention is in Critical to Poor Condition.

- ❖ The West Cottonwood—East Cottonwood AU boundary is delineated by Cottonwood Springs Road, which is fenced on both sides with no wildlife passage across the road. Functional connectivity between AUs without human intervention is in Critical to Poor Condition.

We determined connectivity within West Cottonwood AU (intra-AU connectivity) is in Moderate Condition (Table 14). Important *G. agassizii* clusters to connect include a large grouping in the south (the densest cluster in Red Cliffs Desert Reserve, zone 3), and a previously densely occupied, but burned habitat area in the north. Connectivity within the West Cottonwood AU includes the following:

- ❖ The UDWR data indicates that occupancy is relatively uniformly distributed in the West Cottonwood AU. However a large cluster, which may be the most important in the recovery unit (see above), previously extended further north in the West Cottonwood AU. High fatalities and reduction in range of the cluster resulted from the drought and wildfires in the early 2000s (Figure 14). However, habitat restoration efforts are underway to restore habitats in this AU. In addition, only one major wildfire has burned in this AU and the habitat appears to be recovering, albeit very slowly (USFWS 2019a). *G. agassizii* exhibits high site fidelity and we expect expanding their home ranges would reoccupy the burned areas at similar, pre-wildfire densities once they are restored; locally, *G. agassizii* that survived the wildfire continue to use the burned areas, exhibiting this site fidelity. Preserving connectivity between the recovering, area and the dense cluster of individuals further south may be key to the long-term demographics and distribution in this AU. Overall, connectivity above Red Hills Parkway exhibits relatively low resistance with few topographical barriers and remains in Good Condition.

- ❖ Red Hills Parkway is a four-lane highway that crosses the southwest corner of West Cottonwood AU. Two *G. agassizii* have been documented using one of the five culverts installed on this highway (over three years of monitoring). We assume infrequent passage may occur at a level necessary to support some genetic integrity, though not enough is known to determine if this would support population recovery, demographic needs, or even all genetic needs. Thus, Red Hills Parkway effectively cuts off about 450 acres of the area demographically (7 percent of the already small West Cottonwood AU). We consider this a Poor to Moderate Condition, including Poor demographically, and Moderate genetically, or likely sufficient for some genetic needs.

Overall, West Cottonwood habitat factors exhibit Moderate Condition overall, though size of the area is a concern (Table 14 and Figure 13). Demographic factors of Good densities, Moderate abundance, Moderate connectivity within the unit, and Poor connectivity outside the unit result in an overall resiliency of Moderate Condition for the West Cottonwood AU.

East Cottonwood AU

As mentioned in West Cottonwood AU, we determined the core zone of the Red Cliffs Desert Reserve, zone 3, is effectively (and purposefully) segmented into two disparate AUs by Cottonwood Springs Road: West Cottonwood AU and East Cottonwood AU (10,446 and 28,909 acres overall, and 7,489 and 21,669 acres modelled suitable habitat, respectively) (Table 2). East Cottonwood AU extends from Cottonwood Springs Road to I-15. The *G. agassizii* habitat area is a mix of land ownership with the majority owned by Utah Department of Natural Resources and BLM and managed for conservation (Table 2).

In addition to being bordered on the west by the fenced Cottonwood Springs Road, the entire south and east boundary of *G. agassizii* habitat is fenced adjacent to urban development and I-15. There are no road crossings designed or maintained for *G. agassizii* passage between East Cottonwood AU and Babylon or Cinder Knolls AUs (Red Cliffs Desert Reserve, zones 4 and 5).

East Cottonwood AU was affected by drought prior to a large wildfire in 2005 and some areas had burned in the 1990s (Figure 11). Repeat burn areas appear to be transitioning to a new state, which is predominately *Bromus* spp. mixed with other non-native invasive species (C. Rognan, Washington County HCP Administrator, personal communication, May 5, 2020) that increase the probability of future wildfires. Recent fires in July and October 2020 burned thousands of acres in this AU and in suitable *G. agassizii* habitat (Figure 11). Nevertheless, isolated pockets of habitat did not burn and islands of habitat with no or very little non-native invasive plant species persist in this area. Workshop experts described this area as having diverse soils including sandstone and basalt soils. Areas that are burned have a high prevalence of *Bromus* spp., but the east end of the AU is mostly unburned with areas of high shrub diversity and cover. The west side of the AU is primarily creosote bush-white bursage scrub with some warm-season grassland and a few areas with small desert sand shrub (Provencher *et al*. 2011). The east side of East Cottonwood AU is predominantly blackbrush-mesic and desert sand shrub, with a small strip of creosote bush-white bursage on the east edge.

Experts have noted that in areas where only one wildfire has occurred (no repeat burns), shrubs and native vegetation are coming back, albeit slowly (15 years later). Unfortunately, non-native invasive *Bromus* spp. increased exponentially throughout the recovery unit and in this AU due to significant winter, spring, and summer precipitation that occurred in 2019. Workshop experts characterized East Cottonwood AU as supporting moderate native plants, moderate shrub diversity, and an abundance of seasonal *G. agassizii* burrow availability. The amount of suitable habitat acres mapped in 2009 were Moderate (Table 14) and are unlikely to support the management target of 3,000 *G. agassizii* without connectivity to other AUs. Since that time, wildfires likely reduced the carrying capacity of suitable habitat further. Modelling reports calculate ecological departure (from an ideal pristine reference condition) at about 52 percent due to high levels of *Bromus* spp. invasion in this habitat type in the Red Cliffs Desert Reserve (Provencher *et al.* 2011). Based on this information, habitat quality is in Moderate Condition (Table 14).

The UDWR has systematically and rigorously collected over 20 years of data (14 separate survey periods) in Red Cliffs Desert Reserve, focusing most of their effort on Red Cliffs Desert Reserve, zone 3 (McLuckie *et al.* 2020). Thus, we can conclude that the sex ratios and life stages in East Cottonwood AU are in Good Condition (Table 14). Potential annual survival based on habitat characteristics is likely Moderate, especially in the areas still recovering from repeat or single wildfires where nutrition, reproduction, and shelter may be compromised. This area was impacted by drought prior to the 2006 wildfires and population declines were exacerbated by the two stochastic events occurring relatively close in time. The Red Cliffs Desert Reserve, zone 3 population declined 66 percent, from a high of 3,351 (95% CI: 2481 to 4525) to a low of 1,181 *G. agassizii* (95% CI: 830 to 1682; McLuckie *et al*. 2020). Surviving *G. agassizii* continue to use the burned areas, though their numbers are diminished (USFWS 2019a). However, density in East Cottonwood may be three times lower in this area compared to West Cottonwood (Figure 14). Thus, abundance may range from 700 to a maximum of 2,100 (calculated from the Red Cliffs Desert Reserve, zone 3 abundance), both of which result in a Moderate Condition (Table 14). Even with the largest abundance of all AUs, inbreeding depression is likely occurring in this AU. In addition, the recent Turkey Farm Road wildfire in this AU may have directly impacted *G. agassizii* through flames and smoke.

We determined West Cottonwood AU connectivity with adjacent AUs (inter-AU) is in Critical to Poor Condition because the two adjacent AUs are fenced with *G. agassizii* barriers installed specifically to eliminate *G. agassizii* movement across roads and reduce *G. agassizii* injuries and fatalities (Table 14). These fences are well maintained, and although breaches occur, *G. agassizii* are typically captured and released on the same side of the fence. West Cottonwood AU connectivity with adjacent AUs includes the following:

- ❖ The East Cottonwood—West Cottonwood AU boundary is in Critical to Poor Condition due to *G. agassizii*-fencing on Cottonwood Springs Road (West Cottonwood AU).

- ❖ The East Cottonwood—Babylon AU boundary is separated by I-15, with fencing on the west side of the 6-lane highway and no *G. agassizii* passage underneath the road. Quail Creek Reservoir is a major barrier on the west side of Babylon. The connectivity model (Gray *et al*. 2019) suggests there are additional topographical barriers to *G. agassizii* movement where fencing does not exist on the east side of the highway. *Gopherus agassizii* would need to occupy habitat continuously north from Babylon AU, south through Silver Reef—and individuals would need to cross I-15. Although potential habitat exists that could provide dispersal avenues, *G. agassizii* have not been observed in these areas and functional connectivity between AUs without human intervention is in Critical to Poor Condition.

We determined connectivity within East Cottonwood AU (intra-AU connectivity) is Good Condition (Table 14). This unit supports five primary clusters (west of Green Springs, middle Mill Creek, Grapevine, east Cottonwood Hill, Grapevine, and a cluster southwest of the Red Cliffs Recreation Area). Connectivity within East Cottonwood AU includes the following:

- While individuals are relatively uniformly distributed across this AU there appears to be a small cluster near Cottonwood Springs Road in the west side of the AU with densities tapering off travelling east. However, habitat is occupied continuously between the three primary clusters. Overall, connectivity is good, exhibiting relatively lower resistance with a few, but not many, topographical barriers and thus rating in Good Condition.

Overall, East Cottonwood AU habitat factors exhibit Moderate Condition overall (Table 14 and Figure 13), and even though this is the largest AU in Red Cliffs, size remains a concern given current densities and established target densities. Demographic factors of Moderate density, Poor abundance, Good connectivity within the unit, and Poor connectivity outside the unit result in an overall Moderate Condition for East Cottonwood AU resiliency.

Sand Mountain AU

The Sand Mountain AU (47,432 acres) is on the southeastern edge of the UVR recovery unit and is estimated to contain 41,115 acres of modeled suitable habitat (Table 2). Suitable habitat within the AU is distributed across BLM, private, and SITLA lands (Table 2). This AU also includes one BLM Areas of Critical Environmental Concern (ACECs) comprising 4,825 acres of this AU. ACECs confer conservation protections and management for other listed or sensitive species (BLM 2016).

Workshop experts characterized the habitat in the Sand Mountain AU as supporting sand dunes but also containing moderate levels of native herbaceous vegetation, shrubs, and burrows. A large portion of the AU is within the Sand Mountain Special Recreation Management Area and Sand Hollow State Park which are managed under Open area designations for OHV use. This recreational use is the primary stressor in this AU and has likely degraded the overall habitat conditions (Moderate Condition; Table 14). Suitable habitat acreage is also Moderate, though densities would need to be higher to support a viable population over several generations (Table 14).

Information on the *G. agassizii* population within the Sand Mountain AU is limited. Based on expert knowledge (USFWS 2019a), we estimated Poor Condition 3.4 *G. agassizii* per mi^2, or 216 adult *G. agassizii* in the AU (Table 3) which is also Poor Condition for abundance (Table 14). Recreation in the area likely influences survival and life stages (e.g., ravens and other impacts associated with human access) and we considered these in Poor Condition (Table 14).

We determined connectivity between Sand Mountain AU and adjacent or nearby AUs (inter-AU connectivity) is in Poor to Moderate Condition (Table 14). I-15 runs along the western border of the AU and urban development continues to expand from the northwest and west. Boundaries with four of the five adjacent or nearby AUs are in Critical to Poor Condition, though the most important boundary, Sand Mountain—Arizona AUs, is in Good Condition. Connectivity between Sand Mountain AU and adjacent or nearby AUs includes the following:

- ❖ The Sand Mountain—Arizona AU boundary appears relatively unimpeded per the habitat connectivity model (Gray *et al.* 2019) and most of the development along the Arizona Strip occurs west of Sand Mountain AU. We have very little information in this area and tentatively assume connectivity is in Good Condition.

- ❖ The Sand Mountain—Green Valley AU boundary exhibits high resistance to movement (I-15, airports, residential and commercial developments) and is in Poor Condition (Green Valley AU).

- ❖ Connectivity between Sand Mountain—Babylon AUs and Cinder Knolls AU areas is unlikely. These AUs are separated by three to seven miles of non-Federal lands. While habitat and connectivity seemingly remain, open spaces in these areas are dwindling rapidly and it intersected by high volume roads *G. agassizii* access to the Babylon AU is impeded by major roads and the Virgin River, and access to Cinder Knolls AU is impeded by major roads and urban development. Connectivity is extremely unlikely and is rated Critical to Poor Condition.

- ❖ The boundary between the Sand Mountain—Springdale AUs exhibits high resistance and is in Poor Condition. *Gopherus agassizii* would need to occupy continuously more than 15 miles of high elevations, cliffs, and State routes to the northeast.

We determined Sand Mountain intra-AU connectivity to be in Good Condition (Table 14). Large tracts of modelled potential habitat occur within the AU, though occupancy is not well known. *Gopherus agassizii* observations have occurred within 0.5 mile of Sand Hollow State Park and within the footprint of the Sand Hollow Water Pipeline, as well as a known cluster in the northwest of the AU. Protecting connectivity between known *G. agassizii* clusters in the northwest and habitat areas to the south could be valuable. This AU includes large areas of rocky, gravelly, and otherwise good habitat (C. Rognan, Washington County HCP Administrator, personal communication, May 5, 2020). There are many sand dunes in this AU, which are not ideal habitat but pose low resistance to movement. From a topographic and habitat perspective, connectivity looks Good Condition (Gray *et al*. 2019) (Table 14). However, a large portion of the AU is within the Sand Mountain Special Recreation Management Area and Sand Hollow State Park, which are managed under Open area designations for OHV use.

Overall, Sand Mountain AU habitat factors, including size, exhibit Moderate Condition (Table 14). Demographic factors are generally Poor with low density, and abundance and survival is likely further depressed by OHV recreation. Connectivity between AUs is poor, but may be Good Condition within the AU. Overall, resiliency in the Sand Mountain AU is in Moderate Condition (Table 14 and Figure 13).

Babylon AU

The Babylon AU is also known as Red Cliffs Desert Reserve, zone 4. Babylon AU is 5,489 acres, with 5,404 acres of modeled suitable habitat (Table 2). Suitable habitat in the AU is distributed across BLM, State, private, and SITLA lands (Table 2).

Habitat quality factors, including native herbaceous vegetation, shrubs, and burrows, are in Good Condition (Table 14). However, the overall size of the AU may not be large enough to support target abundances (Poor Condition). The Babylon AU experiences low levels of disturbance although some stressors do exist that can influence habitat factors. For example, there are presently two mining claims within the AU, although they have not been developed. Existing utility developments can be improved and small new utility development is allowed, if they follow specific guidelines designed to minimize impacts to *G. agassizii* (Washington County 2006). The Babylon AU is also used for motorized and non-motorized recreation. Housing developments are encroaching the south side of the Virgin River, and while not within the AU, recreational usage could be expected to increase.

The Babylon AU has two unpaved off-highway access roads from the north that parallel the main wash in the center of the AU (900 North, or Babylon Road, and an unnamed road). The two roads join about halfway through the Babylon AU area and continue south as one road to the southern border and Virgin River. Three short roads spur off of the two roads. Frontage Road (also known as Old Highway 91) also briefly enters this zone on the far northwestern edge.

Gopherus agassizii habitat within the Babylon AU was marginally impacted by the 2012 Quail Fire, which burned the northwestern section of the AU. Mapping from 2001 through 2011 indicates over half of this AU supports high abundance and density of non-native invasive *Bromus* spp. throughout the AU (USGS 2019). One of these persistent problem areas runs parallel to the main wash.

This AU has been the primary translocation zone for *G. agassizii* displaced by residential and commercial development on non-Federal lands in the UVR recovery unit for over two decades (McLuckie *et al.* 2019). The Babylon area was selected as an experimental translocation site in 1996. Its isolation and low resident *G. agassizii* occupancy decreased the risk of disease transmission to the other Red Cliffs Desert Reserve zones. The UDWR has translocated 475 *G. agassizii* into Red Cliffs Desert Reserve, zone 4 from 1999 to 2017, 304 of which were adults. Translocation efforts appear to be successful, with evidence of reproduction and growth of recaptured translocated individuals (McLuckie *et al.* 2019). However, data estimate an adult abundance of 285 *G. agassizii* which is in Poor Condition (95% CI: 160 to 507, McLuckie *et al.* 2018) (Table 14). This is the only AU where survival analyses have been conducted and results indicate a 90 percent annual survival rate (standard error 87 and 92 percent), which is Moderate Condition (McLuckie *et al.* 2019) (Table 14). Given a survival rate of 90 percent, an adult *G. agassizii* has a 7 percent probability of surviving to the next generation (25 years). We also note that most fatalities in Zone 4 were attributed to vehicular collisions along Babylon Road and disease. Studies in other AUs have not been conducted to determine if this is consistent with the natural survival rate or potentially a result of density dependence or translocations. However, the habitat factors in the Babylon AU area are all in Good Condition (Table 14) and densities have not reached densities in other similar habitats, thus density dependence is unlikely causing the decline. There may be a possible translocation effect or it is also possible that the local natural annual survival may be lower than elsewhere in the range. Regardless, this survival rate for a long-lived and slow-to-reproduce species suggests that, without intensive management or continued translocations, this sub-population may not be viable for the long-term.

The densities in the Babylon AU are in Moderate Condition (Table 14), but the UDWR suggests that the densities in this zone are still below carrying capacity based on the density of Red Cliffs Desert Reserve, the nearest monitored area (McLuckie *et al*. 2019). Translocations initially occurred directly adjacent to Babylon Road but release sites have expanded east and west over time and most *G. agassizii* are found in the southern (southcentral, southeast) and central areas (McLuckie *et al*. 2019). From the available data, sex ratios and life stage representation appear to be in Good Condition, while annual survival is in Moderate Condition (Table 14).

We determined connectivity between Babylon AU and adjacent or nearby AUs (inter-AU connectivity) is in Critical to Poor Condition (Table 14). Functional connectivity without human intervention is not likely between Babylon and the four closest AUs. Connectivity between Babylon AU and adjacent or nearby AUs includes the following:

- Connectivity between the Babylon—East Cottonwood AUs is impeded by I-15, fenced on the west side of the 6-lane highway with no *G. agassizii* passage across the road. Functional connectivity between AUs without human intervention is Critical to Poor.

- The Babylon—Cinder Knolls AUs are prevented from connectivity by the Virgin River. During drought years, reduced water flows are still high enough that even intrepid swimming *G. agassizii* are unlikely to cross (22 cubic ft per second; USGS 2020. Functional connectivity between AUs without human intervention is in Critical to Poor Condition.

- Connectivity between the Babylon—Springdale AUs could be possible along modelled habitat and provide dispersal avenues adjacent to the Virgin River. However, actual connectivity is highly improbable, requiring *G. agassizii* to occupy continuous and large areas adjacent to steep gorge walls, urban development areas, and agricultural areas. There have been a few sightings in this area (J. Stroud-Settles, Zion National Park Wildlife Program Manager, personal communication, March 24, 2020) but continuous occupancy and long-distance travel along this specific route is improbable.

- The Babylon—Sand Mountain AUs exhibit high resistance to genetic exchange. *Gopherus agassizii* access to the Babylon AU is impeded by major roads and the Virgin River resulting in a connectivity condition of Critical to Poor (Sand Mountain AU).

We determined Babylon intra-AU connectivity is currently in Moderate to Good Condition (Table 14). There appear to be three main *G. agassizii* clusters (Central-road, South-road, and Southeast-central) in the Babylon AU, all within one home range of another cluster. While an unpaved road bisects the center of the Babylon AU, it is not fenced. This road may act as a population sink, but it does not impede genetic exchange. There is another *G. agassizii* cluster south of the Virgin River that is likely cutoff from the Babylon and Cinder Knolls AUs, excepting perhaps the most intrepid individuals that may cross the river. Habitat may be limiting in the west. The least resistance to connectivity is in the center of the AU in a narrow strip along the wash.

Overall, habitat factors in Babylon are in Good Condition, though space is limiting (Table 14). Demographic factors are in Moderate Condition, with Poor abundance and Moderate survival. Connectivity with other AUs was intentionally designed to be non-existent, but genetic exchange and movement potential within the AU appear Good. Despite some promising attributes and generally successful translocations, the small size, low abundance, and lack of inter-AU connectivity result in an overall Moderate Condition for Babylon AU resiliency (Table 14 and Figure 13). Given the documented survival rate in Babylon AU, it unlikely that *G. agassizii* will be able to survive long-term without connectivity, continued translocations, or head-starting.

Cinder Knolls AU

The Cinder Knolls AU contains the easternmost section of Red Cliffs Desert Reserve also known as zone 5 (Figure 5). The Cinder Knolls AU is 741 acres, with 429 acres of modelled suitable habitat (Table 2). The AU is mostly managed by the BLM.

Impacts to habitat quality from disturbance within Cinder Knolls AU are low to moderate. There are no mining claims in Cinder Knolls and no Federal grazing allotments. However, hiking, mountain biking, and equestrian use is allowed and recreation has increased since the area was protected. Braided redundant illegal trails are a concern along with dogs off leash (A. McLuckie, UDWR, personal communication, July 9, 2020). There is only one primitive dirt road that is unfenced but gated and not open to the public. Housing developments are encroaching three sides of the Cinder Knolls AU and recreation is likely to increase in the future. Existing utility developments can be improved and small new utility developments are allowed if they follow specific guidelines designed to minimize impacts to *G. agassizii* (Washington County 2006).

There are no records of wildfires in the BLM database within the Cinder Knolls AU (Figure 11). Occupancy mapping from 2001 through 2011 indicate nearly the entire zone (> 90 percent) may support high abundance and density of *Bromus* spp. grasses in problem areas, and over half the AU continued to exhibit persistent invaded areas in drier years (USGS 2019).

Our assessments of current conditions were made by *G. agassizii* experts that had familiarity with the populations in this region (USFWS 2019a), and were also based on current monitoring data (McLuckie *et al*. 2018). Despite the presence of *Bromus* spp., habitat quality factors, including native herbaceous vegetation, shrub cover, and burrow availability were assessed as still being in Good Condition (Table 14). *Gopherus agassizii* densities in the Cinder Knolls AU are among the highest in the Red Cliffs Desert Reserve (Good Condition), but being the smallest zone, it supports low abundances (an estimated 99 adult *G. agassizii*; McLuckie *et al*. 2018; abundance = Critical to Poor Condition). Given the small size of this sub-population, the long-term viability of this AU is questionable (i.e., the area's size is in Critical to Poor Condition).

The Cinder Knolls population shows the highest prevalence of clinical signs of URTD within Red Cliffs Desert Reserve (44 percent), which may be a result of high *Bromus* spp. occupancy and high *G. agassizii* densities which may increase stress levels. Evidence of raven predation on juvenile tortoises has also been documented in the Cinder Knolls AU, especially on the East Cinder Knoll, though the data is not sufficient to draw conclusions about sub-population level impacts (McLuckie *et al*. 2018). Based on good habitat quality, but high disease prevalence, and increasing raven predation, survival is in Moderate Condition (Table 14). The Cinder Knolls AU *G. agassizii* sex ratio is in Good Condition.

Cinder Knolls is isolated from the rest of Red Cliffs by the Virgin River to the north and urban development to the south, west, and east. Although *G. agassizii* can swim, it is highly improbable individuals are crossing the Virgin River–at the lowest flow, the Virgin River flows at 22 cubic ft per second (USGS 2020).

We determined connectivity between Cinder Knolls AU and adjacent or nearby AUs (inter-AU connectivity) is in Critical to Poor Condition (Table 14). Functional connectivity without human intervention is not likely between Cinder Knolls and the three closest AUs. Connectivity between Cinder Knolls AU and adjacent or nearby AUs includes the following:

- ❖ Connectivity between the Cinder Knolls—Babylon AUs is impeded by the Virgin River (Babylon AU). Functional connectivity without human intervention is in Critical to Poor Condition.

- ❖ Connectivity between the Cinder Knolls—Sand Mountain AUs is unlikely (Critical to Poor) due to residential and commercial development and major roads (Sand Mountain AU).

- ❖ Connectivity between the Cinder Knolls—Springdale AUs is limited to the east topographically. If area *G. agassizii* could somehow occupy or bypass over a mile of urban development through a narrow patch of habitat on the Virgin River (under a road south of Confluence Park South Entrance in La Verkin, up steep cliffs), they would then need to occupy continuously an additional 10 to 15 miles east to connect with the Springdale population. While there are several primitive roads and trails that *G. agassizii* could traverse, this scenario seems highly improbable given the few sightings in these areas and results in Critical to Poor connectivity.

We determined connectivity within the Cinder Knolls AU (intra-AU connectivity) is in Good Condition (Table 14). *Gopherus agassizii* clusters are difficult to discern due to relatively uniform distribution across this AU. However, there does appear to be a concentration of individuals in the center on East Cinder Knoll. This area is crossed by one primitive dirt road and, while the road is not fenced, it is also not open to the public and is gated. It is used as a trail, but because it is gated and rarely used it is unlikely to act as a typical road population sink or impede connectivity within the Cinder Knolls AU.

Overall, habitat factors in Cinder Knolls AU are Good, though space is limiting (Table 14). Demographic factors are good, however abundance is in critical condition and disease prevalence suggests Moderate Condition for survival. Connectivity with other AUs is non-existent though genetic exchange and movement potential within the AU appears in Good Condition. Despite some promising attributes, the small size, low abundance, and lack of inter-AU connectivity result in an overall Moderate Condition for Cinder Knolls AU resiliency (Table 14 and Figure 13). Intensive management will need to continue to preserve this AU.

Springdale AU

The Springdale AU occurs in the northeast extent of the UVR recovery unit and is also the most northeast known *G. agassizii* cluster in the species' range (Figure 3 and Figure 5). The area may include approximately 727 to 920 acres (J. Stroud-Settles, Zion National Park Wildlife Program Manager, personal communication, March 14, 2019; USFWS 2019a), 280 of which are modelled suitable habitat (Table 2). More than half of the modelled habitat is privately owned (113 acres) and in an incidental take area, but the National Park Service also manages a large portion of the modelled habitat (176 acres; Table 2). Adjacent *G. agassizii* habitat within Zion National Park is not fenced and includes a trail where dogs off leash have been a concern (A. McLuckie, UDWR, personal communication, July 9, 2020). In the early 2000s, UDWR estimated 1.7 *G. agassizii* per acre (0.44 to 6.3; McLuckie *et al.* 2000). Zion National Park monitoring data included a very small sub-population of 36 adult *G. agassizii* occurring in the foothills adjacent to the town of Springdale. It is unknown if this sub-population is the result of natural dispersal or human movement (Zion National Park 2019). Monitoring occurred from 1994 to 2017 when radio transmitters were removed from *G. agassizii*. Monitoring efforts documented breeding, including egg shell fragments and six hatchlings.

The habitat in the Springdale AU is characterized by a juniper-dominated vegetation community primarily within the Mathis-rock outcrop complex, which is unusual for *G. agassizii* to occupy. The majority of deep burrows are constructed under large sandstone boulders (McLuckie *et al.* 2000, Zion National Park 2019). Habitat quality appears resilient with low non-native herbaceous presence; however, presence of *Bromus* spp. grasses overlaps most observation points in heavy infestation years. Two small wildfires in the BLM data base have occurred within two miles of the main *G. agassizii* cluster, with larger wildfires occurring approximately four miles or more away. Native herbaceous vegetation and shrub condition are currently Good, while burrow availability is in Moderate Condition (Table 14).

The Springdale AU is exceptionally small (Critical Condition) and *G. agassizii* occur in low densities (Poor Condition), but over time this area could represent important genetic and behavioral differences for the recovery unit as a whole (Table 14). However, it is unlikely a cluster of *G. agassizii* can thrive long-term in this unique range-edge habitat given that the suitable habitat area may be too small to support viable abundances (Critical Condition) *G. agassizii* in this area encounter marginal habitat conditions and face unique physiological challenges (colder temperatures, shorter activity season) that may further limit survival, growth, and reproduction. We presently lack survival data for the Springdale AU, but expect it to be in Moderate Condition based on the habitat conditions (Table 14). *Gopherus agassizii* persistence in this unique habitat further supports the species capability to occupy a variety of habitats, and as such, this AU may contribute to the representation value for the UVR recovery unit and the species rangewide.

We determined connectivity between the Springdale AU and adjacent or nearby AUs (inter-AU connectivity) is in Critical to Poor Condition (Table 14). Functional connectivity without human intervention is not likely between the Springdale AU and the three closest AUs (Cinder Knolls, Babylon, and Sand Mountain). Connectivity between Springdale AU and adjacent or nearby AUs includes the following:

- ❖ Connectivity between *G. agassizii* in the Springdale—West AUs (Cinder Knolls, Babylon, and Sand Mountain) is extremely unlikely. All connectivity options involve great distances and significant topographical barriers. Functional connectivity without human intervention is not likely between the Springdale AU and the three closest AUs (Critical to Poor Condition).

We determined connectivity within the Springdale AU (intra-AU connectivity) is in Moderate Condition (Table 14). All *G. agassizii* observations are in one small pocket of identified habitat. Individual observations are all within one home range of each other (Moderate to Good Condition). However, it is unclear how much movement and connectivity can occur further out from this small area. In addition, there are two observations disjunct from this main cluster that are likely escaped captives. These observations are across the Virgin River, a road, and more than two miles southwest (> six home ranges). While *G. agassizii* do occasionally travel farther than this, the few observations and anthropogenic and topographical barriers suggest the habitat is not continuously occupied (Poor Condition).

Overall, habitat factors in Springdale AU are Good, though space is limiting (Table 14). Demographic factors are a mix of conditions, abundance and density is in Poor and Critical condition, respectively. Connectivity with other AUs is extremely unlikely though genetic exchange and movement potential within the AU appears Moderate. The extremely small size and abundance, and lack of inter-AU connectivity result in an overall Poor Condition for Springdale AU resiliency (Table 14 and Figure 13). Intensive management will need to continue to preserve this AU.

APPENDIX 4. Estimating Resiliency Contribution from each Analytical Unit

The condition of the entire UVR recovery unit is not equally divided among the AUs. For example, the Springdale AU is a very small and highly isolated sub-population and the West Cottonwood AU supports the highest abundance of *G. agassizii* and centrally located (USFWS 2020). The contribution of an area to the UVR recovery unit overall resiliency is important to understand the stressors that contribute to the current condition. In addition, we can scale these resiliency values to each other to help understand the relative effectiveness of conservation actions in each AU (e.g., habitat restoration in Springdale compared to West Cottonwood).

In this report, we characterized the past condition of the 11 AUs with the oldest population data estimates available that use the same methods as today (i.e., line distance sampling) and our knowledge of connectivity between AUs at that time. These past data (20 years) represent conditions closer to the time when stressors (e.g., urbanization, invasive species, wildfires) were just starting to accelerate. In evaluating past conditions we considered available data and what we could reasonably include from the habitat and demographic condition categories described in Resiliency: Condition Categories. We described habitat quantity using the same modelled suitable habitat acreage for current conditions. This 2009 model used observational data over time and should be similar in 1999 (10 years prior to the model) compared to today (11 years after the model). We did not try to describe or compare past habitat quality because we do not have habitat quality data; however we note that stressors have likely worsened conditions, especially in areas without active management, over time. Likewise, for demographic condition factors, we estimate abundance and density in each area using data from 1999 survey reports, but we do not try to quantitatively describe or compare past survival, life stages, or sex ratios. Finally, we describe connectivity based on our understanding of anthropogenic barriers in 1999.

The metrics we used include the following: *G. agassizii* abundance (number of adult *G. agassizii* calculated from 1999 density or abundance estimates in each AU), percent of the recovery unit population (AU 1999 abundance divided by total 1999 abundance in the recovery unit), percent of the protected population as of 1999, historic connectivity, uncertainty multiplier for areas with limited surveys, and indexing and scaling values. Because we lack historic data for the Zone 6 area, we applied the 1999 Zone 3 density to the Zone 6 area. We describe each of these metrics in more detail below.

Adult G. agassizii abundance

Given the importance of abundance to the demographic needs of *G. agassizii*, we determined the potential historical abundance capacity in each AU (Table 4-1, column B). The UDWR started using their current monitoring protocol in the Red Cliffs Desert Reserve in 1999, with an estimated 74.6 (54.9 to 101.5) *G. agassizii* per square mile (mi^2) in Zones 2, 3, and 5 and 80.0 (55.9 to 114.0) *G. agassizii* per mi^2 in just Zone 3. West Cottonwood AU is approximately three times denser than East Cottonwood, so we applied a 3 to 1 split between the Zone 3 data. For the Snow Canyon AU and Cinder Knolls AU, where we modelled potential connectivity and habitat acquisition conservation measures, we applied the abundance estimate from McLuckie *et al*. 1999 from Zone 2 and estimated Zone 1 using the additive Zone 2, 3, and 5 density, 74.6. For areas in this analysis outside Red Cliffs Desert Reserve with no formal line distance surveys, we used the 2017 estimate from the closest adjacent area surveyed with the same methods, the Beaver Dam Slope (3.4 per mi^2. [1.0 to 10.6] adult *G. agassizii* per mi^2; USFWS 2018a) and back-calculated to 1999 using the -3.2% annual trend from the UVR recovery unit (Allison and McLuckie 2018). This produced an estimated 1999 density of 6.03 adult *G. agassizii* per mi^2. We note that lack of formal surveys result in high uncertainty about this estimate. In 1999, total abundance in protected areas within the Red Cliffs Desert Reserve may have been 3,481, and the total UVR recovery unit, with the Arizona AU, may have supported 7,043 *G. agassizii*.

In column C through F (Table 4-1) we determined the percentage of the total 1999 recovery unit population within each AU to determine their relative contribution to resiliency of the 1999 recovery unit population. We rescaled each AU's abundance value to range between 0 and 10 (by dividing the percentage by 10). This rescaling preserved the relative abundance among AUs while providing a similar range of values for comparison with connectivity scores. *Gopherus agassizii* within the Red Cliffs Desert Reserve are a key component of the 1995 Washington County Habitat Conservation Plan strategy, allowing the incidental take of *G. agassizii* in known areas outside the Red Cliffs Desert Reserve (USFWS 1996). Thus, the UVR recovery unit conservation strategy specifically identified conservation measures and high-precision monitoring for implementation within the Red Cliffs Desert Reserve, where *G. agassizii* were known to inhabit (Washington County 1995). Because of the known occupancy and extra layer of protection, conservation, and monitoring, all of which increase the contribution to resiliency, we also calculated the percentage of the total protected 1999 population in each AU. If future projects protected known occupied areas and abundance estimates from line distance sampling are available (e.g., the proposed Zone 6 in the amended HCP; USFWS 2020), this report can easily be updated. However, under current conditions, the proposed Zone 6 area is not managed for *G. agassizii* and the area is heavily impacted, lowering the area's ability to contribute to resiliency of the UVR recovery unit.

Connectivity

Populations of *G. agassizii* across the range of the species were historically broadly interconnected, which allowed demographic exchange of individuals and gene flow (Hagerty *et al*. 2011). Thus, in column G (Table 4-1), we evaluated how the AUs may have connected and supported the UVR recovery unit population in the past. As most *G. agassizii* fencing was installed in the late 1990s and early 2000s, it is reasonable within this analysis to assume there was little to no fencing on roads and higher *G. agassizii* injury and mortality rates on these roads. Red Cliffs Desert Reserve, zone 3 is the core area of the Red Cliffs Desert Reserve (McLuckie *et al.* 2018) and in 1999 supported 80 percent of the protected population and at least 45 percent of the estimated UVR recovery unit population (Table 4-1). Thus, we assigned 2 points to AUs adjacent to West Cottonwood AU or East Cottonwood AU (collectively Zone 3). We assigned 1 point to each additional adjacent AU and 1 point if the AU could connect with the NEM recovery unit.

Uncertainty

Knowing the distribution and connectivity of *G. agassizii* increases our ability to protect and conserve the demographic and habitat factors necessary for the species' recovery. Because line distance sampling has only occurred in the Red Cliffs Desert Reserve, certainty of abundance estimates is relatively high in these AUs and relatively low in the other AUs, where monitoring surveys are not conducted.

To address this uncertainty, we first added the abundance in each AU sub-population to the AU connectivity scores to determine a preliminary score of the value of the AU sub-population to the recovery unit (Table 4-1, column H). This preliminary score was then adjusted by an uncertainty multiplier (Table 4-1, column I). In the unsurveyed areas, we applied a surrogate estimate (from Beaver Dam Slope) that also has a lower level of precision than the surveys from the Red Cliffs Desert Reserve. For example, the coefficient of variation[1], a measure of precision, in the 2017 Beaver Dam Slope estimate was four times higher (less precise) than the coefficient of variation in the Red Cliffs Desert Reserve (65.64 and 15.77, respectively). Exceptions to uncertainty outside Red Cliffs Desert Reserve are Springdale, which has been monitored closely in the past by Zion National Park (J. Stroud-Settles, Zion National Park Wildlife Program Manager, personal communication, March 14, 2019), and the proposed Zone 6 area, which has had a one-time survey on 5,150 acres (Rognan *et al*. 2017). In addition, many of the AUs' habitat conditions are less well understood than those within the Red Cliffs Desert Reserve where extensive monitoring and recreation occur. Overall, we have the greatest uncertainty in the remote Far West AU and Arizona AU. The multipliers were 1 for low uncertainty (higher precision), 0.75 for moderate uncertainty, and 0.5 for high uncertainty (lower precision). Final value (column 10) is the preliminary value multiplied by uncertainty.

Final Steps and Model Robustness

These final scores were normalized to 100 percent, which provides an index of the resiliency value of the area to the recovery unit. We also scaled all areas to West Cottonwood as the most effective area (based on abundance and proximity to other known abundant AUs) where conservation can occur to benefit the UVR recovery unit (based on the previous columns in Table 4-1. This relative effectiveness of different habitat areas allows managers to identify the benefit from conservation projects (e.g., habitat restoration) to preserving or recovering the resiliency value of an area to the UVR recovery unit.

This model appears relatively robust at each layer of human decision points in the analysis; for example, if we only apply the estimated 1999 recovery unit abundance without consideration of connectivity or other variables in the table, the contribution of each area to the recovery unit remains similar to the final contribution determination. The only exceptions to this are the Arizona AU and the Unassigned areas that decrease in contribution with increasing uncertainty.

1 The Coefficient of variation, or CV, is also known as the relative standard deviation, which allows for the comparison of variance (spread) between two different estimates.

Table 4- 1. Potential Resiliency Contribution from each AU to the UVR recovery unit as a whole and Relative Effectiveness compared to West Cottonwood AU.

A	B	C	D	E	F	G	H	I		K	L
Analytical Unit Name	***G. agassizii*** **estimated 1999 abundance** based on suitable habitat model (Nussear *et al.* 2009)	**Percent of recovery unit population x 10 = relative abundance**	**Percent of protected population x 10 = relative abundance**	**Connectivity** + 2 points: adjacent to West or East Cottonwood AU + 1 point each adjacent AU + 1 point if adjacent to Northeastern Mojave recovery unit	**Preliminary value** to 1999 UVR recovery unit resilience index Columns C + D + E	**Uncertainty** high = 0.5 medium = 0.75 low = 1	**Final value** to 1999 UVR recovery unit resilience index Columns F x G	**Normalized Resiliency Contribution to UVR**		**Relative Effectiveness of Conservation Actions to UVR (Scaled to West Cottonwood)**	
								without uncertainty Preliminary value (Column F ÷ Total Column F)	with uncertainty Final value (Column H ÷ Total Column H)	without uncertainty	with uncertainty
Far West	428	0.6	-	0 + 3 + 1 = 4	4.6	0.5	2.3	9.8%	5.8%	37.2%	18.6%
Arizona	819	1.2	-	0 + 3 + 1 = 4	5.2	0.5	2.6	11.0%	6.5%	41.7%	20.8%
Green Valley	886	1.3	-	0 + 2 + 0 = 2	3.3	0.75	2.5	7.0%	6.1%	26.4%	19.8%
Snow Canyon (Zones 1 and 2)	77	0.1	1.7	2 + 1 + 0 = 3	4.8	1	4.8	10.3%	12.1%	39.0%	39.0%
Urban Interface	229	0.3	-	2 + 0 + 0 = 2	2.3	0.75	1.7	5.0%	4.4%	18.7%	14.1%
West Cottonwood (Zone 3)	2,356	3.4	6.0	2 + 1 + 0 = 3	12.4	1	12.4	26.4%	31.0%	100.0%	100.0%
East Cottonwood (Zone 3)	785	1.1	2.0	2 + 2 + 0 = 4	7.1	1	7.1	15.2%	17.8%	57.5%	57.5%
Sand Mountain	388	0.6	-	0 + 1 + 0 = 1	1.6	0.75	1.2	3.3%	2.9%	12.6%	9.4%
Babylon (Zone 4)	52	0.1	-	2 + 1 + 0 = 3	3.1	1	3.1	6.6%	7.8%	25.1%	25.1%
Cinder Knolls (Zone 5)	107	0.2	0.2	0 + 1 + 0 = 1	1.3	1	1.3	2.8%	3.3%	10.7%	10.7%
Springdale	16	0.0	-	0 + 0 + 0 = 0	0.0	1	0.0	0.0%	0.0%	0.1%	0.1%
Unassigned areas	806	1.2	-	NA	1.2	0.75	0.9	2.5%	2.2%	9.3%	7.0%
Total 1999 UVR recovery unit	6,949	-	-	-	-	-	-	-	-	-	-

Table 4- 2. Resiliency contribution and relative effectiveness of conservation actions in each AU (west to east) to improve the resiliency of the UVR recovery unit.

Analytical Unit Name	**Red Cliffs Desert Reserve Zone**	**Normalized Resiliency Contribution to the UVR recovery unit**		**Relative Effectiveness of Conservation Actions for the UVR recovery unit**	
		Without uncertainty	With uncertainty	Without uncertainty	With uncertainty
Far West	-	10%	6%	37%	19%
Arizona	-	11%	7%	42%	21%
Green Valley	-	7%	6%	26%	20%
Snow Canyon	Zones 1 and 2	10%	12%	39%	39%
Urban Interface (Three subunits)	-	5%	4%	19%	14%
West Cottonwood	Zone 3	26%	31%	100%	100%
East Cottonwood	Zone 3	15%	18%	57%	57%
Sand Mountain	-	3%	3%	13%	9%
Babylon	Zone 4	7%	8%	25%	25%
Cinder Knolls	Zone 5	3%	3%	11%	11%
Springdale	-	0%	0%	0%	0%
Unassigned Areas	-	2%	2%	9%	7%
Total UVR recovery unit	-	100%	100%	Scaled to West Cottonwood	Scaled to West Cottonwood

Table 4- 3. Resiliency contribution (Table 4-2) and current resiliency condition score (Table 13) for each AU sub-population (listed west to east) of the UVR recovery unit.

Analytical Unit Name	**Red Cliffs Desert Reserve Zone**	**Resiliency Contribution to the UVR recovery unit**		**Current Condition**
		Without uncertainty	With uncertainty	
Far West	-	10%	6%	Poor
Arizona	-	11%	7%	Moderate
Green Valley	-	7%	6%	Good
Snow Canyon	Zone 1 and 2	10%	12%	Moderate
Urban Interface (Three subunits)	-	5%	4%	Poor
West Cottonwood	Zone 3	26%	31%	Moderate
East Cottonwood	Zone 3	15%	18%	Moderate
Sand Mountain	-	3%	3%	Moderate
Babylon	Zone 4	7%	8%	Moderate
Cinder Knolls	Zone 5	3%	3%	Moderate
Springdale	-	0%	0%	Poor
Unassigned Areas	-	2%	2%	NA
Total UVR recovery unit	-	-	-	**Moderate**

APPENDIX 5. Climate and Environmental Projections

The downscaled climate projections analyzed for this area were selected from the Multivariate Adaptive Constructed Analogs (MACA) Datasets developed by the University of Idaho. Their online tool displays a scatter plot of 33 global climate simulation downscaled to 2.5 miles. We selected the four climate models that represent the range of possible future temperature and precipitation projections. This resulted in using one model with moderate emissions (Representative Concentration Pathways (RCP) 4.5 (INMCM4.rcp45), and three from high emission models, RCP 8.5 (GFDL-ESM2M.rcp85, MIROC5.rcp85, and MIROC-ESM-CHEM.rcp85).

Climate Projections

Future climate precipitation and temperature projections were analyzed on a seasonal basis through 2069, downscaling the climate data using historical climate observation data (1971 to 2000), and matching that data with future projections by 2050 (2040 to 2069) from 33 different climate models. Climate projections are identified as changes relative to the historical average. The location we used is near St. George, Utah: 36.9 to 37.2 N, 113 to 114 W (Rangwala 2020). The timeframe through 2069 was chosen due to the difficulties that occur when you attempt to extrapolate beyond 50 years.

Climate Projection Results

Climate analysis results show that seasonal increases in mean temperature for all seasons will occur in Washington County under all emission scenarios through 2069 (Table 5-1). The difference in mean annual temperature from the four models is +5.3°F, increasing future annual temperatures from a historic average of 61°F to a future average of 66.3°F (range 63 to 70°F). Summer temperatures are projected to increase the most relative to the other seasons under all models, with an average increase of 6°F, increasing average summer temperatures from 81 to 87°F (range 84° to 91°F). Temperatures are projected to increase the least amount under moderate emissions. Daytime maximum temperatures may average 83°F in spring and fall and average 106°F in summer; 123°F is the highest projected future temperature (Table 5-1). Number of days above 100°F may increase from a historic average of 5 days to a future average of 32 days (range 11 to 46 days; Table 5-1) and number of days above 105°F may increase from a historic average of 0 days to a future average of 10 days (range 3 to 17 days). Overall, temperatures are projected in all models to be hotter for more days in all seasons.

Table 5- 1. Summary of future climate projections, slow and rapid change, by averaging upper and lower projections from four climate models. These four models cover the range of projected futures.

Variable	Season	Historic data (average from 1971 to 2000)	Slow climate change Climate projections #1 and #2[2]	Rapid climate change Climate projections #3 and #4
Mean Temperature	Spring	59°F	+1°F to +4°F	+5°F to +9°F
	Summer	81°F	+3°F to +5°F	+6°F to +10°F
	Fall	62°F	+2°F to +5°F	+6°F to +8°F
Daytime Maximum Temperature	Spring	73°F	+2°F to 4°F	+7°F to 10°F
	Summer	95°F	+3°F to 6°F	+6°F to 11°F
	Fall	75°F	+2°F to 5°F	+7°F to 8°F
Hottest summer day	Summer	105°F	108°F to 110°F	112°F to 123°F
Number of days (average) > 100°F	Summer	5 days	16 days to 33 days	34 days to 46 days
Number of days (average) > 105°F	Summer	0 days	3 days to 8 days	10 days to 17 days
Precipitation	Spring	3.0 inches	-5% to 15%	-25% to -5%
	Summer	2.0 inches	+10% to +20%	+10% to +25%
	Fall	3.0 inches	+10% to +0%	-15% to +20%
	Winter	4.0 inches	+20% to 0%	-10% to +25%
	Annual	12.0 inches	+10% to +10%	-10% to 0%
Soil Moisture	Spring	7.5 inches	0% (average all four models)	-10% to +10%
	Summer	6.3 inches	0% (average all four models)	-5% to +5%
	Fall	6.6 inches	0% (average all four models)	-10% to +10%
Severe drought similar to 2002 (frequency)	Annual	NA	Every 15 years to Every 30 years	Every 2 years to Every 0.8 years
High fire danger days	Annual	73 days	73 days to 92 days	106 days to 114 days

Projected changes in winter and spring precipitation vary widely from a maximum decrease of 25 percent in the spring to a maximum increase of 20 percent in the winter (Table 18). Summer precipitation is expected to increase in all models and fall and annual precipitation is expected to

2 The slow climate change column summarizes the first two projections, INMCM4.rcp45 (moderate emission scenario) and GFDL.ESM2M.rcp85 (high emission with lower predicted changes). The rapid climate change column summarizes the third and fourth projection, MIROC5.rcp85 and MIROC-ESM-CHEM.rcp85 (high emission scenarios with higher predicted changes). The first two projections consistently result in the lowest changes in temperatures as well as generally increased precipitation. The third and fourth projections (last column) included the largest changes in temperatures and, while precipitation was more variable, included more decreases in precipitation.

increase in all but one model. While summer and fall evapotranspiration increase in all models (3 to 11 percent), soil moisture has a mean change of zero so the increase in precipitation may in some models be cancelled out by evapotranspiration rates (Table 18).

Overall, precipitation is difficult to project and variable and increases are expected to be balanced by hotter temperatures while dry periods are expected to be even drier due to increased temperatures and evapotranspiration.

The summary table below describes changes in the future climate by 2050 (2040-2069) relative to the 1971-2000 period under four climate scenarios: **#1**=INMCM4.rcp45, **#2**=GFDL-ESM2M.rcp85, **#3**=MIROC5.rcp85, and **#4**=MIROC-ESM-CHEM.rcp85.

*Table 5- 2. Climate Scenarios by 2050 for 12 listed species in Southwestern Utah [1 reptile (*G. agassizii*), 5 listed plants (dwarf bear-poppy, Holmgren milkvetch, Shivwits milkvetch, Siler pincushion cactus, Gierisch mallow), 2 listed fish (Virgin River chub, woundfin), 4 listed birds (Western yellow-billed cuckoo, southwestern willow flycatcher, Mexican spotted owl, California condor—experimental and endangered range)].*

Climate Metric	Season	Scenario #1	Scenario #2	Scenario #3	Scenario #4	*Historical Value*
Mean Temperature (ºF)	Annual	2	4	6	9	*61 ºF*
	Winter	2	4	5	8	*42 ºF*
	Spring	1	4	5	9	*59 ºF*
	Summer	3	5	6	10	*81 ºF*
	Fall	2	5	6	8	*62 ºF*
Precipitation (%)	Annual	10	10	-10	0	*12 inches*
	Winter	20	0	-10	-25	*4 inches*
	Spring	-5	15	-25	-5	*3 inches*
	Summer	10	20	10	25	*2 inches*
	Fall	10	0	-15	20	*3 inches*
Daytime Maximum Temperature (ºF)	Annual	2	5	7	10	*74 ºF*
	Winter	2	4	7	9	*53 ºF*
	Spring	2	4	7	10	*73 ºF*
	Summer	3	6	6	11	*95 ºF*
	Fall	2	5	7	8	*75 ºF*
Daytime Minimum Temperature (ºF)	Annual	2	4	5	8	*48 ºF*
	Winter	3	3	4	8	*31 ºF*
	Spring	1	3	5	8	*46 ºF*
	Summer	4	4	6	9	*66 ºF*
	Fall	2	4	5	7	*48 ºF*
Potential Evapotranspiration (%)	Summer	3	6	9	11	*28.5 inches*
	Fall	4	8	10	9	*14.5 inches*
Hottest Summer Day (ºF) (warmer relative to historical by ºF)		108 (3)	110 (5)	112 (7)	123 (18)	*105 ºF*
Days with Heat Index ≥ 90°F (higher relative to historical by #days)		86 (21)	107 (42)	109 (44)	117 (52)	*65 days*
Days with Heat Index ≥ 100°F (higher relative to historical by #days)		16 (11)	33 (28)	34 (29)	46 (41)	*5 days*
Days with Heat Index ≥ 105°F (higher relative to historical by #days)		3 (3)	8 (8)	10 (10)	17 (17)	*0 days*
Frequency of Severe Drought like 2002		Every 15 years	Every 30 years	Every other year	4 in every 5 years	-
"High" Fire Danger Days (higher relative to historical by #days)		92 (19)	73 (0)	106 (33)	114 (41)	*73 days*
Snow Water Equivalent (%)	February 1**	-70 to -95 (mean change = -85)				*0.07 inches*
Total Runoff* (%)	Spring	-30 to +15 (mean change = -10)				*0.13 inches*
	Summer	-15 to +25 (mean change = +5)				*0.06 inches*
	Fall	-15 to +20 (mean change = +5)				*0.11 inches*
Soil Moisture* (%)	Spring	-10 to +10 (mean change = 0)				*7.5 inches*
	Summer	-5 to +5 (mean change = 0)				*6.3 inches*
	Fall	-10 to +10 (mean change = 0)				*6.6 inches*

Quantities and projected changes described above are for the region bounded by **36.9-37.2ºN; 113-114ºW**. Winter is Dec, Jan, Feb; Spring is Mar, Apr, May; Summer is Jun, Jul, Aug and Fall is Sep, Oct, Nov. Dataset: MACA metdata v2 (4-km downscaled climate projections), VIC (v4.1.2) forced by MACAv2 LIVNEH (6-km hydrology projections) and gridMET (4-km historical). * Hydrology projections data is not available for many of the selected GCMs, therefore a whole range of response from 10 GCMs x 2RCPs (total 20 projections) are shown. **Region has the highest snowpack by end of January.

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