National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Tonto National Monument

Natural Resource Condition Assessment

Natural Resource Report NPS/SODN/NRR—2019/2012

ON THE COVER

A view of cliff dwellings at Tonto National Monument with cloudy sky in background and vegetation in foreground, including saguaro cacti. Photo Credit: NPS.

Tonto National Monument

Natural Resource Condition Assessment

Natural Resource Report NPS/SODN/NRR—2019/2012

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Executive Summary

The Natural Resource Condition Assessment (NRCA) Program, administered by the National Park Service's (NPS) Water Resources Division, provides a multidisciplinary synthesis of existing scientific data and knowledge about current conditions of important national park natural resources through the development of a park-specific report. The NRCA process for Tonto National Monument (NM) began with a December 2017 conference call and an on-site scoping meeting held in May 2018.

Nine of the monument's natural resources, grouped into four broad categories, were selected for condition assessment reporting. The categories included landscapes, air and climate, water, and biological integrity, (i.e., wildlife and vegetation resources).

With the exception of the air quality condition, which is considered to be of significant concern, the majority of the monument's resources are found to be in good condition. Some unknown conditions exist, especially pertaining to the wildlife topics due to the lack of repeat, comparable surveys. Aspects of the upland vegetation/soils, Cave Canyon riparian area, and night sky warrant moderate concern. The conditions reported represent 'a snapshot in time' based on the best available data. Unfortunately, as of June 2019, a major wildfire, the Woodbury Fire, has burned 50,111 ha (123,827-ac) throughout Tonto National Forest, which includes Tonto NM. While the full effects of the fire's impact to the monument's and surrounding region's resources are currently unknown, the fire has undoubtedly created natural resource conditions that are vastly different from those delivered in this report.

Acknowledgements

We thank Tonto National Monument's Brett Cockrell, Chief of Resources, and Stephanie Mack, Archaeological Technician, for providing data, reports, and reviews. We also are indebted to the National Park Service Sonoran Desert Inventory and Monitoring Network (SODN) staff, Andy Hubbard, Kristen Bonebrake, Sarah Studd, and Evan Gwilliam for their assistance in gathering data; establishing indicators, measures, and reference conditions; and for reviewing drafts of the assessments and chapters. For some of the resources evaluated, an initial condition assessment draft was provided.

SODN's inventory and monitoring data informed current conditions for several of the park's natural resource topics. Kara Raymond, hydrologist with the NPS Southern Arizona Office, provided expert reviews and information for most assessment topics.

Phyllis Pineda Bovin, NPS Intermountain Region Office NRCA Coordinator, assisted with overall project facilitation and served as subject matter expert review manager. Jeff Albright, NPS NRCA Program Coordinator, provided programmatic guidance.

And finally, to all of the additional reviewers and contributors, who are listed in Appendix A, we thank you. Your contributions have increased the value of Tonto National Monument's report.

Upper Cliff Dwelling at Tonto National Monument. Photo Credit: NPS.

NRCA Background Information

Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and resource indicators in national park units, hereafter "parks." NRCAs also report on trends in resource condition (when possible), identify critical data gaps, and characterize a general level of confidence for study findings. The resources and indicators emphasized in a given project depend on the park's resource setting, status of resource stewardship planning and science in identifying high-priority indicators, and availability of data and expertise to assess current conditions for a variety of potential study resources and indicators.

NRCAs represent a relatively new approach to assessing and reporting on park resource conditions. They are meant to complement, not replace, traditional issue- and threat-based resource assessments. As distinguishing characteristics, all NRCAs

- Are multi-disciplinary in scope; [1]
- Employ hierarchical indicator frameworks; [2]
- Identify or develop reference conditions/values for comparison against current conditions; [3]
- Emphasize spatial evaluation of conditions and Geographic Information System (GIS) products;[4]
- Summarize key findings by park areas; and [5]
- Follow national NRCA guidelines and standards for study design and reporting products.

[1] The breadth of natural resources and number/type of indicators evaluated will vary by park.

[2] Frameworks help guide a multi-disciplinary selection of indicators and subsequent "roll up" and reporting of data for measures - conditions for indicators - condition summaries by broader topics and park areas

[3] NRCAs must consider ecologically-based reference conditions, must also consider applicable legal and regulatory standards, and can consider other management-specified condition objectives or targets; each study indicator can be evaluated against one or more types of logical reference conditions. Reference values can be expressed in qualitative to quantitative terms, as a single value or range of values; they represent desirable resource conditions or, alternatively, condition states that we wish to avoid or that require a follow-up response (e.g., ecological thresholds or management "triggers").

[4] As possible and appropriate, NRCAs describe condition gradients or differences across a park for important natural resources and study indicators through a set of GIS coverages and map products.

[5] In addition to reporting on indicator-level conditions, investigators are asked to take a bigger picture (more holistic) view and summarize overall findings and provide suggestions to managers on an area-by-area basis: 1) by park ecosystem/habitat types or watersheds, and 2) for other park areas as requested.

Although the primary objective of NRCAs is to report on current conditions relative to logical forms of reference conditions and values, NRCAs also report on trends, when appropriate (i.e., when the underlying data and methods support such reporting), as well as influences on resource conditions. These influences may include past activities or conditions that provide a helpful context for understanding current conditions, and/or present-day threats and stressors that are best interpreted at park, watershed, or landscape scales (though NRCAs do not report on condition status for land areas and natural resources beyond park boundaries). Intensive cause-and-effect analyses of threats and stressors, and development of detailed treatment options, are outside the scope of NRCAs. Due to their modest funding, relatively quick timeframe for completion, and reliance on existing data and information, NRCAs are not intended to be exhaustive. Their methodology typically involves an informal synthesis of scientific data and information from multiple and diverse sources. Level of rigor and statistical repeatability will vary by resource or indicator, reflecting differences in existing data and knowledge bases across the varied study components.

The credibility of NRCA results is derived from the data, methods, and reference values used in the project work, which are designed to be appropriate for the stated purpose of the project, as well as adequately documented. For each study indicator for which current condition or trend is reported, we will identify critical data gaps and describe the level of confidence in at least qualitative terms. Involvement of park staff and National Park Service (NPS) subject-matter experts at critical points during the project timeline is also important. These staff will be asked to assist with the selection of study indicators; recommend data sets, methods, and reference conditions and values; and help provide a multi-disciplinary review of draft study findings and products.

NRCAs can yield new insights about current park resource conditions, but, in many cases, their greatest value may be the development of useful documentation regarding known or suspected resource conditions within parks. Reporting products can help park managers as they think about near-term workload priorities, frame data and study needs for important park resources, and communicate messages about current park resource conditions to various audiences. A successful NRCA delivers science-based information that is both credible and has practical uses for a variety of park decision making, planning, and partnership activities.

An NRCA is intended to provide useful science-based information products in support of all levels of park planning. Photo Credit: NPS.

However, it is important to note that NRCAs do not establish management targets for study indicators. That process must occur through park planning and management activities. What a NRCA can do is deliver science-based information that will assist park managers in their ongoing, long-term efforts to describe and quantify a park's desired resource conditions and management targets. In the near term, NRCA findings assist strategic park resource planning[6] and help parks to report on government accountability measures.[7] In addition, although in-depth analysis of the effects of climate change on park natural resources is outside the scope of NRCAs, the condition analyses and data sets developed for NRCAs will be useful for park-level climate-change studies and planning efforts.

NRCAs also provide a useful complement to rigorous NPS science support programs, such as the NPS Natural Resources Inventory & Monitoring (I&M) Program.[8] For example, NRCAs can provide current condition estimates and help establish reference conditions, or baseline values, for some of a park's vital signs monitoring indicators. They can also draw upon non-NPS data to help evaluate current conditions for those same vital signs. In some cases, I&M data sets are incorporated into NRCA analyses and reporting products.

Over the next several years, the NPS plans to fund an NRCA project for each of the approximately 270 parks served by the NPS I&M Program. For more information visit the NRCA Program website at http://www.nature.nps.gov/water/nrca/.

[6] An NRCA can be useful during the development of a park's Resource Stewardship Strategy (RSS) and can also be tailored to act as a post-RSS project.

[7] While accountability reporting measures are subject to change, the spatial and reference-based condition data provided by NRCAs will be useful for most forms of "resource condition status" reporting as may be required by the NPS, the Department of the Interior, or the Office of Management and Budget.

[8] The I&M program consists of 32 networks nationwide that are implementing "vital signs" monitoring in order to assess the condition of park ecosystems and develop a stronger scientific basis for stewardship and management of natural resources across the National Park System. "Vital signs" are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values.


Wildlife camera photo of a coyote at Tonto NM. Photo Credit: NPS.

Introduction and Resource Setting

Introduction

Enabling Legislation/Executive Orders

Tonto National Monument (NM) was established in 1907 to "preserve and protect critical archeological evidence of the prehistoric Salado culture of central Arizona's Tonto Basin. Most notable are two large cliff dwellings constructed during the 14th century. The monument also protects the areas within the Tonto National Monument Archeological District along with the arid habitat of the northeastern edge of the Sonoran Desert (NPS 2017a)."

Supporting the monument's purpose are three significance statements explaining why its "resources and values are important enough to merit designation as a unit of the national park system" (NPS 2017a). These statements are as follows (text excerpted from NPS (2017a)):

1. The distinctive Salado architecture at Tonto National Monument represents some of the best-preserved cliff dwellings in the American Southwest.
2. The complex Upland Sonoran Desert environment at Tonto National Monument has led to diverse types of archeological resources and a high site density, representing a broad range of cultural groups extending for more than 10,000 years.
3. Natural and cultural resources within Tonto National Monument are significant to a number of contemporary American Indian tribes, as evidenced by oral history and continuing traditional practices.

Geographic Setting

Tonto NM is located approximately two hours northeast of the Phoenix metro area, off of Arizona (AZ) Highway 188 near Roosevelt Lake. The town of Globe, AZ lies 48 km (30 mi) southeast of the monument and Payson, AZ is 80 km (50 mi) almost due north. As of July 1, 2018, the population estimate for Globe, Arizona (the closest city to the monument) was 7,346, representing a population decline of 2.3% (U.S. Census Bureau 2018).

The monument is 452 ha (1,117 ac) in size and is surrounded by the 1.2 million ha- (2.9 million ac-) Tonto National Forest—the fourth largest national forest in the United States (Figure 1).

Figure 1. Tonto NM is surrounded by Tonto National Forest along Arizona Highway 188. Figure Credit: NPS.

The climate in the area is described by the National Park Service (NPS) Sonoran Desert Inventory and Monitoring Network (SODN) (2018) as follows:

> Tonto National Monument experiences climate typical of the Sonoran Desert ecoregion: highly variable, bimodal precipitation with a considerable range in daily and seasonal air temperature, and relatively high potential evapotranspiration rates. From 1981 to 2010, 29% of the annual precipitation near the monument fell during thunderstorms from July through September, when maximum air temperatures can exceed 104°F and lead to violent (and often localized) rainstorms. The bulk of the remaining annual precipitation falls in relatively gentle events of broad extent from November through March. Average annual precipitation from 2006 to 2010 was 16.3".

Visitation Statistics

Visitation data for Tonto NM are available from 1934–2018 (NPS Public Use Statistics Office 2019). The highest number of visitors was 82,784 in 1986 (Figure 2). The months with the highest average number of visitors are February and March based on data collected from 1979-2018 (NPS Public Use Statistics Office 2019).

Natural Resources

Ecological Units and NPScape Landscape-scale

Tonto NM lies within the Sonoran Desert ecoregion in the Tonto Basin of central Arizona (Figure 3). It is surrounded by the Apache Highlands ecoregion, creating an ecotone that is reflected in the monument's diverse assemblage of plants and animals. The elevation at Tonto NM ranges between 431–1,219 m (1,414–3,999 ft).

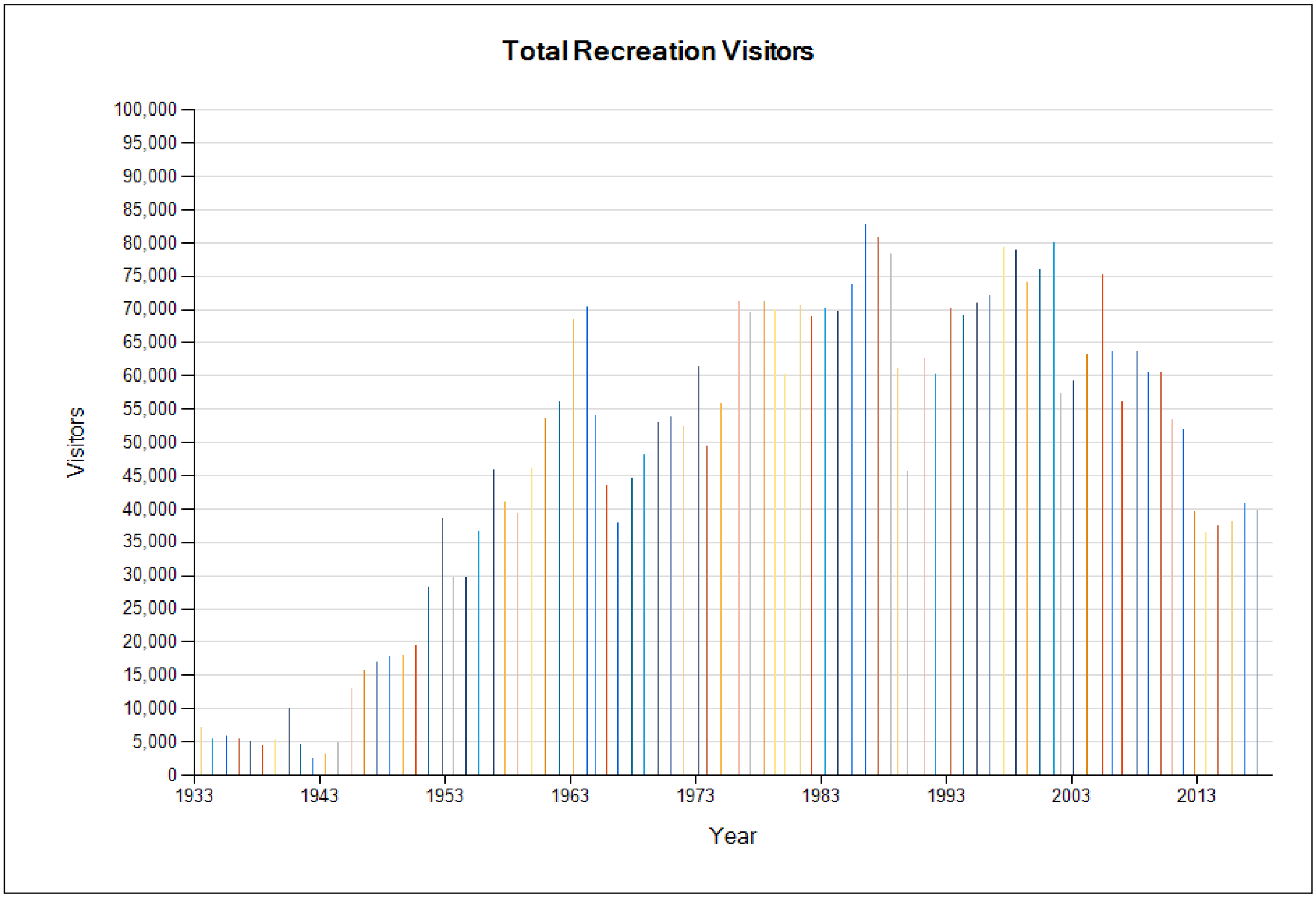


Figure 2. **Total number of annual visitors to Tonto NM from 1934-2018. Figure Credit: NPS Public Use Statistics Office 2019.**

Most of Tonto NM's natural resources (e.g., viewshed, night sky, air quality, water, wildlife, etc.) are affected by landscape-scale processes. As a result, landscape-scale metrics can provide a broader perspective and more comprehensive information to better understand resource conditions throughout the monument. Studies have shown that natural resources rely upon the larger, surrounding area to support their life cycles (Coggins 1987 as cited in Monahan et al. 2012), however, most parks are not large enough to encompass self-contained ecosystems for the resources found within their boundaries. When feasible, landscape-scale indicators and measures were included in the national monument's condition assessments to provide an ecologically relevant, landscape-scale context for reporting resource conditions. NPS NPScape metrics were used to report on the landscape-scale measures, providing a framework for conceptualizing human effects (e.g., housing densities, road densities, etc.) on landscapes surrounding the monument (NPS 2014a,b).

Resource Descriptions

An overview of Tonto NM resources is summarized by NPS SODN (2018) as follows:

> Considered some of the most rugged terrain in Arizona, slopes in the monument range from 2 to 90%. The monument rises high above a valley now filled by Roosevelt Lake, a 7,015-ha reservoir created by the completion of Roosevelt Dam in 1911. The monument lies on the southeastern flanks of the rugged Mazatzal Mountains, facing the even more precipitous Sierra Ancha Mountains to the northeast. These steep, angular mountains are typical of the Basin and Range physiographic province, with northwest–southeast aligned ranges separated by the Salt River Valley, which was the focus of prehistoric human uses in the region.

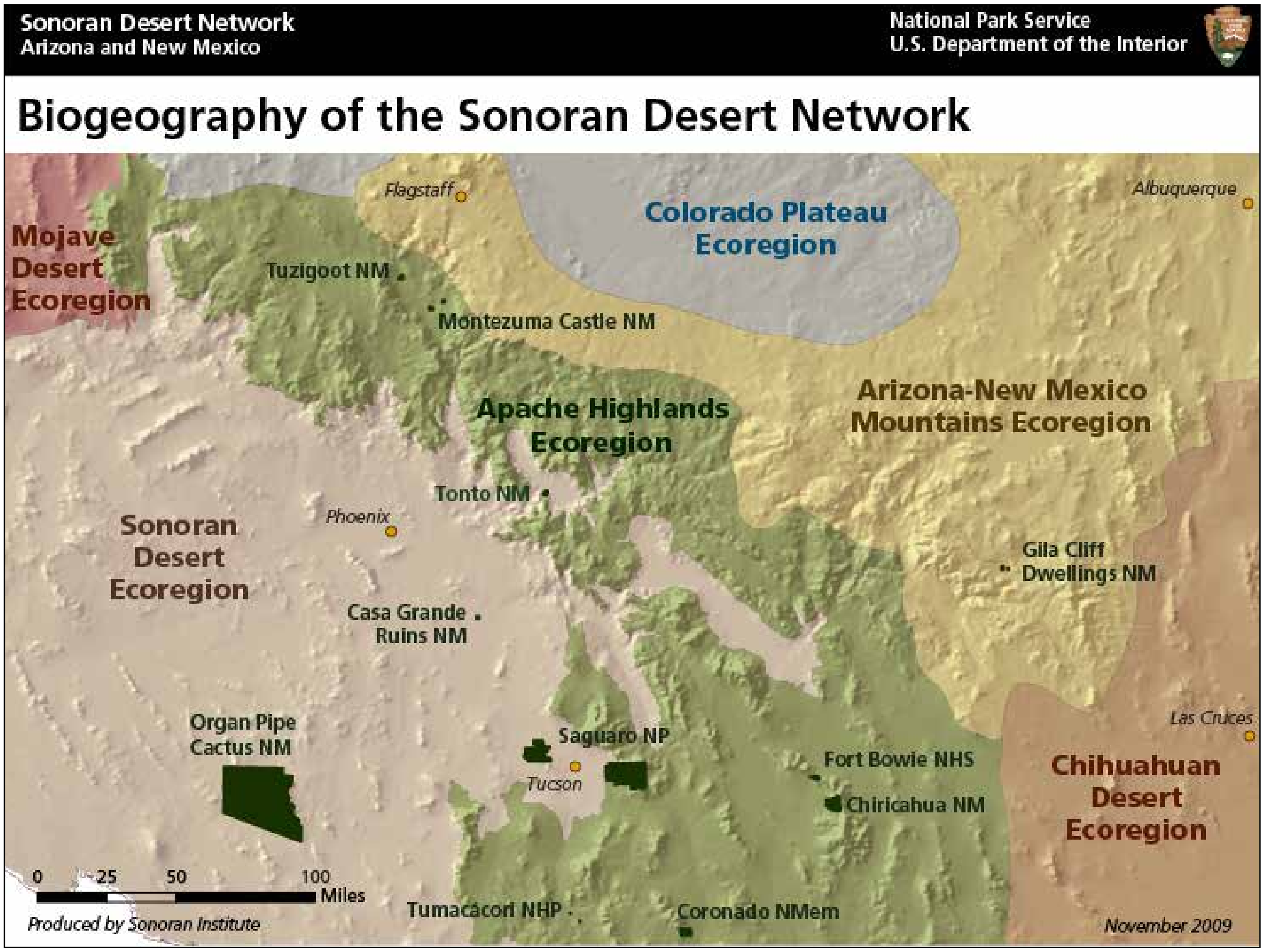


Figure 3. **Tonto NM is one of 11 park units within the NPS Sonoran Desert Inventory and Monitoring Network. Figure Credit: NPS SODN.**

The northeastern third of the park is composed of alluvial outwash fans and bajadas emanating from the steep mountains that comprise the remainder of the monument. The monument contains three steep-gradient, ephemeral riparian systems: Cave Canyon, Deadman Canyon, and the smaller Cholla Canyon. The only perennial surface water in the park is Cave Canyon Spring.

The park occurs in three biomes: desert, thornscrub, and semi-desert grassland. Most of the elevational rise occurs within the space of three-quarters of a mile.

The Tonto Basin is an intermontane basin filled with a mixture of marine sediments and debris eroded from nearby mountains. The mountains in the region present today are the result of cycles of deposition, uplift, and erosion. Other landforms in the Tonto Basin include alluvial fans, bajadas, and pediments.

The geologic strata at Tonto National Monument are composed of the Precambrian Apache Group, and the entire Precambrian section is exposed in the monument. From oldest to youngest, the group includes Pioneer shale, Dripping Spring quartzite, Mescal limestone, and basalt. The Dripping Springs quartzite is notable because it houses the alcoves with cliff dwellings. The alcoves were created by weathering and erosional processes that likely started 50,000–400,000 years ago. The people of the Salado culture used sedimentary and igneous rocks in the area to form tools and building materials.

The park's soil families can be grouped based on where they occur on the landscape: hills, bajadas, or drainageways. The Bodecker and Tonto families occur in drainageways, with the Bodecker family in the Cave Creek riparian area and the Tonto family in areas of active wash cutting and sediment movement. The bajada or alluvial-fan soils include older surfaces that are mapped as Eba and Topawa families and the Tubac family, formed by erosion uncovering old, fine-grained lacustrine sediments. Hill or mountain soils include unstable steep colluvial sideslope soils mapped as Lampshire family, and several more stable summit soils that differ in composition based on age and composition of parent materials.

Open spaces on the soils at Tonto National Monument are typically covered by biological soil crusts, a community of cyanobacteria, algae, lichens, and bryophytes. Lichens are a composite, symbiotic organism composed of a fungus and either a cyanobacteria or a green algae. Bryophytes are small, non-vascular plants, including mosses and liverworts.

Biological soil crusts provide key ecosystem functions. They increase resistance to erosion by water and wind, contribute organic matter, and fix atmospheric nitrogen. Cyanobacteria weave through the upper few millimeters of soil, binding soil particles together by secreting polysaccharides. The polysaccharides also contribute to soil aggregate structure, which is directly correlated with soil erosion resistance. Mosses and lichens have small, anchoring structures that help them protect the soil surface. On most soils, biological soil crusts increase infiltration.

The distribution and species composition of biological soil crusts is influenced by soil chemistry and disturbance. The recovery of biological soil crusts from disturbance depends on factors that include the climatic regime and type of disturbance. Generally, crusts recover slowly in areas with high annual temperature and low annual precipitation, such as Tonto National Monument. Biological soil crusts follow a recovery sequence in which, typically, cyanobacteria first colonize a site, followed by cyanolichens, other lichens, and then moss.

Resource Issues Overview

The Southwest is already experiencing the impacts of climate change. According to Kunkel et al. (2013), the historical climate trends (1895-2011) for the southwest (including the states of Arizona, California, Colorado, Nevada, New Mexico, and Utah) have seen an average annual temperature increase of 0.9 ºC (34 ºF) (greatest in winter months) and more than double the number of four-day periods of extreme heat. The western U.S., especially the Southwest, has also experienced decreasing rainfall (Prein et al. 2016). Since 1974 there has been a 25% decrease in precipitation, a trend that is partially counteracted by increasing precipitation intensity (Prein et al. 2016).

Monahan and Fischelli (2014) evaluated which of 240 NPS parks have experienced extreme climate changes during the last 10-30 years, including Tonto NM. Twenty-five climate variables based on temperature and precipitation were evaluated to determine which ones were either within <5th percentile or >95th percentile relative to the historical range of variability (HRV) from 1901-2012. Results for Tonto NM were reported as follows:

- Five temperature variables were "extreme warm" (annual mean temperature, maximum temperature of the warmest month, minimum temperature of the coldest month, mean temperature of the warmest quarter, mean temperature of the coldest quarter).
- No temperature variables were "extreme cold."
- No temperature variables were "extreme dry."
- No precipitation variables were "extreme wet."

Results for the temperature of each year between 1901-2012, the averaged temperatures over progressive 10-year intervals, and the average temperature of 2003-2012 (the most recent interval) are shown in Figure 4. The blue line shows temperature for each year, the gray line shows temperature averaged over progressive 10-year intervals (10-year moving windows), and the red asterisk shows the average temperature of the most recent 10-year moving window (2003–2012). The most recent percentile is calculated as the percentage of values on the gray line that fall below the red asterisk. The results indicate that recent climate conditions

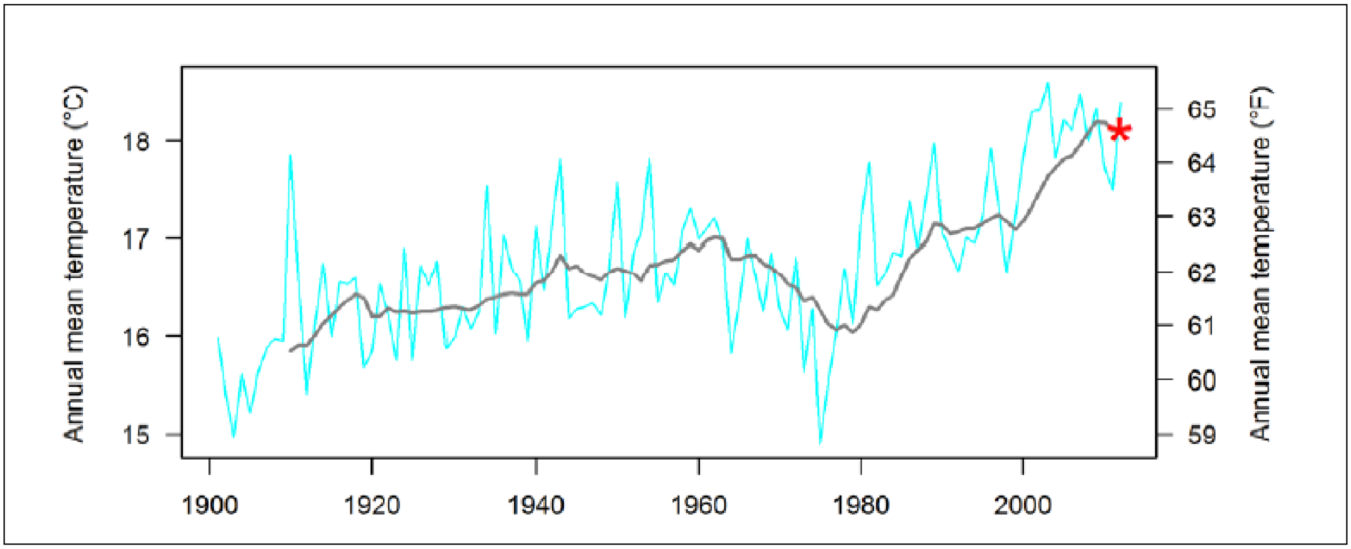


Figure 4. Time series used to characterize the historical range of variability and most recent percentile for annual mean temperature at Tonto NM (including areas within 30-km [18.6-mi] of the park's boundary). Figure Credit: Monahan and Fisichelli (2014).

have already begun shifting beyond the HRV, with the 2003-2012 decade representing the warmest on record for the national monument.

Climate predictions are that the Southwest will likely continue to become warmer and drier with climate change (Garfin et al. 2014, Monahan and Fisichelli 2014). Kunkel et al. (2013) estimate that temperatures could rise between 2.5 °C (37 °F) and 4.7 °C (40 °F) for 2070-2099 (based on climate patterns from 1971-1999). Monahan and Fisichelli (2014) state that "climate change will manifest itself not only as changes in average conditions, but also as changes in particular climate events (e.g., more intense storms, floods, or drought). Extreme climate events can cause widespread and fundamental shifts in conditions of park resources."

In addition to changing temperature and precipitation patterns, NPS SODN (2018) cites additional issues of concern relative to Tonto NM's natural resources. These include "preserving the park's small riparian area, unknown impacts of human presence on avian nesting activities, the introduction and spread of invasive exotic plants, and adjacent land-use activities, including grazing, increased recreational use, and alteration of the fire regime."

As of June 8, 2019, the 50,111 ha (123,827-ac) Woodbury Fire has been burning in the Tonto National Forest in and near the Superstition Wilderness and throughout the monument (USFS 2019). As of July 1, 2019, only 80% of the fire's perimeter has been contained (USFS 2019). USFS (2019) states that "fuel continuity and loading is highly variable across the landscape as determined by elevation, aspect and topography." The USFS (2019) reported that the fuels involved include tall grass, brush, and chaparral. While the full effects of the fire's impact to the monument's and surrounding region's resources are currently unknown, the fire has undoubtedly created natural resource conditions that are vastly different from those reported in this report.

Resource Stewardship

Management Directives and Planning Guidance

In addition to Tonto NM's purpose, significance, and fundamental resources and values, and other potential resources/ecological drivers of interest, the NPS Washington (WASO) level programs guided the selection of key natural resources for this condition assessment. This included the SODN, I&M NPScape Program for landscape-scale measures, Air Resources Division for air quality, and the Natural Sounds and Night Skies Program for the night sky assessment.

In an effort to improve overall national park management through expanded use of scientific knowledge, the I&M Program was established to collect, organize, and provide natural resource data as well as information derived from data through analysis, synthesis, and modeling (NPS 2011). The primary goals of the I&M Program are to:

- inventory the natural resources under NPS stewardship to determine their nature and status;
- monitor park ecosystems to better understand their dynamic nature and condition and to provide reference points for comparisons with other altered environments;
- establish natural resource inventory and monitoring as a standard practice throughout the National Park System that transcends traditional program, activity, and funding boundaries;
- integrate natural resource inventory and monitoring information into NPS planning, management, and decision making; and
- share NPS accomplishments and information with other natural resource organizations and form partnerships for attaining common goals and objectives (NPS 2011).

To facilitate this effort, 270 parks with significant natural resources were organized into 32 regional networks. Tonto NM is part of the SODN, which includes 10 additional parks. Through a rigorous multi-year, interdisciplinary scoping process, SODN selected a number of important physical, chemical, and/or biological elements and processes for long-term monitoring. These ecosystem elements and processes are referred to as 'vital signs', and their respective monitoring programs are intended to provide high-quality, long-term information on the status and trends of those resources to help managers "make sound decisions about the future" (NPS SODN 2017).

The structural framework for NRCAs is based upon, but not restricted to, the fundamental and other important values identified in a park's Foundation Document or General Management Plan. NRCAs are designed to deliver current science-based information translated into resource condition findings for a subset of a park's natural resources. The NPS Resource Stewardship Strategy (RSS) and other strategic planning reports rely on credible information found in NRCAs as well as a variety of other sources.

Foundation documents describe a park's purpose and significance and identify fundamental and other important park resources and values. A foundation document was completed for Tonto NM in 2017 (NPS 2017a) and was used to identify some of the primary natural features throughout the park for the development of its NRCA.

An RSS uses past and current resource conditions to identify potential management targets or objectives by developing comprehensive strategies using all available reports and data sources including NRCAs. National parks are encouraged to develop an RSS as part of the park management planning process. Indicators of resource condition, both natural and cultural, are selected by park staff. After each indicator is chosen, a target value is determined and the current condition is compared to the desired condition. An RSS has not been completed for the national monument.

Status of Supporting Science

Available data and reports varied depending upon the resource topic. The existing data used to assess the condition of each indicator and/or to develop reference conditions are described in each of the Chapter 4 assessments in this report.

Field tour at Tonto National Monument during the NRCA scoping meeting. Photo Credit: NPS/Phyllis Pineda Bovin.

Study Scoping and Design

he Natural Resource Condition Assessment (NRCA) for Tonto National Monument (NM) was coordinated by the National Park Service (NPS) Intermountain Region Office (IMRO), Utah State University (USU), and the Colorado Plateau Cooperative Ecosystem Studies Unit through task agreement, P17AC01073. The NRCA scoping process was a collaborative effort between the staffs of Tonto NM, NPS Sonoran Desert Inventory and Monitoring Network (SODN), the NPS IMRO NRCA Coordinator, and USU's NRCA team.

Preliminary scoping for Tonto NM's NRCA began on December 18, 2017 with a conference call. Prior to the call, USU staff reviewed the monument's foundation document (NPS 2017a) and website (NPS 2018b), SODN's website (NPS SODN 2018), and the NPS integrated resource management applications (IRMA portal; NPS 2018c). Additionally, the NPS Natural Resource Stewardship and Science Directorate (NRSS) divisions provided data for night sky, air quality, geology, and climate change discussions (NPS NRSS 2018).

Based on the information gathered, a preliminary list of potential focal resources for the monument's NRCA was developed and discussed during the December conference call. Tonto NM's conference call participants, Chief of Resources, Brett Cockrell, and SODN Vegetation Ecologist, Sarah Studd, discussed and refined the list of resources, and identified additional reports and datasets.

After the call, USU NRCA writers reviewed reports and datasets to determine a logical study plan of the prioritized resources. USU writers then developed the Phase I draft indicators, measures, and reference condition tables for the nine preliminary focal resources selected by monument staff, reflecting the proposed NRCA study plan. Note that non-native invasive plants were used as an indicator and measures to evaluate the condition of vegetation instead of addressing non-native plants as a stand-alone topic. The draft Phase I tables served as the primary discussion guide during Tonto NM's on-site NRCA scoping workshop.

The monument's NRCA workshop and field outing was held over a two day period from May 10-11, 2018 at the park (a list of meeting participants is included in Appendix A). During the workshop, meeting participants reviewed, discussed, and refined the Phase I tables, which formed the basis of USU's study plan for the monument's NRCA report. Additional datasets and reports were further identified and gathered for the selected focal resources. Monument staff also identified threats, issues, and data gaps for each natural resource topic, which are discussed in each of the nine Chapter 4 condition assessments.

Study Design

Indicator Framework, Focal Study Resources and Indicators

An NRCA report represents a unique assessment of key natural resource topics at each park. Tonto NM's NRCA focal resources, indicators, and measures are listed in Tables 1 – 6. Due to USU's timeline and budget constraints, this list of resources *does not* include every natural resource of interest to monument staff, rather the list is comprised of the natural resources and processes that were of greatest interest/concern to monument staff at the time of this effort.

Table 1. Tonto NM natural resource condition assessment framework based on the NPS Inventory & Monitoring Program's Ecological Monitoring Framework for landscapes patterns and processes.

Resources	Indicators	Measures
Viewshed	Scenic and Historic Integrity	Conspicuousness of Non-contributing Features
	Scenic and Historic Integrity	Extent of Development
	Scenic and Historic Integrity	Proportion of Viewshed Protected
Night Sky	Sky Brightness	All-sky Light Pollution Ratio (ALR)

Table 2. Tonto NM natural resource condition assessment framework based on the NPS Inventory & Monitoring Program's Ecological Monitoring Framework for air and climate.

Resource	Indicators	Measures
Air Quality	Visibility	Haze Index
	Ozone	Human Health
	Ozone	Vegetation Health
	Wet Deposition	Nitrogen
	Wet Deposition	Sulfur
	Wet Deposition	Mercury
	Wet Deposition	Predicted Methylmercury Concentration

The selected natural resources were grouped using the NPS Inventory & Monitoring (I&M) Program's "NPS Ecological Monitoring Framework" (NPS 2005), which is endorsed by the Washington Office NRCA Program as an appropriate framework for listing resource components, indicators/measures, and resource conditions. Additionally, SODN's Vital Signs Plan (Mau-Crimmins et al. 2005), and the RM-77 NPS Natural Resource Management Guideline (NPS 2004) are all organized similarly to the I&M framework.

Table 3. Tonto NM natural resource condition assessment framework based on the NPS Inventory & Monitoring Program's Ecological Monitoring Framework for water.

Resource	Indicators	Measures
Cave Canyon Riparian Area	Water Quantity	Persistence (Water Level Sensor Data)
	Water Quality	Temperature
	Water Quality	Dissolved Oxygen (%)
	Water Quality	Dissolved Oxygen (mg/L)
	Water Quality	Specific Conductance
	Water Quality	pH
	Water Quality	Turbidity
	Water Quality	Nutrients
	Water Quality	Metals and Metalloids
	Water Quality	Inorganics
	Riparian/Wetland Vegetation	Richness and Composition

Table 4. Tonto NM natural resource condition assessment framework based on the NPS Inventory & Monitoring Program's Ecological Monitoring Framework for geology.

Resource	Indicators	Measures
Geologic Resources	Erosion Index	Extent of Affected Area by Feature Type (all strata)
	Anthropogenic Impacts	Anthropogenic Impacts to Geological/Cultural/ Paleontological Resources (e.g., graffiti or other vandalism, erosion from developed areas, etc.)
	Natural Events that Affect Geological/ Cultural Resources	Natural Events that Affect Geological/ Cultural Resources
	Presence/Absence	Presence/Absence

Table 5. Tonto NM natural resource condition assessment framework based on the NPS Inventory & Monitoring Program's Ecological Monitoring Framework for biological integrity (plants).

Resource	Indicators	Measures
Upland Sonoran Desert Vegetation and Soils	Erosion Hazard	Bare Ground Cover (all strata)
	Erosion Hazard	Soil Aggregate Stability (all strata)
	Erosion Hazard	Mature Biological Soil Crust Cover (Bajada)
	Site Resilience	Foliar Cover of Dead Perennial Plants (field layer, all strata)
	Site Resilience	Foliar Cover of Dead Perennial Plants (subcanopy layer, all strata)
	Site Resilience	Tree and shrub cover (subcanopy, foothills)
	Saguaro Cacti	Extent (bajada)
	Saguaro Cacti	Recruitment (bajada)
	Non-native Plants	Extent of Non-native Plants (all strata)
	Non-native Plants	Total Non-native plant cover (field, all strata)
	Non-native Plants	Ratio of Non-native Plant Cover to Total Plant Cover (field layer, all strata)
	Fire Hazard	Grass and Forb Cover (field layer, bajada)
	Fire Hazard	Ratio of Annual Plant Cover to Total Plant Cover (field layer, foothills)
	Fire Hazard	Litter and Duff (foothills)

Reporting Areas

The primary focus of the condition assessment reporting area was within Tonto NM's legislative boundary; however, some of the data and analyses encompassed areas beyond its boundary. Natural resources assessed at the landscape level included viewshed, night sky, air quality, and habitat suitability for selected mammals.

General Approach and Methods

The general approach to developing the condition assessments included reviewing literature and data

Table 6. Tonto NM natural resource condition assessment framework based on the NPS Inventory & Monitoring Program's Ecological Monitoring Framework for biological integrity (animals).

Resources	Indicators	Measures
Birds	Species Occurrence	Presence/Absence
	Species Occurrence	Presence of Species of Concern
	Mexican Spotted Owl	Presence/Absence
Mammals	Species Occurrence	Presence/Absence (Persistence over time)
	Species Occurrence	Presence of Species of Conservation / Management Concern
Herpetofauna	Species Occurrence	Presence/Absence (Persistence Over Time)
	Species Occurrence	Presence of Species of Conservation / Management Concern
	Arizona Black Rattlesnake	Habitat Quality

and/or speaking to subject matter expert(s) for assistance in condition reporting. Following the NPS NRCA guidelines (NPS 2010a), each Chapter 4 condition assessment includes six sections (listed below), with a condensed literature cited section included at the end of the full report.

1. The background and importance section of each condition assessment provides information regarding the relevance of the resource to the national monument.
2. The data and methods section describe the existing datasets and methodologies used for evaluating the indicators/measures for current conditions.
3. The reference conditions section describe the good, moderate concern, and significant concern definitions used to evaluate the condition of each measure.
4. The condition and trend section provides a discussion for each indicator/measure based on the reference condition(s). Condition icons are presented in a standard format consistent with State of the Park reporting (NPS 2012b) and served as visual representations of condition/trend/level of confidence for each measure. Table 7 shows the

condition/trend/confidence level scorecard used to describe the condition for each assessment, Table 8 provides examples of conditions and associated interpretations.

Circle colors convey condition. Red circles signify that a resource is of significant concern; yellow circles signify that a resource is of moderate concern; and green circles denote that a measure is in good condition. A circle without any color, which is often associated with the low confidence symbol-dashed line, signifies that there is insufficient information to make a statement about condition; therefore, condition is unknown.

Arrows inside the circles signify the trend of the measure. An upward pointing arrow signifies that the measure is improving; double pointing arrows signify that the measure's condition is currently unchanging; a downward pointing arrow indicates that the measure's condition is deteriorating. No arrow denotes an unknown trend.

The level of confidence in the assessment ranges from high to low and is symbolized by the border around the condition circle.

5. Overall condition, key uncertainties, and resource threats are discussed for each resource topic.
6. The sources of expertise list the individuals who were consulted. Assessment author(s) are also listed in this section for each condition assessment.

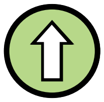
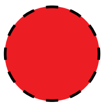
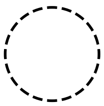
Resource management staff at Tonto National Monument. Photo Credit: NPS/Phyllis Pineda Bovin.

After the report is published, a disk containing a digital copy of the published report, copies of the literature cited (with exceptions listed in a READ ME document), original GigaPan viewshed images, reviewer comments and writer responses if comments weren't included, and any unique GIS datasets created for the purposes of the NRCA is sent to Tonto NM staff and the NPS IMRO NRCA Coordinator.

Table 7. Indicator symbols used to indicate condition, trend, and confidence in the assessment.

Condition Status		Trend in Condition		Confidence in Assessment	
	Resource is in good condition.		Condition is Improving.		High
	Resource warrants moderate concern.		Condition is unchanging.		Medium
	Resource warrants significant concern.		Condition is deteriorating.		Low
	An open (uncolored) circle indicates that current condition is unknown or indeterminate; this condition status is typically associated with unknown trend and low confidence.				

Table 8. Example indicator symbols and descriptions of how to interpret them.

Symbol Example	Description of Symbol
	Resource is in good condition; its condition is improving; high confidence in the assessment.
	Condition of resource warrants moderate concern; condition is unchanging; medium confidence in the assessment.
	Condition of resource warrants significant concern; trend in condition is unknown or not applicable; low confidence in the assessment.
	Current condition is unknown or indeterminate due to inadequate data, lack of reference value(s) for comparative purposes, and/or insufficient expert knowledge to reach a more specific condition determination; trend in condition is unknown or not applicable; low confidence in the assessment.

Bobcat at Tonto NM. Photo Credit: NPS.

Natural Resource Conditions

Chapter 4 delivers current condition reporting for the nine important natural resources and indicators selected for Tonto National Monument's NRCA report. The resource topics are presented following the National Park Service's (NPS) Inventory & Monitoring Program's NPS Ecological Monitoring Framework that is presented in Chapter 3.

Viewshed

Background and Importance

The conservation of scenery was established in the National Park Service (NPS) Organic Act of 1916 ("… to conserve the scenery and the wildlife therein…"), reaffirmed by the General Authorities Act, as amended, and addressed generally in the NPS 2006 Management Policies sections 1.4.6 and 4.0 (Johnson et al. 2008). Although no management policy currently exists exclusively for scenic or viewshed management and preservation, parks are still required to protect scenic and viewshed quality as one of their most fundamental resources. According to Wondrak-Biel (2005), aesthetic conservation, interchangeably used with scenic preservation, has been practiced in the NPS since the early twentieth century. Aesthetic conservation strives to protect scenic beauty for park visitors to better experience the values of the park. The need for scenic preservation management is as relevant today as ever, particularly with the pervasive development pressures that challenge park stewards to conserve scenery today and for future generations.

Viewsheds are considered an important part of the visitor experience at Tonto National Monument (NM), and features on the visible landscape influence a visitor's enjoyment, appreciation, and understanding of the area's cultural significance (NPS 2003). Much of the landscape surrounding Tonto NM is managed by the U.S. Forest Service (USFS), providing visitors the opportunity to immerse themselves in a natural landscape (Mau-Crimmins et al. 2005). Visitors to Tonto NM are provided opportunities to literally "visualize" their connection to nature and past cultures. The views offered at Tonto NM represent much more than just scenery; they represent a way to better understand the connection between the past and the present. Inherent in virtually every aspect of this assessment is how features on the visible landscape influence the enjoyment, appreciation, and understanding of the national monument by visitors.

Data and Methods

The indicator (scenic and cultural integrity) and measures (conspicuousness of non-contributing features, extent of development, and conservation status) used for assessing the condition of Tonto NM's viewshed were based on studies related to perceptions people hold toward various features and attributes of scenic landscapes. The scenic and cultural integrity indicator is defined as the state of natural and cultural features that contribute to the scenic attractiveness of an area (USFS 1995). Integrity focuses on the features of the landscape related to non-contributing human alteration/development. In general, there has been a wealth of research demonstrating that people tend to prefer natural landscapes over human-modified landscapes (Zube et al. 1982, Kaplan and Kaplan

View from the Upper Cliff Dwellings in Tonto National Monument. Photo Credit. NPS/Phyllis Pineda Bovin.

1989, Sheppard 2001, Kearny et al. 2008, Han 2010). Human-altered components of the landscape (e.g., roads, modern buildings, power lines, and other features) that do not contribute to the natural or cultural scene are often perceived as detracting from the scenic character of a viewshed. Despite this generalization for natural landscape preferences, studies have also shown that not all human-made structures or features have the same impact on visitor preferences. Visitor preferences can be influenced by a variety of factors including cultural and historical background, familiarity with the landscape, and their environmental values (Kaplan and Kaplan 1989, Virden and Walker 1999, Kaltenborn and Bjerke 2002, Kearney et al. 2008).

While we recognize that visitor perceptions of an altered landscape are highly subjective, and that there is no completely objective way to measure these perceptions, research has shown that there are certain landscape types and characteristics that people tend to prefer over others. Substantial research has demonstrated that human-made features on a landscape were perceived more positively when they were considered in harmony with the landscape (e.g., Kaplan and Kaplan 1989, Gobster 1999, Kearney et al. 2008). Kearney et al. (2008) showed that survey respondents tended to prefer development that blended with the natural setting through use of colors, fine scale features, and vegetative screening. These characteristics, along with distance from non-contributing features, and movement and noise associated with observable features on the landscape, are discussed below.

Three key observation points were selected by Tonto NM staff for inclusion in the viewshed analysis. The points were chosen based on viewsheds that are accessible to the public, are located upon a prominent landscape feature, and are inclusive of cultural resources, natural resources, and scenic views (Figure 5). The three observation points are as follows: Upper Cliff Dwellings, Visitor Center, and Scenic View-Highway (HWY) 188. Although the Scenic View-HWY 188 point is located outside of the monument, it offers views of the cliff dwellings after the nightly closure of the monument.

We used panoramic images collected at these three locations in addition to GIS analyses of modeled visible areas overlaid with housing density, road density, and land management datasets to evaluate viewshed conditions from the monument.

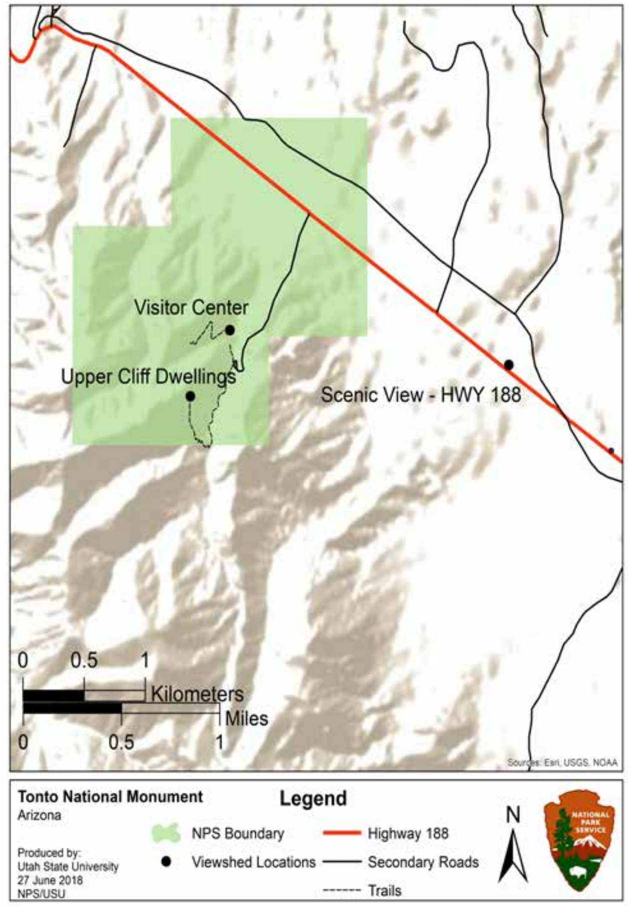


Figure 5. Viewshed locations in and around Tonto NM.

The conspicuousness of non-contributing features, the first measure, was evaluated using high-quality panoramic photos of the three key observation points. Photos were taken on 10-11 May 2018 with a Canon PowerShot digital camera mounted to a GigaPan Epic 100 system. At the Scenic View-HWY 188 point, panoramas were collected from the four cardinal directions (i.e., north to east, east to south, south to west, and west to north). At the Visitor Center, we also collected images from each of the four cardinal directions; however, due to an equipment failure, only images from north to east and east to south were collected. At the Upper Cliff Dwellings point, images were collected from the northeast to southeast and southeast to southwest, which included the entire viewshed as seen by an observer at the cliff dwellings. The images for each direction were then stitched together into a single high-resolution panoramic image using GigaPan Stitch software. These photos portray the viewshed from an observer's perspective and provide a means of assessing the non-contributing features on the landscape. Non-contributing features were qualitatively evaluated based on four characteristics of human-made features, the first of which is distance to objects in the viewshed.

The impact that individual human-made features have on perception is substantially influenced by the distance from the observer to the feature(s). Viewshed assessments using distance zones or classes often define three classes: foreground, middle ground, and background. For this assessment, we have used the distance classes that have been recently used by the NPS:

- *Foreground* = 0-0.8 km (0-0.5 mi) from key observation point
- *Middle ground* = 0.8-5 km (0.5-3 mi) from key observation point
- *Background* = 5-97 km (3-60 mi) from key observation point.

Over time, different agencies have adopted minor variations in the specific distances used to define these zones, but the overall logic and intent has been consistent.

The foreground is the zone where visitors should be able to distinguish variation in texture and color, such as the relatively subtle variation among vegetation patches, or some level of distinguishing clusters of tree boughs. Large birds and mammals would likely be visible throughout this distance class, as would small or medium-sized animals at the closer end of this distance class (USFS 1995). Within the middle ground there is often sufficient texture or color to distinguish individual trees or other large plants (USFS 1995). It is also possible to still distinguish larger patches within major plant community types (such as riparian areas), provided there is sufficient difference in color shades at the farther distance. Within the closer portion of this distance class, it still may be possible to see large birds when contrasted against the sky, but other wildlife would be difficult to see without the aid of binoculars or telescopes. The background distance class is where texture tends to disappear and colors flatten. Depending on the actual distance, it is sometimes possible to distinguish between major vegetation types with highly contrasting colors (for example, forest and grassland), but any subtle differences within these broad land cover classes would not be apparent without the use of binoculars or telescopes, and even then may be difficult.

Size is another characteristic that may influence how conspicuous a given feature is on the landscape, and how it is perceived by humans. For example, Kearney et al. (2008) found human preferences were lower for man-made developments that tended to dominate the view, such as large, multi-storied buildings and were more favorable toward smaller, single family dwellings. In another study, Brush and Palmer (1979) found that farms tended to be viewed more favorably than views of towns or industrial sites, which ranked very low on visual preference. This was consistent with other studies that have reported rural family dwellings, such as farms or ranches, as quaint and contributing to rural character (Schauman 1979, Sheppard 2001, Ryan 2006), or as symbolizing good stewardship (Sheppard 2001).

We considered the features on the landscape surrounding Tonto NM as belonging to one of six size classes (Table 9), which reflect the preference groups reported by studies. Using some categories of perhaps mixed measures, we considered size classes within the context of height, volume, and length.

Color and shape is the third characteristic we considered in this assessment. Studies have shown that how people perceive a human-made feature in a rural scene depends greatly on how well it seems to fit or blend in with the environment (Kearney et al. 2008, Ryan 2006). For example, Kearney et al. (2008) found preferences for homes that exhibit lower contrast with their surroundings as a result of color, screening vegetation, or other blending factors (Figure 6). It has been shown that colors lighter in tone or higher in saturation relative to their surroundings have a tendency to attract attention (contrast with

Table 9. Six size classes used for conspicuousness of human-made features.

Size	Low Volume	Substantial Volume
Low Height	Single family dwelling (home, ranch house)	Small towns, complexes
Substantial Height	Radio and cell phone towers	Wind farms, oil derecks
Substantial Length	Small roads, wooden power lines, fence lines	Utility corridors, highways, railroads

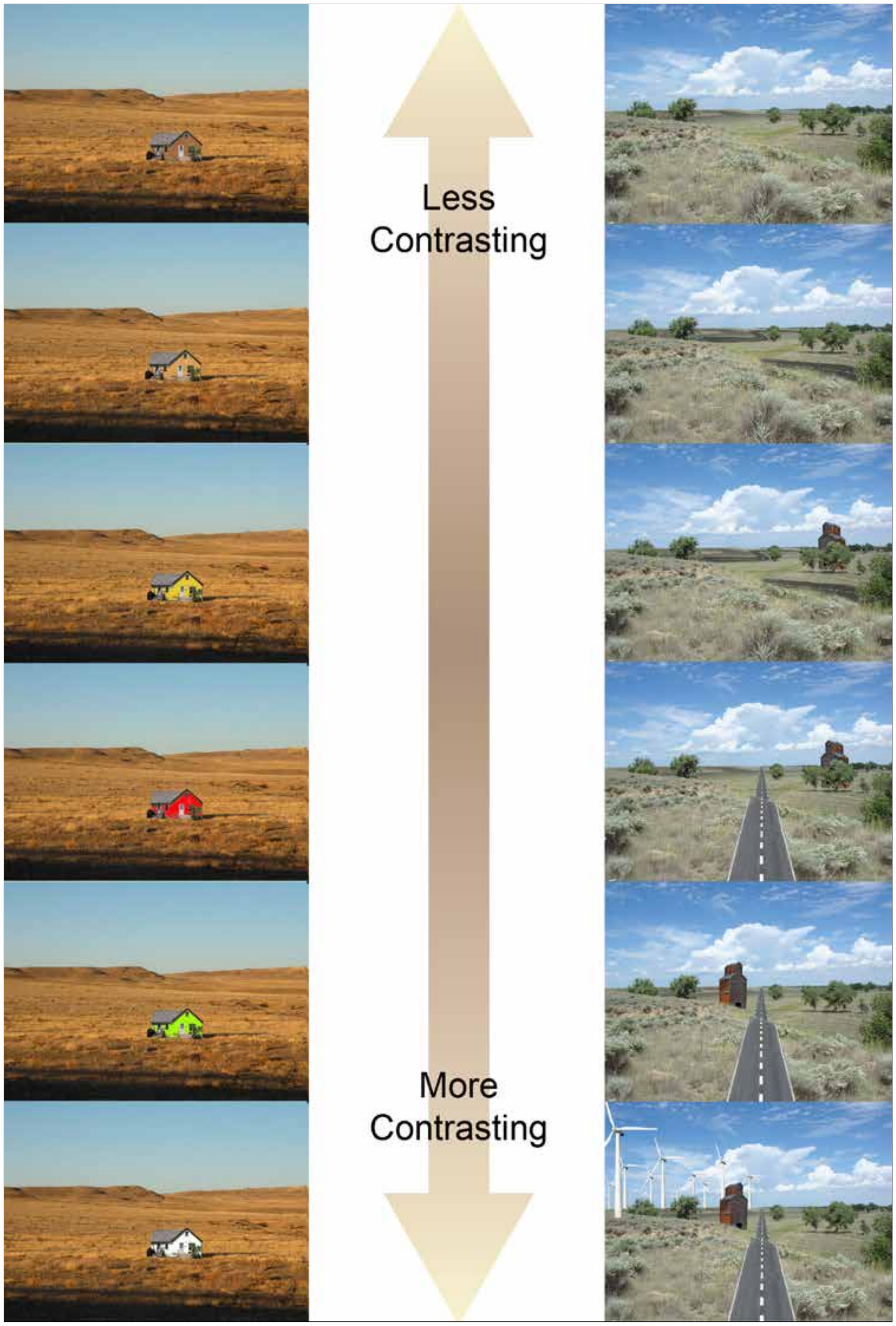


Figure 6. **Graphic illustration of how color (left) and shape (right) can influence whether features were in harmony with the environment, or were in contrast.**

their surroundings), whereas darker colors (relative to their surroundings) tend to fade into the background (Ratcliff 1972, O'Connor 2008). This was consistent with the findings of Kearney et al. (2008) who found that darker color was one of the factors contributing to a feature blending in with its environment and therefore preferred.

Some research indicates that color can be used to offset other factors, such as size, that may evoke a more negative perception (O'Connor 2009). Similarly, shapes of features that contrast sharply with their surroundings may also influence how they are perceived (Ribe 2005). The Visual Resource Management Program of the Bureau of Land Management (BLM 2016), for example, places considerable focus on design techniques that minimize visual conflicts with features such as roads and power lines by aligning them with the natural contours of the landscape. Based on these characteristics of contrast, we considered the color of a feature in relative harmony with the landscape if it closely matched the surrounding environment, or if the color tended to be darker relative to the environment. We considered the shape of a feature in relative harmony with the landscape if it was not in marked contrast to the environment.

Lastly, noise and movement can both influence how a landscape is perceived (Hetherington et al. 1993), particularly by attracting attention to a particular area of a viewshed. Movement and noise parameters can be perceived either positively or negatively, depending on the source and context. For example, the motion of running water generally has a very positive influence on perception of the environment (Carles et al. 1999), whereas noise from vehicles on a highway may be perceived negatively. In Carles et al.'s 1999 study, sounds were perceived negatively when they clashed with aspirations for a given site, such as tranquility. We considered the conspicuousness of the impact of movement and noise to be consistent with the amount present (that is, little movement or noise was inconspicuous, obvious movement or noise was conspicuous).

In summary, these four characteristics do not act independently with respect to their influence on the conspicuousness of features; rather, they tend to have a hierarchical effect (Figure 7). For example, the color and shape of a house would not be important to the integrity of the park's viewshed if the house was located too far away from the key observation point. Thus, distance becomes the primary characteristic that affects the potential conspicuousness. Therefore, we considered potential influences on conspicuousness in the context of a hierarchy based on the distance characteristics having the most impact on the integrity

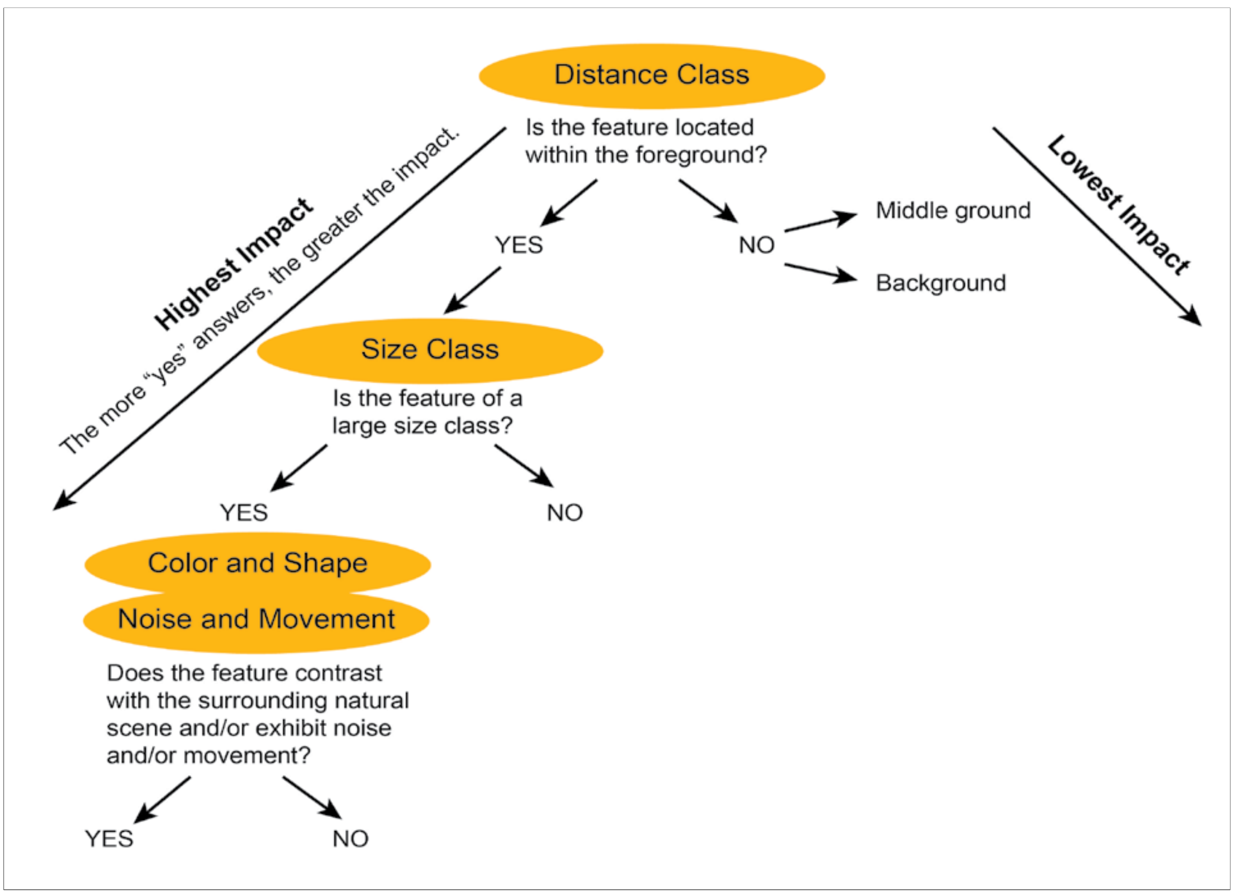


Figure 7. **Conceptual framework for hierarchical relationship of characteristics that influence the conspicuousness of features within a viewshed.**

of the viewshed, followed by the size characteristic, then both the color and shape, and movement and noise characteristics.

The second component of the conspicuousness of non-contributing features included a geographic information system (GIS) analysis of the visible and non-visible areas from each of the three key observation points. Viewshed analyses were conducted using ArcGIS's Spatial Analyst Viewshed tool. We identified the viewshed area of analysis (AOA) as a 98 km (61 mi) area surrounding each of the three key observation points. The viewshed analyses were calculated for this area since it represents the distance to which the average observer may distinguish man-made features depending on the above-mentioned characteristics (USFS 1995). We used the USGS's National Elevation Datasets (NED) at 1/3 arc-second resolution (approximately 10 m/32.8 ft resolution) to determine which areas should be visible from each observation point based on elevation within the AOA (USGS 2018a). The viewshed analysis for each location was used to support the GigaPan images described for the previous measure. The three AOAs were then combined to create a composite viewshed. Composite viewsheds are a way to show multiple viewsheds as one, providing an overview of the visible/non-visible areas across all observation points. The analysis assumes that the viewsheds were not hindered by non-topographic features such as vegetation; the observer was at ground level viewing from a height of 1.68 m (5.5 ft), which is the average height of a human; and visibility did not decay due to poor air quality. Additional details are listed in Appendix B. The composite viewshed was used to support the following two measures (i.e., extent of development and conservation status).

The extent of development provides a measure of the degree to which the viewshed has been altered from its natural (reference) state, particularly the extent to which intrusive or disruptive elements such as structures and roads may diminish the "naturalness" of the view (USFS 1995, Johnson et al. 2008). We considered two key factors in extent of development: road density and housing density.

Data for these two factors were derived from NPScape—a landscape dynamics monitoring program that produces and delivers GIS data, maps, and statistics that are integral to understanding natural resource conservation and conditions within a landscape context (NPS 2016, Monahan et al. 2012). NPScape data include seven major categories (measures), three of which were used in the viewshed condition assessment: housing, roads, and conservation status. These metrics were used to evaluate resource conditions from a landscape-scale perspective and to provide information pertaining to threats and conservation opportunities related to scenic views surrounding Tonto NM. NPScape data were consistent, standardized, and collected in a repeatable fashion over time, and yet were flexible enough to provide analyses at many spatial and temporal scales. The NPScape datasets used in this analysis were described in the sections that follow.

The U.S. Census Bureau's TIGER/Line (Topologically Integrated Geographic Encoding and Referencing) shapefiles were used to calculate the road density within the monument's AOA (U.S. Census Bureau 2017). TIGER/Line products were last updated 1 January 2017 (U.S. Census Bureau 2017). We downloaded the "All Roads" shapefile, which includes primary, secondary, local neighborhood roads, rural roads, city streets, and vehicular trails (4WD) (U.S. Census Bureau 2017). Within the AOA, new road density rasters, feature classes, and statistics were generated from these data using the NPScape road density standard operating procedures (NPS 2014a). Finally, the road density output was overlaid with the composite viewshed from the three key observation locations in order to visualize density within the monument's viewshed.

The NPScape 2010 housing density metrics were derived from Theobald's (2005) Spatially Explicit Regional Growth Model, SERGoM 100-m (328-ft) resolution housing density rasters. SERGoM forecasts changes on a decadal basis using county specific population estimates and variable growth rates that are location-specific. The SERGoM housing densities were grouped into six classes as shown in Table 10. NPScape's housing density standard operating procedure (NPS 2014b) and toolset were used to clip the raster to the monument's AOA then to recalculate the housing densities. The 2010 output was overlaid with the composite viewshed from the three key observation locations in order to visualize housing density within the monument's viewshed. Using the output from this analysis, we also calculated the

Table 10. Housing density classes.

Grouped Housing Density Class	Housing Density Class (units / km^2)
Urban-Regional Park	Urban-Regional Park
Commercial / Industrial	Commercial / Industrial
Urban	1,235
Suburban	146-1,234
Exurban	7-145
Rural and Private Undeveloped	0-6

percent change in housing density from 1970 to 2010 using ArcGIS Spatial Analyst's Raster Calculator tool.

The last measure we used was the conservation status of lands surrounding the monument. According to Monahan et al. (2012), "the percentage of land area protected provides an indication of conservation status and offers insight into potential threats (e.g., how much land is available for conversion and where it is located in relation to the NPS boundary), as well as opportunities (e.g., connectivity and networking of protected areas)." The USGS's Gap Analysis Program's (GAP) Protected Area Database (PAD) provides GIS data on public land ownership and conservation lands in the U.S. (USGS GAP 2016). The lands included in the PAD were assigned one of four GAP Status codes based on the degree of protection and management mandates. Tonto NM is considered GAP Status 1, which is described as follows, along with the remaining three categories:

GAP Status 1: Lands that have permanent protection from conversion of natural land cover and are managed for biodiversity and disturbance events.

GAP Status 2: Lands that have permanent protection from conversion of natural land cover and are managed for biodiversity but disturbance events are suppressed.

GAP Status 3: Lands that have permanent protection from conversion of natural land cover and are managed for multiple uses, ranging from low intensity (e.g., logging) to high intensity (e.g., mining).

GAP Status 4: No known mandate for protection and include legally mandated easements (USGS 2012).

NPScape's conservation status toolset was used to clip the PAD-US version 1.4 (USGS GAP 2016) to the monument's AOA, and then to recalculate the GAP Status and broad land ownership categories (e.g., federal, state, tribal, etc.) within the AOA (NPS 2014c). Finally, the conservation status output was overlaid with the composite viewshed from the three key observation locations in order to determine which GAP Status lands and lands by agency were most likely to be visible from the national monument.

Reference Conditions

We used qualitative reference conditions to assess the scenic and cultural integrity of Tonto NM's viewshed, which are presented in Table 11. Measures were described for resources in good condition, moderate concern condition, or significant concern condition.

Condition and Trend

Below we describe the conspicuousness of non-contributing features at each of the three key observation points beginning with the Upper Cliff Dwellings key observation point. The GIS analysis for

Table 11. Reference conditions used to assess viewshed.

Indicators	Measures	Good	Moderate Concern	Significant Concern
Scenic and Cultural Integrity	Conspicuousness of Non-contributing Features	The distance, size, color and shape, and movement and noise of the non-contributing features blended into the landscape.	The distance, size, color and shape, and movement and noise of some of the non-contributing features were conspicuous and detracted from the natural and cultural aspects of the landscape.	The distance, size, color and shape, and movement and noise of the non-contributing features dominated the landscape and significantly detracted from the natural and cultural aspects of the landscape.
	Extent of Development	Road and housing densities were low, with minor to no intrusion on the viewshed.	Road and housing densities were moderate, with some intrusion on the viewshed.	Road and housing densities were high with significant intrusion on the viewshed.
	Conservation Status	Scenic conservation status was high. The majority of land area in the monument's viewshed was considered GAP Status 1 or 2.	Scenic conservation status was moderate. The majority of land area in the monument's viewshed was considered GAP Status 3.	Scenic conservation status was low. The majority of land area in the monument's viewshed was considered GAP Status 4.

this location shows a wide swath of visible landscape to the northeast and east (Figure 8). According to the analysis, the viewshed extends well beyond Theodore Roosevelt Lake to the mountains behind the lake. In addition, the viewshed analysis shows that a narrow band to the south is visible, but it does not extend more than approximately 3.5 km (2.2 mi). This is consistent with the panoramic images, which show the lake in the middle ground and the mountains in the background to the southeast (Figure 9). The viewshed extends only to the foreground in the southeast because of the topography of the canyon, but the viewshed opens up again to the southwest with views into lands managed by the USFS.

Non-contributing features include a campground located on the west side of the lake and highway 188, but neither of those non-contributing features are conspicuous from this distance. The lake, however, could be considered a non-contributing feature since the Salt River was dammed in 1911 to form the lake (NPS 2003). The lake now provides recreational opportunities for fishing, motorized boating, camping, and other activities. There is also a marina on the lake, but it is not visible from the monument.

The Cave Springs riparian area below the viewpoint and within the monument is visible from this location with vegetation mostly comprised of native species, including Arizona sycamore (*Platanus wrightii*) and Arizona walnut (*Juglans major*) (Studd et al. 2017). The trail leading up to the cliff dwellings is also visible in the bottom image of Figure 9. Overall, the vegetation on the USFS from this location does not contrast with the monument's vegetation, but about halfway to the dwellings, the trail abuts the boundary of the USFS. From this location, visitors may notice a change in species composition and density of vegetation as a result of differing management practices by the NPS vs. USFS. Grazing was common in and around the monument until the late 1970s when construction of boundary fences began (NPS 2003). Grazing continued on USFS lands, and trespass grazing in the monument occurred until the boundary fence was finished in 1981 (NPS 2003). Figure 10 shows vegetation on the USFS side, while Figure 11 shows

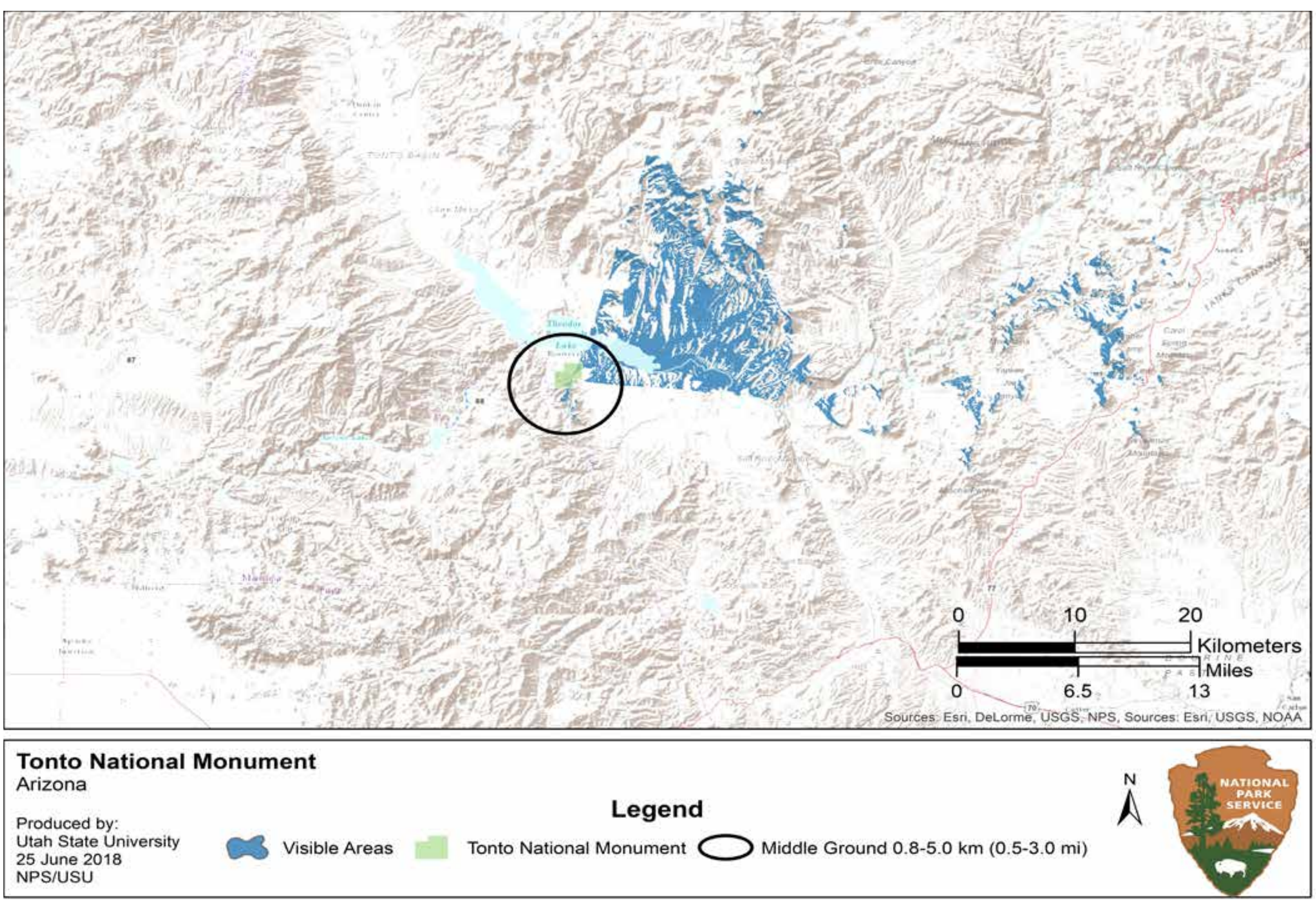


Figure 8. **The viewshed analysis from the Upper Cliff Dwellings key observation location.**

Figure 9. The northeast to southeast (top) and southeast to southwest (bottom) viewshed from the Upper Cliff Dwellings.

Figure 10. Vegetation on the USFS as observed from the Upper Cliff Dwellings trail.

Figure 11. Vegetation in Tonto NM as observed from the Upper Cliff Dwellings trail.

vegetation on the NPS side. However, even some areas within the monument may be damaged due to the effects of past grazing (Studd et al. 2017). Overall however, the viewshed from this location is in good condition. Confidence in the condition rating is high. Because these are baseline data, trend is unknown.

The viewshed from the Visitor Center key observation point extends to the immediate area, or foreground, and a large swath to the northeast that extends well into the background (Figure 12). The view is narrow in the middle ground as one looks down canyon and then widens to include views of Theodore Roosevelt Lake and the mountains behind the lake. This is consistent with the panoramic images which show a limited viewshed to the north, east, and south (Figure 13). The viewshed to the northeast is narrow but allows for distant views. As previously mentioned, panoramas for the south to west and west to north were not available due to an equipment failure. However, the viewshed in these directions includes lands managed by the monument, the visitor center, restrooms, parking area,

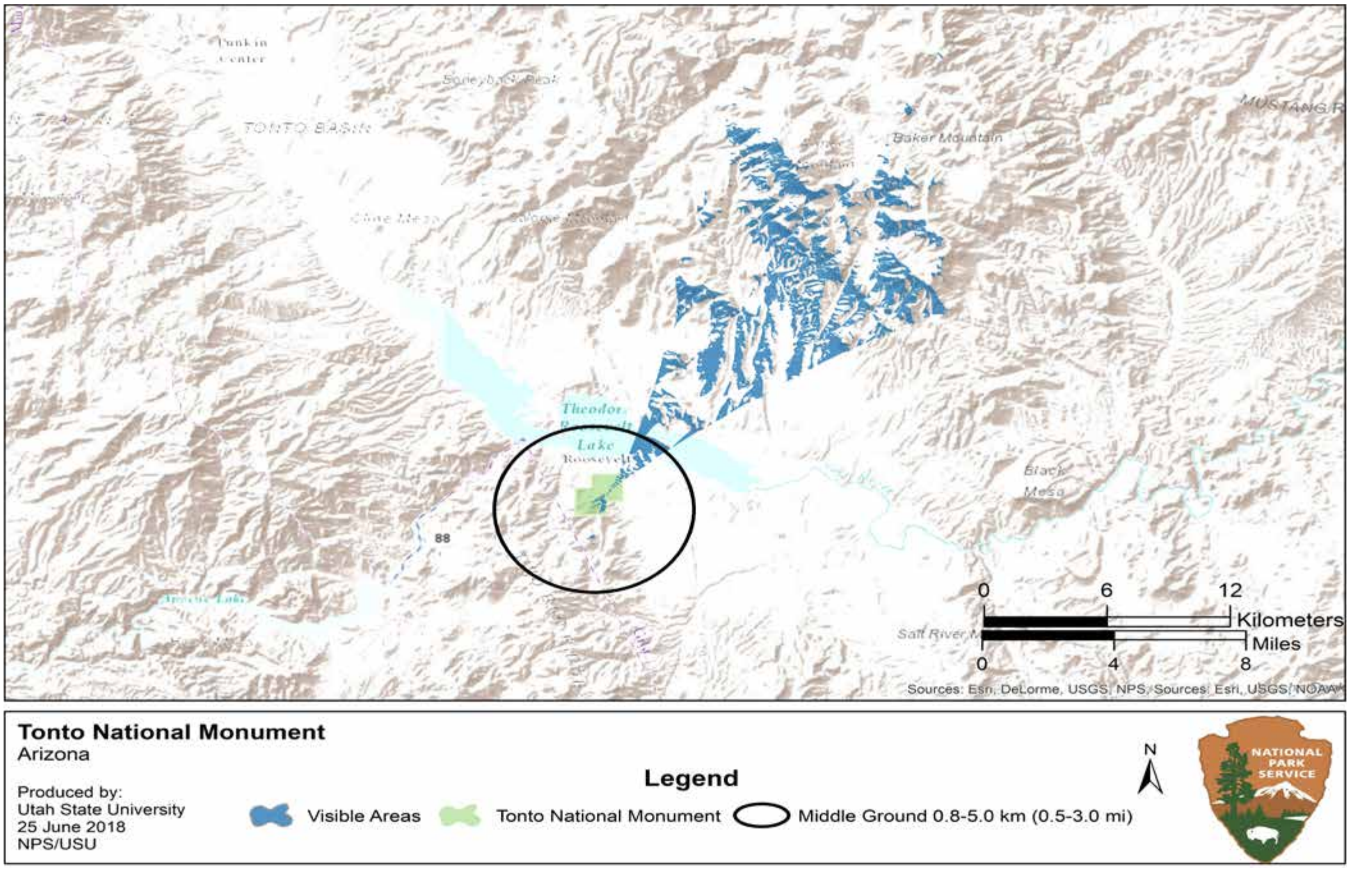


Figure 12. **The viewshed analysis from the Visitor Center key observation location.**

Figure 13. **The north to east (top) and east to south (bottom) viewshed from the Visitor Center.**

a picnic area, and a view of the lower cliff dwellings in the middle ground. All of these features except for the Lower Cliff Dwellings are non-contributing features. However, the non-contributing footprint in the monument is relatively small, and these services generally enhance the visitor experience. The overall viewshed from this location is good. Confidence in the condition rating is high. Trend is unknown.

The viewshed from Scenic View-HWY188 was the longest, extending almost to the farthest extent of the background (Figure 14). Unlike the other locations, the viewshed from this area offers views to the northwest and limited views to the northeast. The scenic pullout offers visitors the opportunity to view the cliff dwellings from the highway when the monument is closed. The panoramas are consistent with the viewshed analysis. Figure 15 shows views to the north and east that extend beyond the lake (top image) as well as views of the mountains in the background from the east to south (bottom image). Aside from vegetation that is blocking foreground and middle ground views toward the south, the rolling topography also limits views of these areas. The lower cliff dwellings are visible in Figure 16. The viewshed from the south to north shown in Figure 16 mostly include the foreground and middle ground except for a fairly long view to the northwest (bottom image). The landscape to the northwest includes the national monument, but the rest of the landscape is managed by the USFS.

The non-contributing features include the parking area, vehicles, sidewalks, the highway, power lines, barbed wire fencing, and the interpretive signs. While these features are conspicuous because they are in the foreground, the pullout itself was constructed to offer those who are unable to visit the monument, a way to observe the cliff dwellings. The interpretive signs provide context for these views. Because this location is outside of the monument, the presence of non-contributing features is expected. Probably the most obvious are the power lines, poles, and towers. Despite these non-contributing features, the overall viewshed from this location is good. Confidence in the condition rating is high. Trend is unknown.

In summary, the viewsheds at the three locations in Tonto NM are mostly intact. There are few non-contributing features and those that are visible detract little from the overall viewshed because of

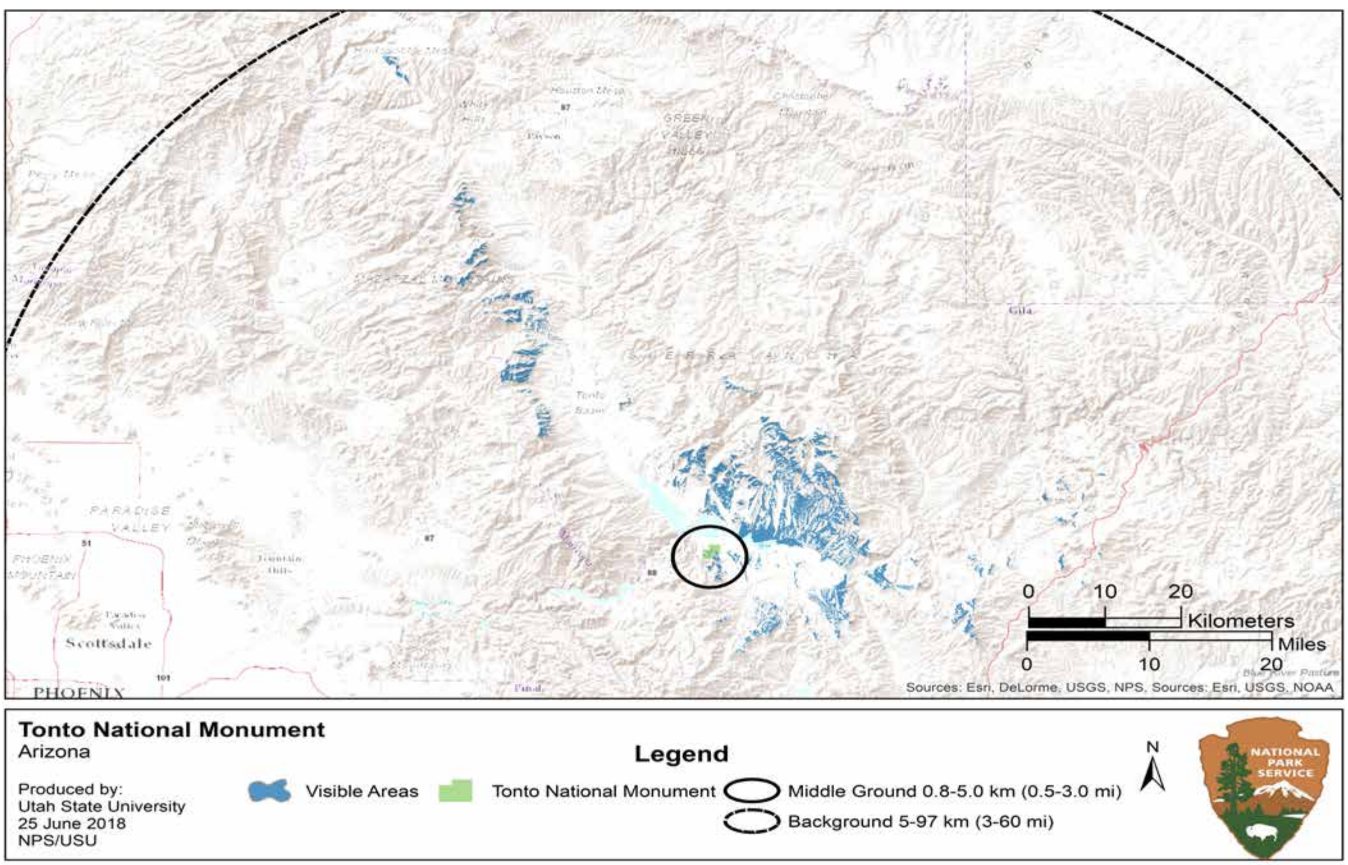


Figure 14. **The viewshed analysis from the Scenic View-HWY 188 key observation location.**

Figure 15. **The north to east (top) and east to south (bottom) viewshed from the Scenic View-HWY 188.**

Figure 16. **The south to west (top) and west to north (bottom) viewshed from the Scenic View-HWY 188.**

either distance, color, or context (e.g., interpretive signs). Therefore, the condition is good. Confidence in the condition rating is high. Trend could not be determined. Rather, these images provide baseline data that can be used to compare to future panoramas.

The second measure, extent of development, was evaluated using road density and housing density. Figure 17 shows road density by various classes. Total road density within the 98 km (61 mi) AOA surrounding the monument was 1.63 km/km^2. Road density within the monument's viewshed was less dense than it was elsewhere in the AOA. The lower road density in the AOA suggests that roads probably do not detract significantly from viewshed quality in areas of the monument that were not included in this assessment. From the three viewshed locations included in this assessment, Highway 188 was the only road visible, but it did not detract significantly from the viewshed because, except for the Scenic View-HWY 188 location, the road was distant with generally light traffic, at least during the NRCA scoping meeting in early May. Although other roads occur in the viewshed, they were not noticeable. Furthemore, the monument's only visitor access road was not visible in any of the panoramas, nor were any of the maintenance roads or NPS housing and administrative areas visible.

Based on data compiled in NPScape (Monahan et al. 2012), housing densities surrounding the monument were low (Table 12). The majority of all housing consisted of rural and private undeveloped lands (77%). The white spaces within the 98 km (61 mi) boundary shown in Figure 18 indicate no census data; thus, housing densities could not be calculated for these areas. However, these data originated with the U.S. Census Bureau, and units with unknown densities were probably not reported, which likely indicates undeveloped areas. Most of the monument's viewshed was located within these white spaces. This was expected since the monument is surrounded by the USFS. From 1970 to 2010, 72% of the AOA showed no change in housing density, while 28% of the AOA showed an increase in housing density. Virtually none of the AOA declined in housing density.

To summarize the extent of development measure, road density was low and housing density was almost entirely rural or private undeveloped, which indicates good condition. However, confidence is medium

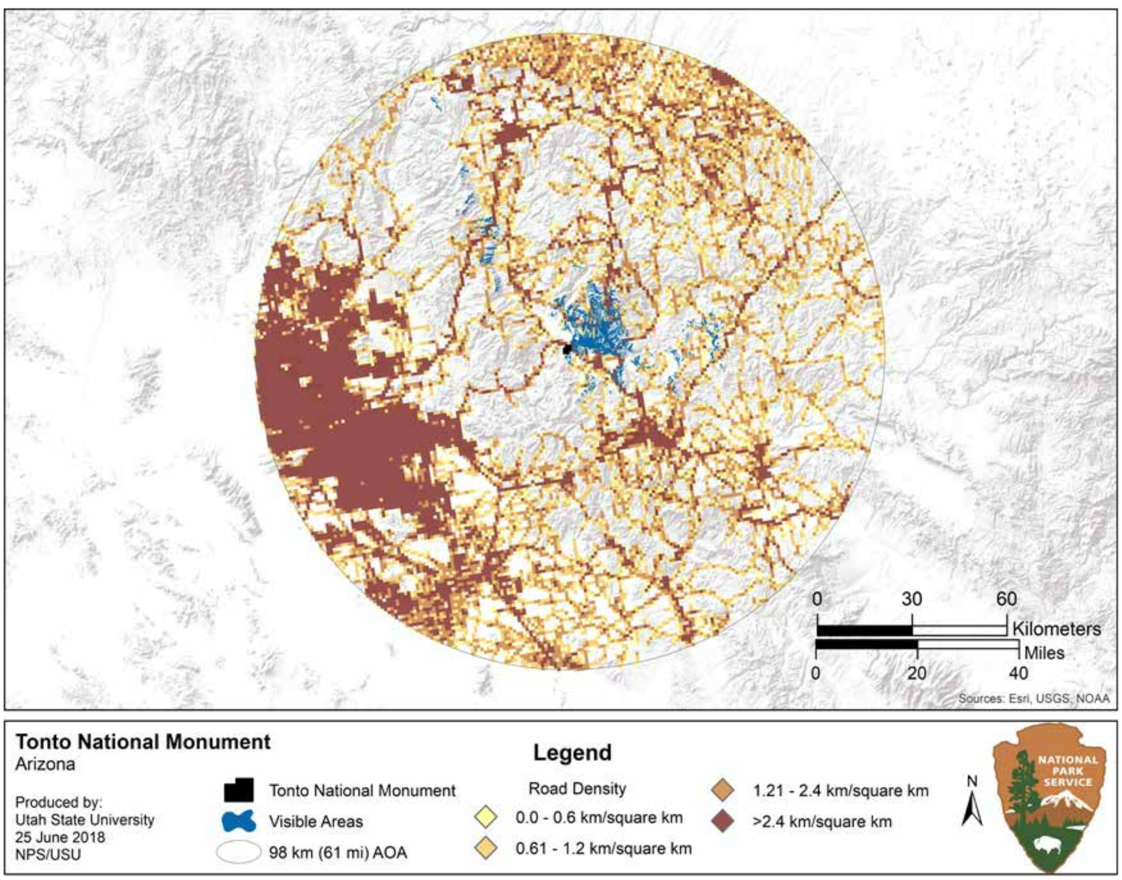


Figure 17. **Road density and visible areas in and around Tonto NM.**

Table 12. Housing densities within a 98 km (61 mi) buffer around Tonto NM.

Density Class	Area (km²)	Percent
Rural and Private Undeveloped	10,195	77
Exurban	1,082	8
Suburban	947	7
Urban	65	0.5
Urban-Regional Park	279	2
Commercial/Industrial	740	5.5
Total Area	13,307	100

because most of the monument's viewshed is located in areas without U.S. Census data for housing. Trend in housing density, which is related to road density, was mostly unchanging, but some areas have increased in housing density.

The following summarizes the condition for the third and final measure—conservation status. Figure 19 shows the amount of land within the composite viewshed and AOA. Of the total AOA, 97% was categorized in one of the four GAP status classes. Nearly half (48.4%) of land area within the AOA was within GAP Status 3, or permanently protected lands managed for multiple uses (e.g., mining or logging). Only 8.7% of land within the AOA was GAP Status 1 (permanently protected lands managed for biodiversity and natural processes) or GAP Status 2 (permanently protected lands managed for biodiversity but with suppression of disturbances). Finally, 40% of land was considered GAP status 4 (no known protections). The remaining 3% of land was not classified in any of the GAP status categories, which indicates private land. Tonto NM's viewshed is primarily within GAP Status 3, which allows for extractive uses, followed by GAP Status 1, which are fully protected lands.

Figure 20 shows the management agencies that administer land within the AOA. The USFS administers the largest land area within the AOA (53%) followed by the Bureau of Indian Affairs (29%). Most of the remaining lands (18%) within the AOA are private (i.e., white spaces), state lands, county land, land owned by cities, or national park service lands. The monument's entire viewshed was within the USFS.

Overall, scenic conservation status was moderate, with GAP Status 3 and 1 lands that are managed by the USFS. Although the viewshed occurred largely in GAP Status 3 lands, the current viewshed of these areas is good based on the panoramas. However, extractive uses on

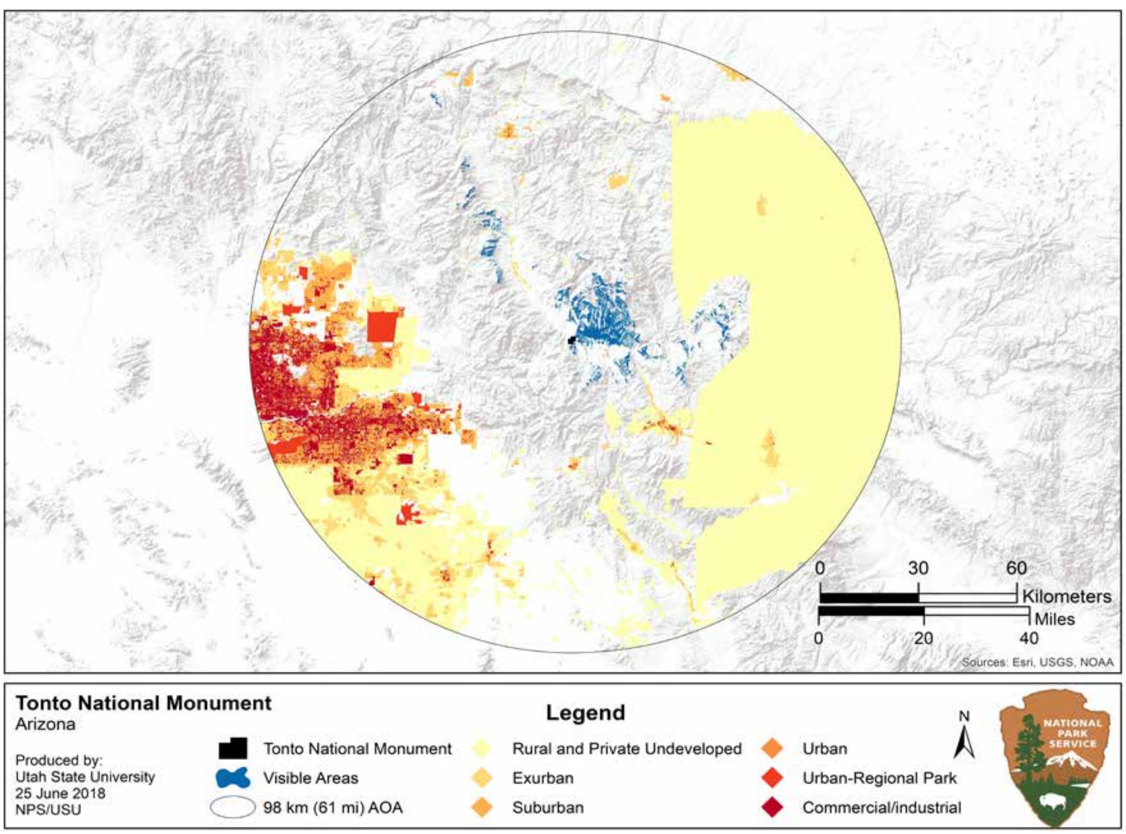


Figure 18. A map of housing density surrounding Tonto NM.

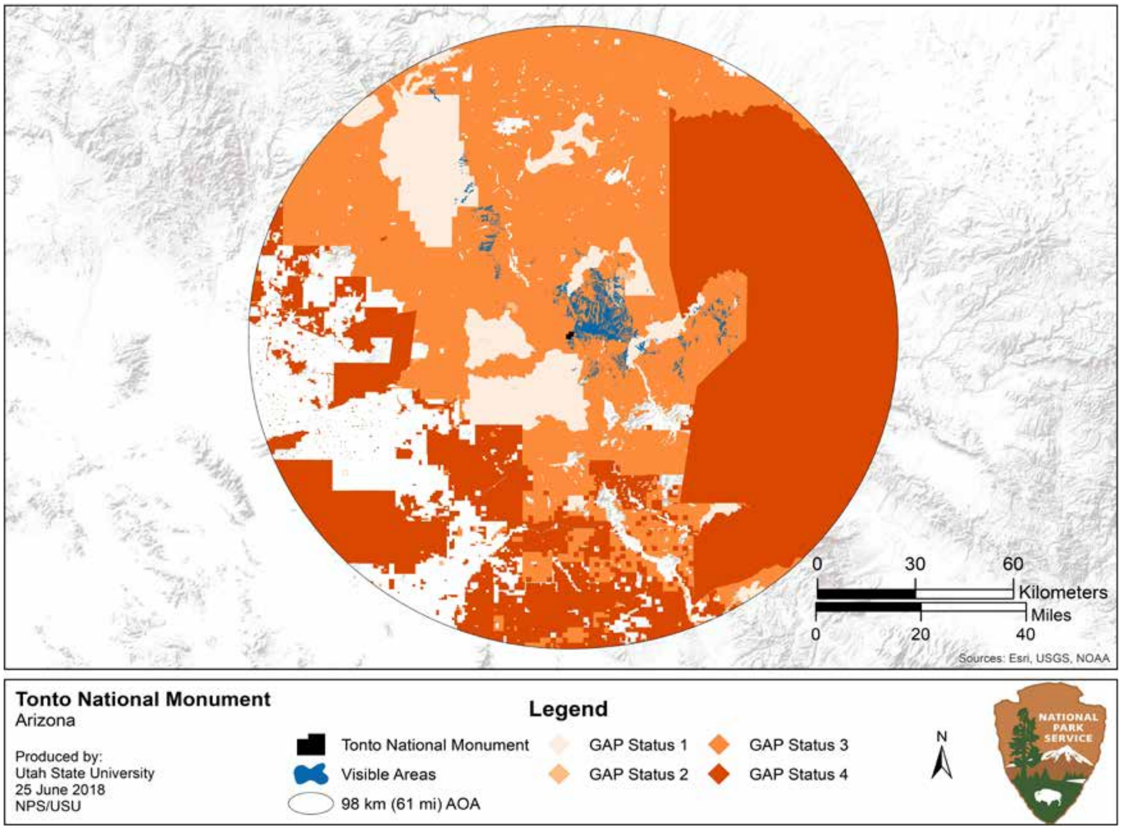


Figure 19. A map of GAP status lands surrounding Tonto NM.

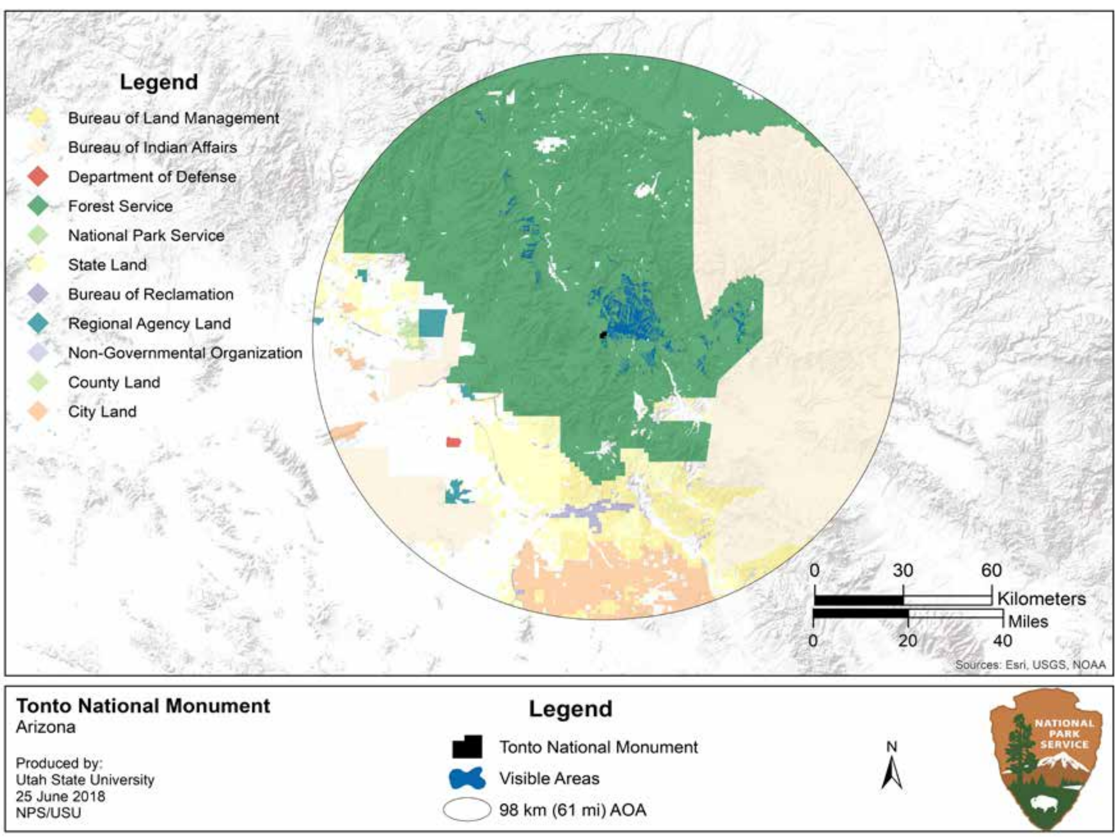


Figure 20. A map of lands managed by various agencies surrounding Tonto NM.

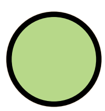
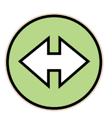
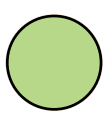
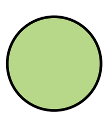
USFS lands could occur. Trend is unknown. Although confidence in the GAP Status and land management agency data is high, the viewshed analysis has medium confidence. A finer scale DEM coupled with an offset to account for vegetation height would possibly increase accuracy. Although vegetation in and around Tonto NM does not generally limit the viewshed since the dominant cover type is short-statured Sonoran desert scrub, semi-desert shrublands, and montane shrublands (Studd et al. 2017). Nevertheless, the confidence in the condition rating for this measure is medium.

Overall Condition, Threats, and Data Gaps

Based on this assessment, the viewshed condition at Tonto NM is good (Table 13). There were few non-contributing features in the monument's viewshed as observed from the three key observation locations, especially from the two points within the monument. Because this assessment represents baseline conditions, we could not report on trend. Two of the three measures were assigned medium confidence and one was assigned high confidence. Factors that influence confidence level include age of the data (<5 years unless the data were part of a long-term monitoring effort), repeatability, field data versus modeled data, and whether data can be extrapolated to other areas in the monument. We assigned medium confidence to extent of development and conservation status measures because the viewshed analysis was based entirely on modeled data with a relatively coarse scale DEM and did not account for vegetation or other factors that may have influenced the viewshed analysis. Thus, the overall confidence is medium. The viewshed analysis should not be used for planning purposes until ground-truthed. Because of the scale of the DEM used, there is some uncertainty regarding the accuracy of the viewshed analysis.

Potential threats to Tonto NM's viewshed include wildfire (including the effects of smoke on visibility and burned vegetation in a non-fire adapted system), mining on USFS lands, commercial recreation on Theodore Roosevelt Lake, expansion or increased use of the campground on the lake, and atmospheric dust and smog as a result of climate change. The haze index, which is a measure of visibility as described in the air quality assessment, warrants moderate concern at Tonto NM; however, the trend has improved over the last ten-year period analyzed (2006-2015) (refer to air quality assessment). Factors that influence air quality may also influence the viewshed. Other threats

Table 13. Summary of the viewshed indicators, measures, and condition rationale.

Indicators	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Scenic and Historic Integrity	Conspicuousness of Non-contributing Features		There were few non-contributing features in the monument's viewshed as observed from the three key observation locations. Most of these features were in the foreground and were there to enhance the visitor experience. Non-contributing features that were not related to visitors included fencing and power lines, poles, and towers at the scenic pullout site. Trend is unknown and confidence is high.
	Extent of Development		The composite viewshed shows that areas to northeast were most visible. The majority of all housing consisted of rural and private undeveloped lands (77%). Total road density (1.63 km/km^2), which indicates a rural landscape. Since 1970, 28% of the AOA increased in housing density while 72% remained unchanged. This is because much of the AOA is managed by the USFS. Based on these results, the condition for this measure is good. Trend is unchanging and confidence is medium.
	Conservation Status		While there were some areas where scenic conservation status was high, many of the land management agencies responsible for the lands that were visible from Tonto NM's key observation points allow for extractive uses from logging to mining. However, none of these activities were visible in the panoramas. Therefore, the condition is good. Because of uncertainties with the viewshed analysis, confidence is medium. Trend is unknown.
Overall Condition	Summary of All Measures		There were few non-contributing features in the monument's viewshed. The housing and road density analyses show that the region surrounding the monument is mostly rural, and most of the landscape in the AOA was GAP Status 3 and, to a lesser extent, GAP Status 1. Confidence in the overall condition rating is medium. Overall trend is unknown.

include the deterioration of cultural features as a result of natural processes, vandalism or theft of cultural artifacts (NPS 2017a), and light pollution from nearby communities as discussed in the night sky assessment.

Data gaps include the need for fine-scale DEM. The 30-m DEM used in this assessment may have excluded some areas that should be visible or, conversely, included areas that are not visible. Although fine-scale LIDAR (light detection and ranging) data exist for the monument, these data were not available for the entire AOA.

Sources of Expertise

Assessment author was Lisa Baril, wildlife biologist and science writer, Utah State University. Subject matter expert reviewers for this assessment are listed in Appendix A. Note that the measures and methods used for assessing the condition of the monument's viewshed are different from the measures/methods recommended by the NPS Visual Resources Program in the Air Resources Division under 2018 draft guidance that post-dates this viewshed assessment. Please contact the NPS Visual Resource Program for more information: visual_resources@nps.gov.

Night Sky

Background and Importance

Natural dark skies are a valued resource within the NPS as reflected in NPS management policies (NPS 2006a), which highlights the importance of a natural photic environment to ecosystem function and the importance of the natural lightscape for aesthetics. The NPS Natural Sounds and Night Skies Division (NSNSD) makes a distinction between a lightscape—which is the human perception of the nighttime scene, including both the night sky and the faintly illuminated terrain, and the photic environment—which is the totality of the pattern of light at night at all wavelengths (Moore et al. 2013).

Lightscapes are an aesthetic and experiential quality that is integral to natural and cultural resources. A 2007 visitor survey conducted throughout Utah national parks found that 86% of visitors thought the quality of park night skies was "somewhat important" or "very important" to their visit (NPS 2010b). Additionally, in an estimated 20 national parks, stargazing events are the most popular ranger-led program (NPS 2010b).

The value of night skies goes far beyond visitor experience and scenery. The photic environment affects a broad range of species, is integral to ecosystems, and is a natural physical process (Longcore and Rich 2004). Natural light intensity varies during the day-night (diurnal) cycle, the lunar cycle, and the seasonal cycle. Organisms have evolved to respond to these periodic changes in light levels in ways that control or influence movement, feeding, mating, emergence, seasonal breeding, migration, hibernation, and dormancy. Plants also respond to light levels by flowering, vegetative growth, and their direction of growth (Royal Commission on Environmental Pollution 2009). Given the effects of light on living organisms, it is likely that the introduction of artificial light into the natural light/darkness regime will disturb the normal routines of many plants and animals (Royal Commission on Environmental Pollution 2009), as well as diminish stargazing recreational opportunities offered to national park visitors.

Tonto National Monument (NM) hosts interpretive programs each winter and spring as part of their "Park After Dark" series (NPS 2018c). These ranger-led programs focus on: teaching visitors how to identify stars, constellations, and planets; making the connection between the night sky and Native Americans and Ancestral Salado peoples; and celebrating celestial events like the solstices (NPS 2018c). Preserving a dark night sky is essential for the continuation of these programs in the monument.

A time lapse photograph of the night sky and cliff dwellings at Tonto NM. Photo Credit: © Rex and Peg Lavoie.

Data and Methods

The NSNSD goals of measuring night sky brightness are to describe the quality of the lightscape, quantify how much it deviates from natural conditions, and to describe changes over time as a result of both natural and anthropogenic sources in areas within and outside of national parks (Duriscoe et al. 2007). This assessment includes a single measure of sky brightness: the all-sky light pollution ratio, which is described below.

The all-sky light pollution ratio (ALR) describes the amount of light that is due to man-made sources compared to light from a natural dark sky. It is the average anthropogenic sky luminance presented as a ratio over natural conditions (Moore et al. 2013). It is a useful metric to average the light flux over the entire sky (measuring all that is above the horizon and omitting the terrain). Recent advances in modeling the natural components of the night sky allow separation of anthropogenic light from natural features, such as the Milky Way. A natural night sky has an average brightness across the entire sky of 78 nL (nanolamberts, a measure of luminance), and includes features such as the Milky Way, Zodiacal light, airglow, and other starlight (Moore et al. 2013). This is figured into the ratio, so that an ALR reading of 0.0 would indicate pristine natural conditions where the anthropogenic component was 0 nL. A ratio of 1.0 would indicate that anthropogenic light was 100% as bright as the natural light from the night sky (Moore et al. 2013).

Supermoon at Tonto NM. Photo Credit: NPS/M. Stewart.

This metric is a convenient and robust measure. It is most accurately obtained from ground-based measurements with the NPS Night Skies Program's photometric system, however, it can also be modeled with moderate confidence when such measurements are not available. Modeled ALR data were based on 2015 National Oceanic and Atmospheric Administration (NOAA) and National Aeronautics and Space Administration (NASA) Day/Night Band data collected by the Visible Infrared Imaging Radiometer Suite instrument located on the Suomi National Polar Orbiting Partnership satellite (NASA 2018).

Reference Conditions

Table 14 summarizes the condition thresholds for an ALR in good, moderate concern, and significant concern condition. The ideal night sky reference condition, regardless of how it's measured, is one devoid of any light pollution. However, results from night sky data collection throughout more than 90 national parks suggest that a pristine night sky is very rare (NPS 2010b). Tonto NM is considered a non-urban NPS unit, or unit with at least 90% of its property located outside an urban area (Moore et al. 2013). For non-urban NPS units thresholds separating reference conditions of good, moderate concern, and significant concern are more stringent than those for urban NPS units because near-pristine skies are more sensitive to the presence of light pollution. The threshold for non-urban night skies in good condition is an ALR <0.33 and the threshold for warranting moderate concern is ALR 0.33-2.00. An ALR >2.00 would warrant significant concern (Moore et al. 2013).

Condition and Trend

The NPS Night Skies Program modeling data show a median monument-wide ALR of 1.76, which corresponds to 176% brighter than average natural conditions. This value falls within the moderate concern condition rating. Confidence in this condition rating is medium since the data were modeled and there are no supporting field measurements. Trend could not be determined.

Figure 21 shows the modeled ALR for the region surrounding Tonto NM. The figure shows that the monument is most influenced by lights from Phoenix, Arizona located approximately 88 km (55 mi) west of the monument. Figure 21 also shows that the light from Tucson, Arizona, located 164 km (102 mi) south of the monument, influences the night sky brightness

Table 14. Reference conditions used to assess the night sky.

Indicator	Measure	Good	Moderate Concern	Significant Concern
Sky Brightness*	All-sky Light Pollution Ratio (ALR)	ALR <0.33 (<26 nL average anthropogenic light in sky)	ALR 0.33-2.00 (26 - 156 nL average anthropogenic light in sky)	ALR >2.00 (>156 nL average anthropogenic light in sky)

*National Park Service Natural Sounds and Night Skies thresholds for non-urban parks. Non-urban parks are those with at least 90% of their land located outside an urban area (Moore et al. 2013).

at Tonto NM. Although the light from these cities influence the night sky environment at Tonto NM, the ALR is relatively low for such close proximity to major urban areas.

Overall Condition, Threats, and Data Gaps

The overall condition for the night sky at Tonto NM is of moderate concern based on the single measure of sky brightness (Table 15). Confidence in the condition rating is medium. Trend could not be determined. A key uncertainty is whether the modeled ALR value accurately reflects conditions within the monument. As with all models, there is some uncertainty associated with the results. Additional data would reduce this uncertainty.

Arizona contains some of the darkest night skies in the U.S. The International Dark-Sky Association (IDA) has awarded dark sky designations to three communities and eight state and national parks throughout Arizona (IDA 2018). The IDA's mission is to protect dark night skies throughout the world. The bordering states of New Mexico and Utah also contain numerous IDA designations. Furthermore, Tonto NM is just south of the Colorado Plateau, which alone contains 17 dark sky designations for parks, monuments, and communities (IDA 2018). The relatively low population density and high elevation of many areas in Arizona enhance dark night skies in the state. Furthermore, there are many communities in Arizona dedicated to protecting dark night skies. For example, by mid-2017, night lighting in Tucson, Arizona was reduced by 7% after thousands

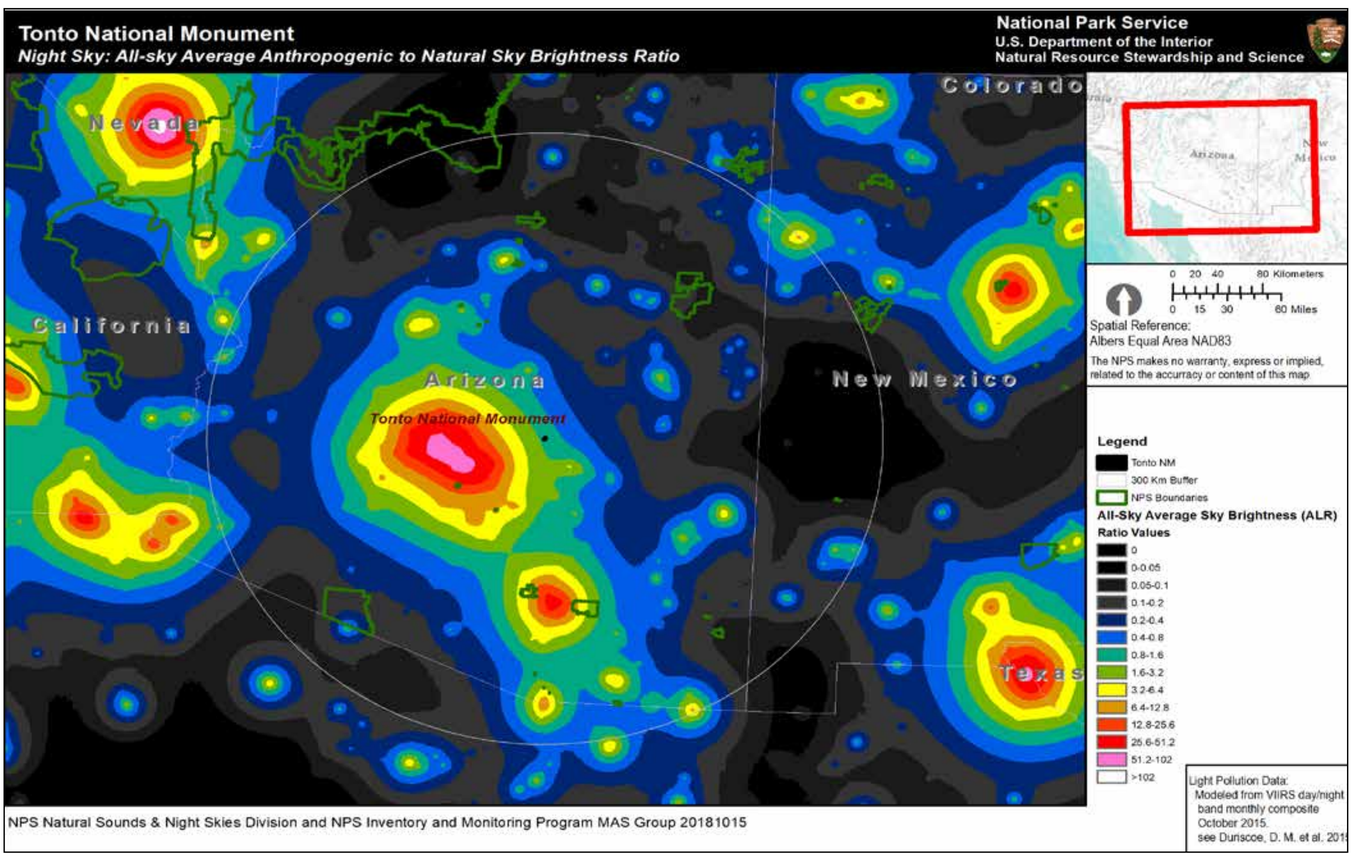


Figure 21. Modeled ALR map for Tonto NM. Figure Credit: NPS Natural Sounds and Night Skies Division.

Table 15. Summary of night sky indicators, measures, and condition rationale.

Indicator	Measure	Condition/ Trend/ Confidence	Rationale for Condition
Sky Brightness	All-sky Light Pollution Ratio (ALR)		Modeled park-wide ALR was 1.76, which corresponds to a condition rating of moderate concern. Confidence in this condition rating is medium since data were modeled. Trend could not be determined.
Overall Condition	Summary of Measure		Overall, the night sky at Tonto NM warrants moderate concern. This condition rating is based on one measure of sky brightness. Confidence in the condition rating is medium since the data were modeled and only one measure was used. Overall trend could not be determined. Data gaps include lack of other night sky measures, including zenith sky brightness and the Bortle Dark Sky Scale.

of street lights were converted to more energy-efficient and night sky-friendly lighting (Barentine et al. 2018).

Because Tonto NM is located within the Tonto National Forest, there are relatively few local threats to the nocturnal lightscape. However, encroaching lights from nearby developed areas (e.g., Globe, Arizona) and the urban expansion of more distant cities (e.g., Phoenix, Arizona) threaten the future of the dark night sky in the monument. Highway 188 traverses the northeastern edge of the monument, and any increase in lighting or traffic along the roadway could impact night skies in the area. Worldwide, the Earth's artificial outdoor lighting has increased by 2.2% per year between 2012 and 2016 (Kyba et al. 2017). Atmospheric dust and pollution from major metropolitan areas may also degrade the visibility of stars and other celestial features. The haze index, which is a measure of visibility, warrants moderate concern at Tonto NM according to NPS Air Resources Division data, although the condition has improved from 2006 to 2015 (refer to air quality assessment).

Not only does nocturnal light pollution degrade aesthetics of the night sky environment, but it also affects nocturnal wildlife. Bats, owls, and even invertebrates are influenced by artificial lighting (Longcore and Rich 2006). There are at least 11 species of bats in the national monument in addition to other nocturnal mammals including skunks (*Mephitis* spp., *Spilogale* sp., *Conepatus* sp.), white-throated woodrats (*Neotoma albigula*), and ringtails (*Bassariscus astutus*) (NPS 2018a).

Data gaps include the absence of other night sky measures such as zenith sky brightness, the Bortle Dark Sky scale, vertical and horizontal illuminance, and ground-based ALR measurements. It would also be useful to repeat measurements on a regular basis to track changes over time. To fill this gap in knowledge and to protect and improve the night sky environment at the monument, staff are pursuing a dark sky designation from the IDA. To facilitate this goal, monument staff are in the process of retrofitting light fixtures to reduce light pollution produced within the monument and to meet IDA standards. Additional data will also be collected to support the application for a dark sky designation.

Sources of Expertise

The NPS Natural Sounds and Night Skies Division helps parks manage the night sky in a way that protects park resources and the visitor experience. They provide technical assistance to parks in the form of monitoring, data collection and analysis, and in developing baselines for planning and reporting purposes. For more information, visit the NPS-NSNSD website (NPS-NSNSD 2018). Assessment author is Lisa Baril, science writer, Utah State University. Subject matter expert reviewers for this assessment are listed in Appendix A.

Air Quality

Background and Importance

The National Park Service's (NPS) Organic Act, Air Quality Management Policy 4.7.1 (NPS 2006a), and the Clean Air Act (CAA) guide the NPS to protect air quality and any air quality related values (e.g., scenic, biological, cultural, and recreational resources) within national parks that may be impaired from air pollutants.

Among the main purposes of the CAA is "to preserve, protect, and enhance the air quality in national parks" and other areas of special national or regional natural, recreational, scenic, or historic value. The CAA includes special programs to prevent significant air quality deterioration in clean air areas and to protect visibility in national parks and wilderness areas (NPS Air Resources Division [ARD] 2018a).

Two categories of air quality areas have been established through the authority of the CAA: Class I and II. The air quality classes are allowed different levels of permissible air pollution, with Class I receiving the greatest protection and strictest regulation. The CAA gives federal land managers responsibilities and opportunities to participate in decisions being made by regulatory agencies that might affect air quality in the federally protected areas they administer (NPS ARD 2005).

Tonto National Monument (NM) is designated as a Class II airshed. The NPS Organic Act and NPS management policies direct that all units of the National Park System be managed so as to protect resources for the benefit of current and future generations (NPS 2006a).

Air quality is deteriorated by many forms of pollutants that either occur as primary pollutants, emitted directly from sources such as power plants, vehicles, wildfires, and wind-blown dust, or as secondary pollutants, which result from atmospheric chemical reactions. The CAA requires the U.S. Environmental Protection Agency (USEPA) to establish National Ambient Air Quality Standards (NAAQS) (40 CFR part 50) to regulate these air pollutants that are considered harmful to human health and the environment (USEPA 2016). The two types of NAAQS are primary and secondary, with the primary standards establishing limits to protect human health, and the secondary standards establishing limits to protect public welfare from air pollution effects, including decreased visibility, and damage to animals, crops, vegetation, and buildings (USEPA 2016).

The NPS ARD (NPS ARD) uses USEPA's NAAQS, natural visibility goals and ecological thresholds as benchmarks to assess current conditions of visibility, ozone, and atmospheric deposition throughout Park Service areas. Visibility affects how well (acuity) and

Wildflowers under a clear blue sky at Tonto NM. Photo Credit: NPS.

how far (visual range) one can see (NPS ARD 2002), but air pollution can degrade visibility. Particulate matter (e.g. soot, dust, and sulfate and nitrate particles) and certain gases in the atmosphere can create haze and reduce visibility.

Ozone is a gaseous constituent of the atmosphere produced by reactions of nitrogen oxides (NO_x) from vehicles, powerplants, industry, fire, and volatile organic compounds from industry, solvents, and vegetation in the presence of sunlight (Porter and Wondrak-Biel 2011). It is one of the most widespread air pollutants, and the major constituent in smog. Ozone can be harmful to human health. Exposure to ozone can irritate the respiratory system and increase the susceptibility of the lungs to infections (NPS ARD 2018b).

Ozone is also phytotoxic, causing foliar damage to plants (NPS ARD 2018c). Ozone penetrates leaves through stomata (openings) and oxidizes plant tissue, which alters physiological and biochemical processes (NPS ARD 2018c). Once the ozone is inside the plant's cellular system, the chemical reactions can cause cell injury or even death but more often reduces the plant's resistance to insects and diseases, limits growth, and lowers reproductive capability (NPS ARD 2018c).

Foliar damage requires the interplay of several factors, including the sensitivity of the plant to the ozone, the level of ozone exposure, and the exposure environment (e.g., soil moisture). The highest ozone risk for plants exists when a species is highly sensitive to ozone, the exposure levels of ozone significantly exceed the thresholds for foliar injury, and the environmental conditions, particularly adequate soil moisture, foster gas exchange and the uptake of ozone by plants (NPS ARD 2018c).

Air pollutants can be deposited to ecosystems through rain and snow (wet deposition) or dust and gases (dry deposition). Nitrogen and sulfur air pollutants are commonly deposited as nitrate, ammonium, and sulfate ions and can have a variety of effects on ecosystem health, including acidification, fertilization or eutrophication. Mercury or toxins can also be deposited to ecosystems (NPS ARD 2010, Fowler et al. 2013). Atmospheric deposition can also change soil pH, which in turn affects microorganisms, understory plants, and trees (NPS ARD 2010). Certain ecosystems are more vulnerable to nitrogen or sulfur deposition than others, including high-elevation ecosystems in the western United States, upland areas in the eastern part of the country, areas on granitic bedrock, coastal and estuarine waters, arid ecosystems, and some grasslands (NPS ARD 2018c). Increases in nitrogen have been found to promote invasions of fast-growing non-native annual grasses (e.g., cheatgrass [*Bromus tectorum*]) and forbs (e.g., Russian thistle [*Salsola tragus*] at the expense of native species (Allen et al. 2009, Schwinning et al. 2005). Increased grasses can increase fire risk (Rao et al. 2010), with profound implications for biodiversity in non-fire adapted ecosystems. Nitrogen may also increase water use in plants like big sagebrush (*Artemisia tridentata*) (Inouye 2006).

According to the USEPA (2017), in the United States, roughly two thirds of all sulfur dioxide (SO_2) and one quarter of all nitrogen oxides (NO_x) come from electric power generation that relies on burning fossil fuels. Sulfur dioxide and nitrogen oxides are released from power plants and other sources, and ammonia is released by agricultural activities, feedlots, fires, and catalytic converters. In the atmosphere, these transform to sulfate, nitrate, and ammonium, and can be transported long distances across state and national borders, impacting resources (USEPA 2017), including at Tonto NM.

Mercury and other toxic pollutants (e.g., pesticides, dioxins, PCBs) accumulate in the food chain and can affect both wildlife and human health. Elevated levels of mercury and other airborne toxic pollutants like pesticides in aquatic and terrestrial food webs can act as neurotoxins in biota that accumulate fat and/or muscle-loving contaminants. Sources of atmospheric mercury include by-products of coal-fire combustion, municipal and medical incineration, mining operations, volcanoes, and geothermal vents. High mercury concentrations in birds, mammals, amphibians, and fish can result in reduced foraging efficiency, survival, and reproductive success (NPS ARD 2018d).

Additional air contaminants of concern include pesticides (e.g., DDT), industrial by-products (PCBs), and emerging chemicals such as flame retardants for fabrics (PBDEs). These pollutants enter the atmosphere from historically contaminated soils, current day industrial practices, and air pollution (Selin 2009).

Data and Methods

The approach we used to assess the condition of air quality within Tonto NM's airshed was developed by the NPS ARD for use in Natural Resource Condition Assessments (NPS ARD 2018e). NPS ARD uses three indicators with a total of six measures. The indicators are visibility (one measure), level of ozone (two measures), and wet deposition (three measures) (Table 16). NPS ARD uses all available data from NPS, USEPA, state, and/or tribal monitoring stations to interpolate air quality values. Even though the data were derived from all available monitors, data from the closest stations "outweigh" the rest. Trends are computed from data collected over a 10-year period (2006-2015) at on-site or nearby representative monitors. Trends are calculated for sites that have at least six years of annual data and an annual value for the end year of the reporting period.

The haze index is the single measure of the visibility indicator used by NPS ARD. Visibility is monitored through the Interagency Monitoring of Protected Visual Environments (IMPROVE) Program (NPS ARD 2010) and annual average measurements for Group 50 visibility (i.e,. days during which the visibility is between the 40th and 60th percentiles) are averaged over a 5-year period (2011-2015) at each visibility monitoring site with at least 3-years of complete annual data. Five-year averages are then interpolated across all monitoring locations to estimate 5-year average values for the contiguous U.S. The maximum value within Tonto NM's boundaries is reported as the visibility condition from this national analysis. Visibility trends were computed from the Haze Index values on the 20% haziest days and the 20% clearest days, consistent with visibility goals in the CAA and Regional Haze Rule, which include improving visibility on the haziest days and allowing no deterioration on the clearest days. Although this legislation provides special protection for NPS areas designated as Class I, the NPS applies these standard visibility metrics to all units of the NPS. If the Haze Index trend on the 20% clearest days is deteriorating, the overall visibility trend is reported as deteriorating. Otherwise, the Haze Index trend on the 20% haziest days is reported as the overall visibility trend. The IMPROVE monitor TONT1 used to determine trends is located in Tonto, Arizona.

Table 16. Summary of indicators and their measures.

Indicators	Measures
Visibility	Haze Index
Level of Ozone	Human Health, Vegetation Health
Wet Deposition	Nitrogen, Sulfur, Mercury, Predicted Methylmercury Concentration

The second indicator (ozone) is monitored across the U.S. through air quality monitoring networks operated by the NPS, USEPA, states, and others. Aggregated ozone data were acquired from the USEPA Air Quality System (AQS) database. Note that prior to 2012, monitoring data were also obtained from the USEPA Clean Air Status and Trends Network (CASTNet) database. Trends were derived from AQS monitor 040070010 located at Tonto NM.

The first measure of ozone is related to human health and is referred to as the annual 4th-highest 8-hour concentration. The primary NAAQS for ground-level ozone was set by the USEPA (USEPA 2016). Annual 4th-highest daily maximum 8-hour ozone concentrations were averaged over a 5-year period at all monitoring sites. Five-year averages were interpolated for all ozone monitoring locations to estimate 5-year average values for the contiguous U.S. The ozone condition for human health risk at the park was the maximum estimated value within its boundaries derived from this national analysis.

The second measure of ozone is related to vegetation health and is referred to as the 3-month maximum 12-hour W126. Exposure indices are biologically relevant measures used to quantify plant response to ozone exposure. These measures are better predictors of vegetation response than the metric used for the human health standard. The annual index (W126) preferentially weighs the higher ozone concentrations most likely to affect plants and sums all of the weighted concentrations during daylight hours (8am-8pm). The highest 3-month period that occurs from March to September was reported in "parts per million-hours" (ppm-hrs) and was used for vegetation health risk from ozone condition assessments. Annual maximum 3-month 12-hour W126 values were averaged over a 5-year period (2011-2015) at all monitoring sites with at least three years of complete annual data. Five-year averages were interpolated for all ozone monitoring locations to estimate 5-year average values for the contiguous U.S. The estimated current ozone condition for vegetation health risk at the park was the maximum value within its boundaries derived from this national analysis.

The indicator of atmospheric wet deposition was evaluated using three measures, two of which are nitrogen and sulfur. Nitrogen and sulfur were monitored across the United States as part of the National Atmospheric Deposition Program/National Trends Network (NADP/NTN). Wet deposition was used as a surrogate for total deposition (wet plus dry), because wet deposition was the most widely available monitored source of nitrogen and sulfur deposition data. Values for nitrogen (N) from ammonium and nitrate and sulfur (S) from sulfate wet deposition were expressed as amount of N or S in kilograms deposited over a one-hectare area in one year (kg/ha/yr). For nitrogen and sulfur condition assessments, wet deposition was calculated by multiplying nitrogen (from ammonium and nitrate) or sulfur (from sulfate) concentrations in precipitation by a normalized precipitation. Annual wet deposition was averaged over a 5-year period (2011-2015) at monitoring sites with at least three years of annual data. Five-year averages were then interpolated across all monitoring locations to estimate 5-year average values for the contiguous U.S. For individual parks, minimum and maximum values within park boundaries were reported from this national analysis. To maintain the highest level of protection in the park, the maximum value was assigned a condition status. NPS ARD considers stations located within 16 km (10 mi) of a park as representative for calculating trends (Taylor 2017).

The third measure of the wet deposition indicator was evaluated using a mercury risk status assessment matrix. The matrix combines estimated 3-year average (2013-2015) mercury wet deposition (ug/ m^2 yr) and the predicted surface water methylmercury concentrations at NPS Inventory & Monitoring parks. Mercury wet deposition was monitored across the United States by the Mercury Deposition Network (MDN). Annual mercury wet deposition measurements were averaged over a 3-year period at all NADP-MDN monitoring sites with at least three years of annual data. Three-year averages were then interpolated across all monitoring locations using an inverse distance weighting method to estimate 3-year average values for the contiguous U.S. The maximum estimated value within park boundaries derived from this national analysis was used in the mercury risk status assessment matrix. NPS ARD considers wet mercury deposition monitoring stations located farther than 16 km (7 mi) outside the range that is representative for calculating trends (Taylor 2017). There were no representative wet deposition monitoring stations for the monument.

Conditions of predicted methylmercury concentration in surface water were obtained from a model that predicts surface water methylmercury concentrations for hydrologic units throughout the U.S. based on relevant water quality characteristics (i.e., pH, sulfate, and total organic carbon) and wetland abundance (U.S. Geological Survey [USGS] 2015). The predicted methylmercury concentration at a park was the highest value derived from the hydrologic units that intersect the park. This value was used in the mercury risk status assessment matrix.

It is important to consider both mercury deposition inputs and ecosystem susceptibility to mercury methylation when assessing mercury condition, because atmospheric inputs of elemental or inorganic mercury must be methylated before they are biologically available and able to accumulate in food webs (NPS ARD 2018d). Thus, mercury condition cannot be assessed according to mercury wet deposition alone. Other factors like environmental conditions conducive to mercury methylation (e.g., dissolved organic carbon, wetlands, pH) must also be considered (Taylor 2017).

Reference Conditions

The reference conditions against which current air quality parameters were assessed are identified by Taylor (2017) for NRCAs and listed in Table 17.

A haze index estimated at less than 2 dv above estimated natural conditions indicates a “good” condition, estimates ranging from 2-8 dv above natural conditions indicate a “moderate concern” condition, and estimates greater than 8 dv above natural conditions indicate “significant concern.” The NPS ARD chose reference condition ranges to reflect the variation in visibility conditions across the monitoring network.

The human health ozone condition thresholds were based on the 2015 ozone standard set by the USEPA (2016) at a level to protect human health: 4th-highest daily maximum 8-hour ozone concentration of 70

Table 17. Reference conditions for air quality parameters.

Indicator and Measure	Very Good	Good	Moderate Concern	Significant Concern
Visibility Haze Index	N/A	< 2	2-8	>8
Ozone Human Health (ppb)	N/A	≤ 54	55-70	≥ 71
Ozone Vegetation Health (ppm-hrs)	N/A	<7	7-13	>13
Nitrogen and Sulfur Wet Deposition (kg/ha/yr)	N/A	< 1	1-3	>3
Mercury Wet Deposition (μg/m²/yr)	< 3	≥ 3 and < 6	≥ 6 and < 9	≥ 9
Predicted Methylmercury Concentration (ng/L)	< 0.038	≥ 0.038 and < 0.053	≥ 0.053 and < 0.075	≥ 0.075

Source: Taylor (2017).

Note: NPS ARD includes very good and very high standards. In order to conform with NRCA guidance, very low was considered good and very high was considered significant concern condition.

ppb. The NPS ARD rates ozone condition as: "good" if the ozone concentration was less than or equal to 54 ppb, which is in line with the updated Air Quality Index breakpoints; "moderate concern" if the ozone concentration was between 55 and 70 ppb; and of "significant concern" if the concentration was greater than or equal to 71 ppb.

The W126 vegetation health condition thresholds were based on information in the USEPA's Policy Assessment for the Review of the Ozone NAAQS (USEPA 2014). Research has found that for a W126 value of:

- ≤ 7 ppm-hrs, tree seedling biomass loss is ≤ 2 % per year in sensitive species; and
- ≥13 ppm-hrs, tree seedling biomass loss is 4-10 % per year in sensitive species.

ARD recommends a W126 of < 7 ppm-hrs to protect most sensitive trees and vegetation; this level was considered good; 7-13 ppm-hrs was considered to be of "moderate" concern; and >13 ppm-hrs was considered to be of "significant concern" (Taylor 2017).

The NPS ARD selected a wet deposition threshold of 1.0 kg/ha/yr as the level below which natural ecosystems are likely protected from harm. This was based on studies linking early stages of aquatic health decline with 1.0 kg/ha/yr wet deposition of nitrogen both in the Rocky Mountains (Baron et al. 2011) and in the Pacific Northwest (Sheibley et al. 2014). Parks with less than 1 kg/ha/yr of atmospheric wet deposition of nitrogen or sulfur compounds are assigned "good" condition, those with 1-3 kg/ha/yr are assigned a "moderate concern" condition, and parks with depositions greater than 3 kg/ha/yr are considered to be of "significant concern."

The mercury condition assessment matrix shown in Table 18 can be used to evaluate mercury wet deposition and predicted methylmercury concentrations. Condition adjustments may be made if the presence of park-specific data on mercury in food webs is available and/or data are lacking to determine the wet deposition rating (Taylor 2017).

Condition and Trend

The values used to determine conditions for all air quality indicators and measures are listed in Table 19.

The estimated 5-year (2011-2015) values for Tonto NM's (5.1 dv) haze index measure of visibility fell within the moderate concern condition rating, which indicates visibility was degraded from the good reference condition of <2 dv above the natural

White sagebrush is an ozone sensitive species. Photo Credit: © Louis Landry.

Table 18. Mercury condition assessment matrix.

Predicted Methylmercury Concentration Rating	Mercury Wet Deposition Rating				
	Very Low	Low	Moderate	High	Very High
Very Low	Good	Good	Good	Moderate Concern	Moderate Concern
Low	Good	Good	Moderate Concern	Moderate Concern	Moderate Concern
Moderate	Good	Moderate Concern	Moderate Concern	Moderate Concern	Significant Concern
High	Moderate Concern	Moderate Concern	Moderate Concern	Significant Concern	Significant Concern
Very High	Moderate Concern	Moderate Concern	Significant Concern	Significant Concern	Significant Concern

Source: Taylor (2017).

condition (Taylor 2017). For 2006–2015, the trend in visibility at Tonto NM improved on the 20% clearest days and improved on the 20% haziest days (Figure 22). Confidence in this measure is high because there was an on-site or nearby visibility monitor.

Visibility on the clearest days resulted primarily from ammonium sulfate, followed by organic carbon and then coarse mass (Figure 23). The same three components were responsible for the majority of haze on the haziest days except that coarse mass was the larges contributor, followed by ammonium sulfate and organic carbon (Figure 24). Ammonium sulfate originates mainly from coal-fired power plants and smelters, and organic carbon originates primarily from combustion of fossil fuels and vegetation. Sources of coarse mass include dust from roads, agriculture, construction sites, mining operations, and other similar activities. The clearest days often occurred during the winter months from October through February, while the haziest days occurred from April through September (NPS ARD 2018f).

Data for the human health measure of ozone (4th highest 8-hour concentration) were derived from estimated five-year (2011-2015) values of 74.2 parts per billion (ppb), which resulted in a condition rating warranting significant concern (NPS ARD 2018f). For 2006–2015, the trend in ozone concentration at Tonto NM remained relatively unchanged (no statistically significant trend) (Figure 25). The degree of confidence at Tonto NM is high because there is an on-site or nearby ozone monitor.

Ozone data used for the W126 vegetation health measure of the condition assessment were derived from estimated five-year (2011-2015) values of 17.9 parts per million-hours (ppm-hrs). This value warrants significant concern (NPS ARD 2018f). For 2006-2015, the trend in the W126 Index improved (Figure 26). There are three ozone sensitive plant species in Tonto

Table 19. Condition and trend results for air quality indicators at Tonto NM.

Data Span	Visibility (dv)	Ozone: Human Health (ppb)	Ozone: Vegetation Health (ppm-hrs)	N (kg/ha/yr)	S (kg/ha/yr)	Mercury (µg/m²/yr)	Predicted Methylmercury (ng/L)
Condition	Moderate Concern (5.1) (2011-2015)	Significant Concern (74.2) (2011-2015)	Significant Concern (17.9) (2011-2015)	Significant Concern (2.1*) (2011-2015)	Good (0.9) (2011-2015)	Moderate Concern (3.7) 2013-2015	Significant Concern (0.12) 2013-2015
Trend 2006-2015	Improved on the 20% clearest and 20% haziest days.	Unchanged (no statistically significant trend).	Improved	No trend data.	No trend data.	No trend data.	No trend data.

* Value is within the range normally considered moderate concern, but ecosystems at the monument may be particularly sensitive to nitrogen-enrichment effects. Thus, the condition has was elevated to significant concern (NPS ARD 2018f).

Sources: NPS ARD (2018f, 2018g)

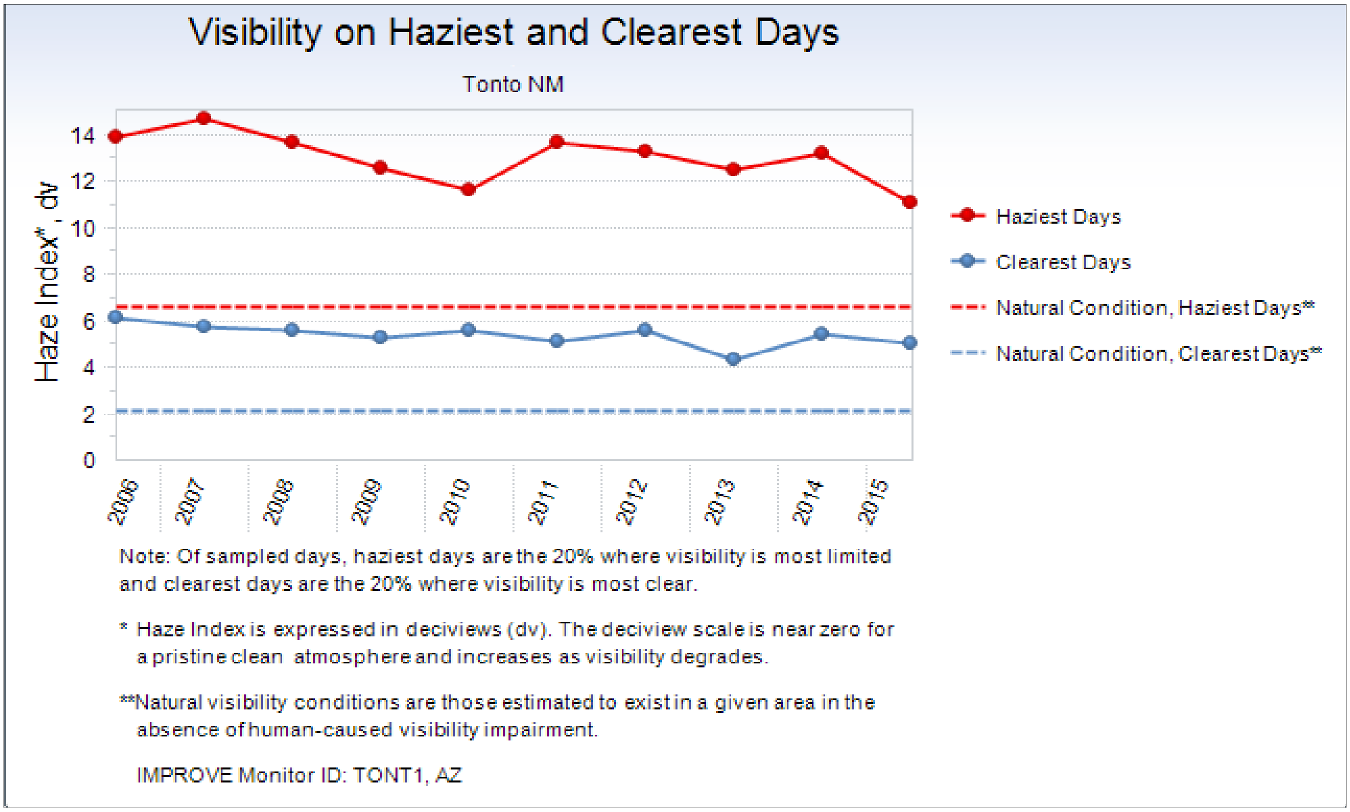


Figure 22. **Visibility on the 20% haziest and the 20% clearest days at Tonto NM from 2006 to 2015. Figure Credit: NPS ARD 2018f.**

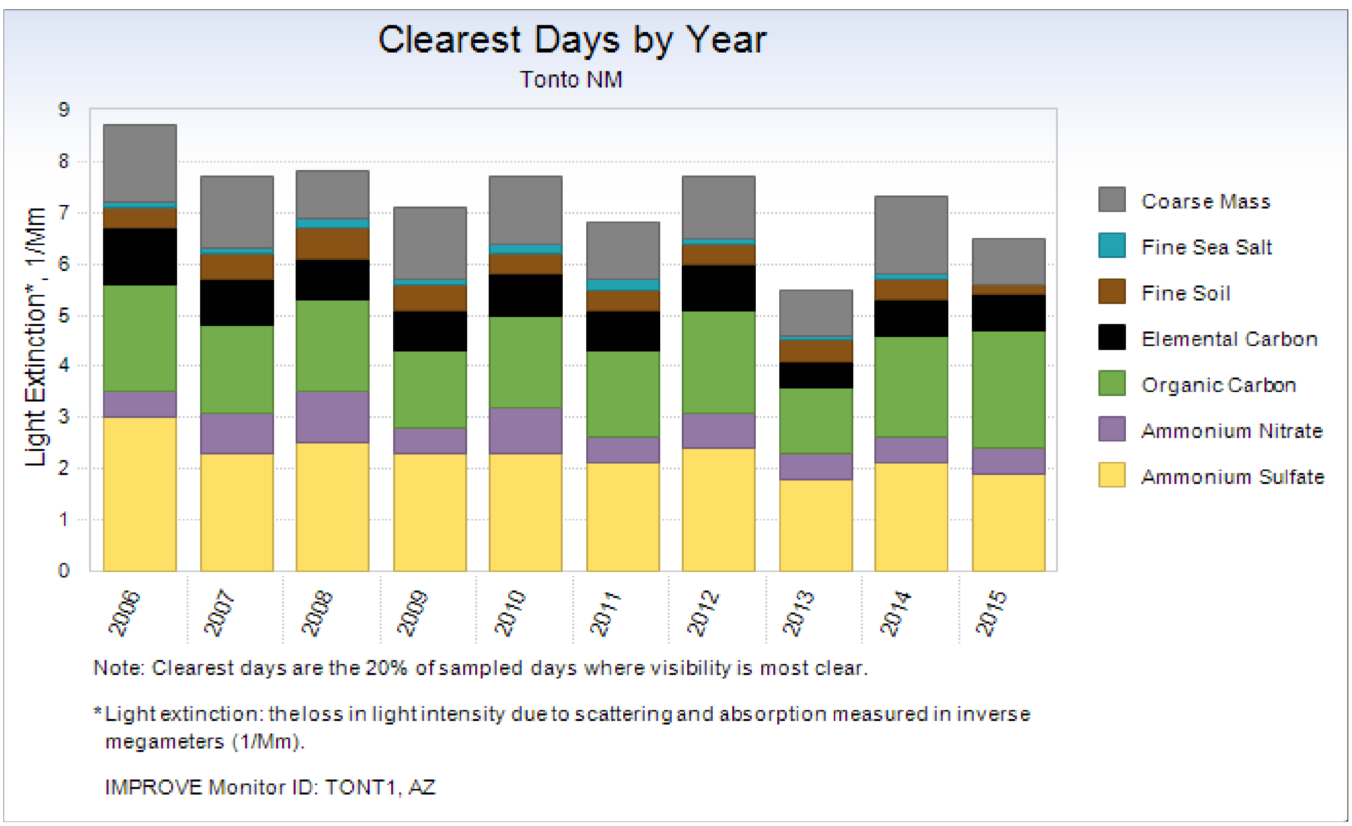


Figure 23. **Visibility data collected at TONT1, AZ IMPROVE station showing the composition of particle sources contributing to haze during the clearest days by year (2006-2015). Figure Credit: NPS ARD 2018f.**

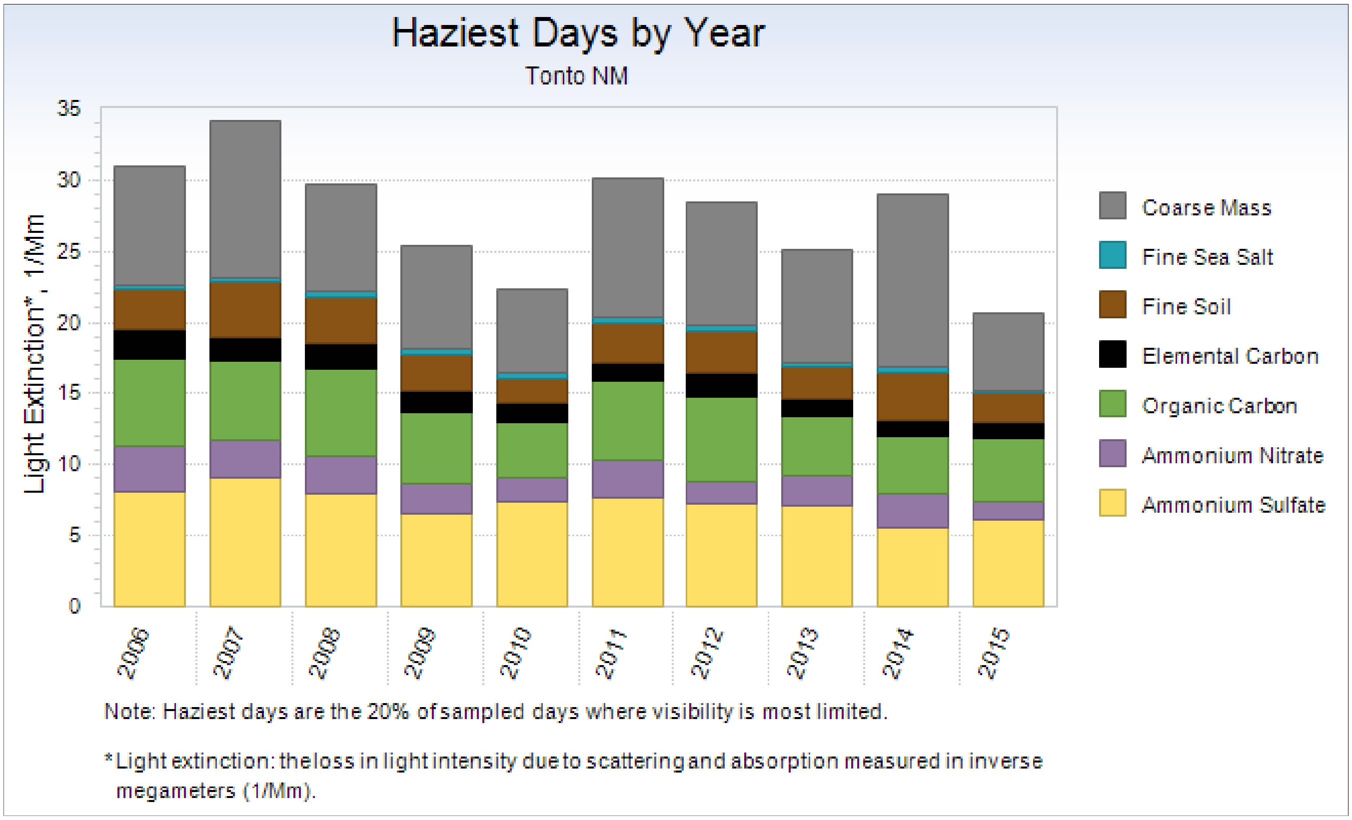


Figure 24. **Visibility data collected at TONT1, AZ IMPROVE station showing the composition of particle sources contributing to haze during the haziest days by year (2006-2015). Figure Credit: NPS ARD 2018f.**

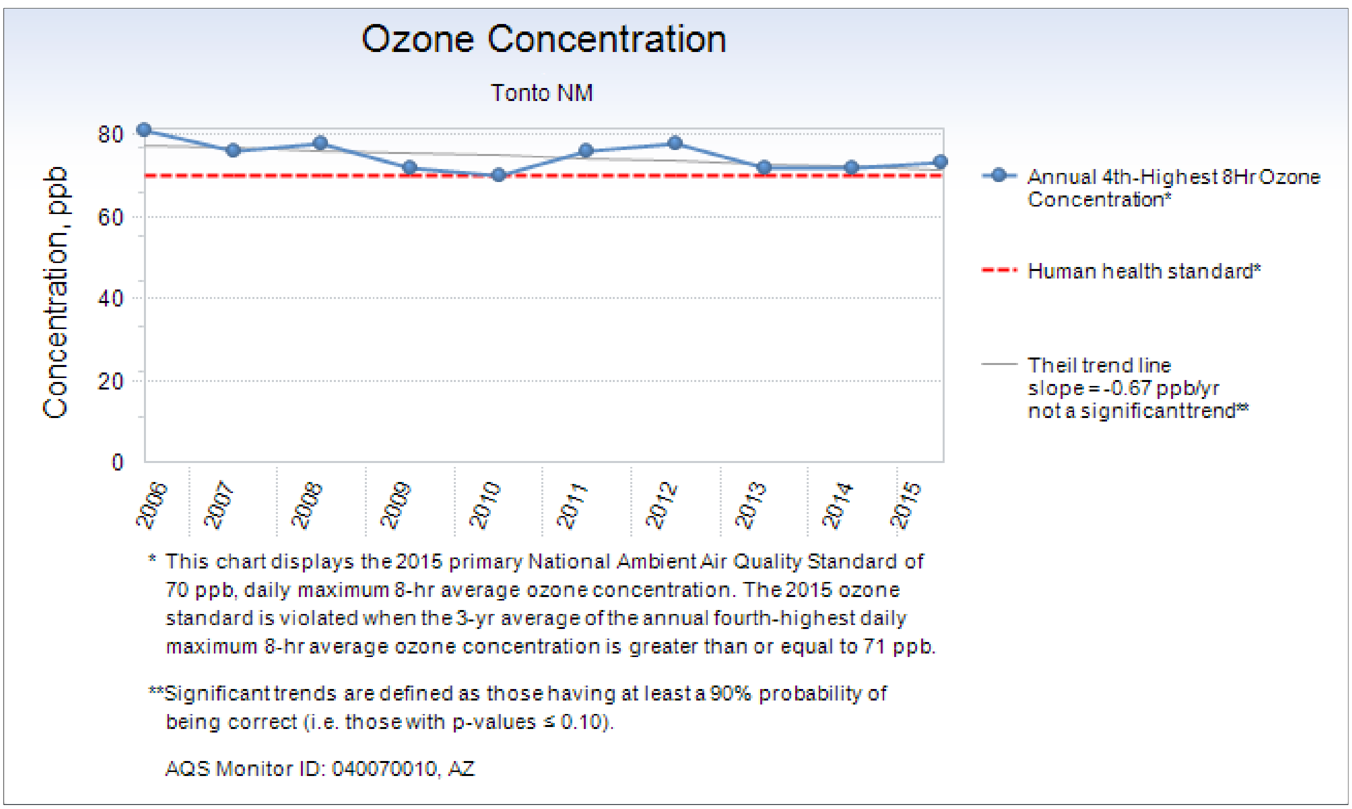


Figure 25. **Ozone trend (2006-2015) for human health at Tonto NM monitor site 040070010. The trend is not statistically significant and is considered stable. Figure Credit: NPS ARD 2018f.**

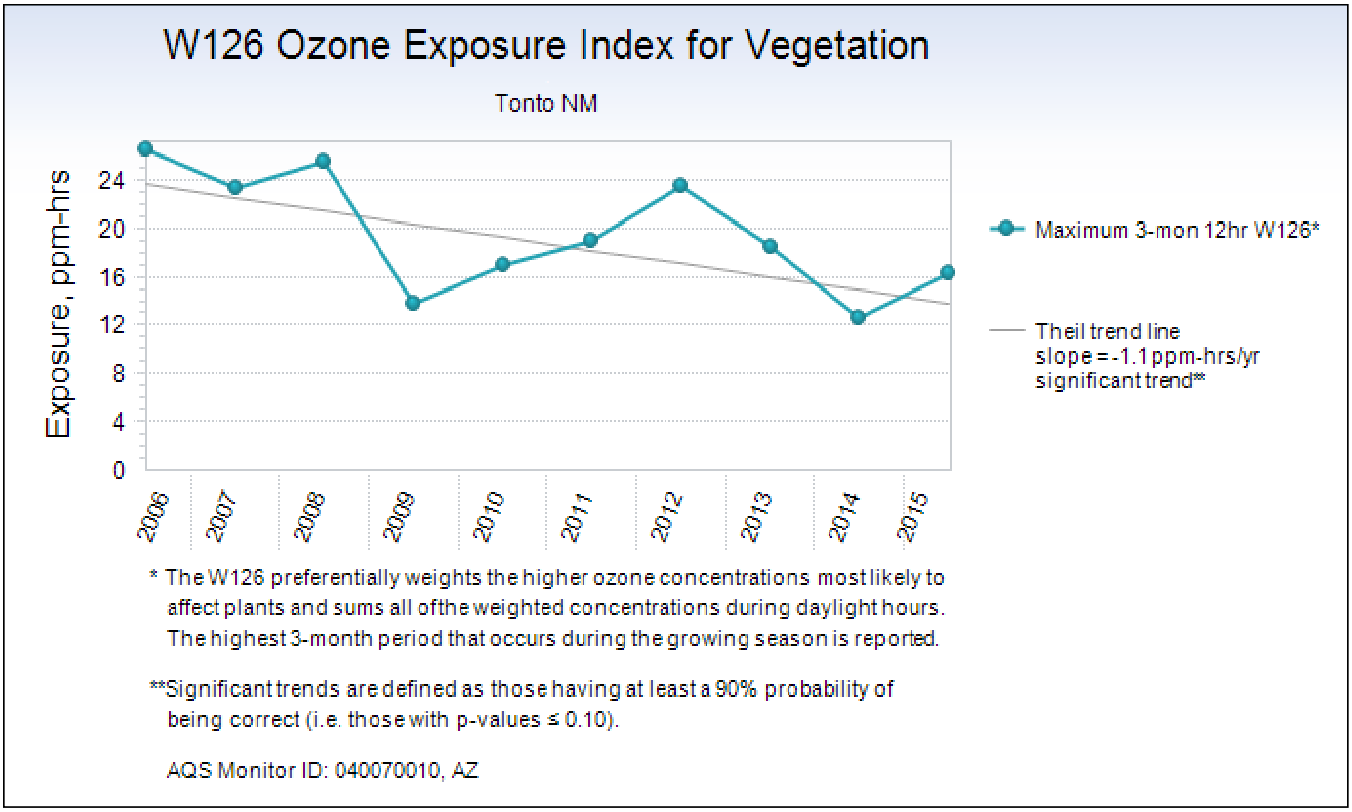


Figure 26. Ozone trend (2006-2015) for vegetation at Tonto NM monitor site 040070010. The trend in the W126 Index has significantly improved. Figure Credit: NPS ARD 2018f.

NM (Bell, In Review). The three species are white sagebrush (*Artemisia ludoviciana*), singleleaf ash (*Fraxinus anomala*), and black elderberry (*Sambucus nigra*).

Wet N deposition data used for the condition assessment were derived from estimated five-year average values (2011-2015) of 2.1 kg/ha/yr. This would normally result in a condition rating of moderate concern; however, the condition rating was elevated to significant concern because ecosystems at Tonto NM may be more vulnerable to the adverse effects of excess nitrogen deposition (NPS ARD 2018f). Furthermore, the 3-year (2014-2016) maximum total nitrogen deposition in the Temperate Sierras ecoregion, which includes Tonto NM, is approaching the minimum critical load for lichens (NPS ARD 2019). Critical loads for other plant groups (e.g., forest and herbaceous) have not been developed for this ecoregion (NPS ARD 2019). No trends could be determined given the lack of nearby monitoring stations. Confidence in the condition is medium because estimates were based on interpolated data from more distant deposition monitors. For further discussion of N deposition, see the section entitled "Additional Information for Nitrogen and Sulfur" below.

Wet S deposition data used for the condition assessment were derived from estimated five-year average values (2011-2015) of 0.9 kg/ha/yr, which resulted in a good condition rating (NPS ARD 2018f). No trends could be determined given the lack of nearby monitoring stations. Confidence in the assessment is medium because estimates were based on interpolated data from more distant deposition monitors. For further discussion of sulfur, see below.

Sullivan et al. (2016) studied the risk from acidification from acid pollutant exposure and ecosystem sensitivity for Sonoran Desert Network parks, which included Tonto NM. Pollutant exposure included the type of deposition (i.e., wet, dry, cloud, fog), the oxidized and reduced forms of the chemical, if applicable, and the total quantity deposited. The ecosystem sensitivity considered the type of terrestrial and aquatic ecosystems present at the parks and their inherent sensitivity to the atmospherically deposited chemicals.

These risk rankings for the monument were considered moderate for acid pollutant exposure and for ecosystem sensitivity (Sullivan et al. 2016). The effects of acidification can include changes in water and soil chemistry that impact ecosystem health.

Sullivan et al. (2016) also developed risk rankings for nutrient N pollutant exposure and ecosystem sensitivity to nutrient N enrichment. These risk rankings were considered moderate for pollutant exposure and for ecosystem sensitivity. Potential effects of nitrogen deposition include the disruption of soil nutrient cycling and impacts to the biodiversity of some plant communities, including alpine communities, grasslands and meadows, arid and semi-arid communities, and wetlands.

Using three datasets, Landscape Fire and Resource Management Planning Tools Project (LANDFIRE), National Wetlands Inventory (NWI) cover data, and National Land Cover Data (NLCD), nitrogen-sensitive vegetation for the monument was identified (E&S Environmental Chemistry, Inc. 2009). In Tonto NM, the LANDFIRE dataset mapped 97% of the monument as arid and semi-arid nitrogen-sensitive areas and less than 1% as meadow and grassland nitrogen-sensitive communities (Figure 27). No nitrogen-sensitive communities were identified by NWI or NLCD.

Since the mid-1980s, nitrate and sulfate deposition levels have declined throughout the United States (NADP 2018a). Regulatory programs mandating a reduction in emissions have proven effective for decreasing both sulfate and nitrate ion deposition, primarily through reductions from electric utilities, vehicles, and industrial boilers. In 2007, the NADP/NTN began passively monitoring ammonium ion concentrations and deposition across the U.S. in order to establish baseline conditions and trends over time (NADP 2018b). In 2012 hotspots of ammonium

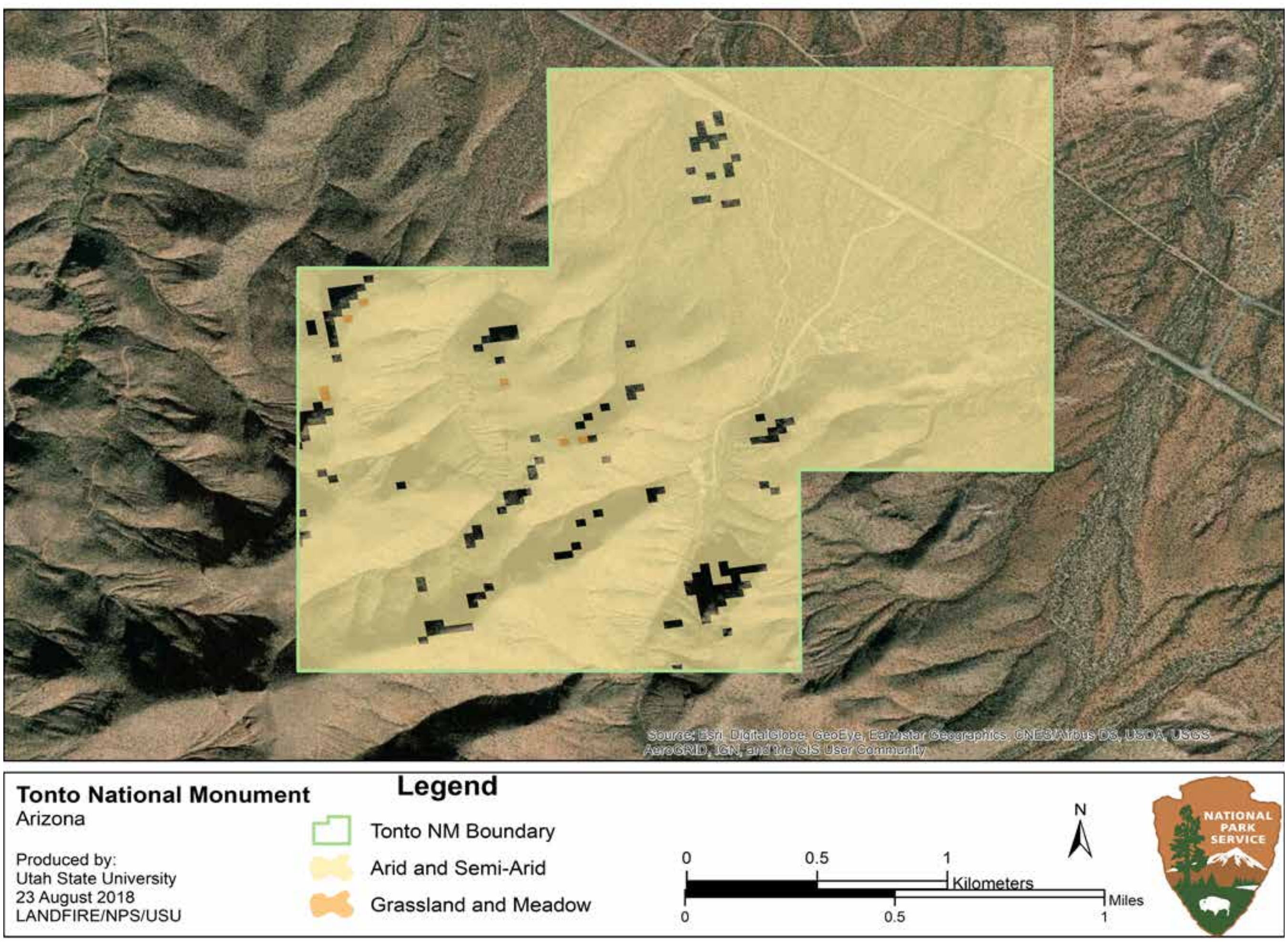


Figure 27. **Map of nitrogen-sensitive plant communities in Tonto NM.**

deposition were concentrated in the midwestern states in large part due to the density of agricultural and livestock industries in that region (NADP 2018b). The area surrounding Tonto NM, however, shows relatively low ammonium, sulfate, and nitrate concentrations and deposition levels (NADP 2018a,b). It seems reasonable to expect a continued improvement or stability in sulfate and nitrate deposition levels because of CAA requirements, but since ammonium levels are not currently regulated by the EPA, they may continue to remain high in certain areas (NPS ARD 2010). However, once baseline conditions for ammonia are established, those data may be used to support regulatory statutes.

The 2013-2015 wet mercury deposition was moderate at the monument with a value of 7.4 micrograms per square meter per year (NPS ARD 2018g). The predicted methylmercury concentration in park surface waters was estimated to be 0.14 ng/L (USGS 2015), a very high concentration (NPS ARD 2018g). When both measures are available (i.e., wet mercury deposition and predicted methylmercury concentration), the mercury status assessment matrix shown in Table 18 can be used to determine overall mercury/toxics status (Taylor 2017). The matrix indicates a condition of significant concern for the combined effects of wet mercury deposition and predicted methylmercury at Tonto NM. However, the level of confidence in this measure is low, because the estimates are based on interpolated or modeled data rather than in-park studies, since there are no park-specific studies examining contaminant levels in taxa from park ecosystems. Trend could not be determined.

Overall Condition, Threats, and Data Gaps

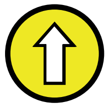
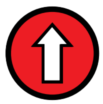
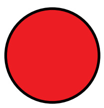
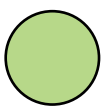
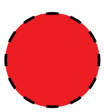
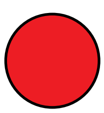
For assessing the condition of air quality, we used three air quality indicators with a total of six measures. The indicators/measures for this resource were intended to capture different aspects of air quality, and a summary of how they contributed to the overall condition is summarized in Table 20. Based on the indicators and measures, we consider the overall condition of air quality at Tonto NM to be of significant concern. Overall confidence level is medium because some estimates were based on interpolated data from more distant monitors. Those measures for which confidence in the condition rating was high were weighted more heavily in the overall condition rating than measures with medium or low confidence. We did not assign an overall trend for air quality at the monument because trend data were not available for a majority of measures. However, those measures with a trend indicate stable or improving conditions. A key uncertainty of this assessment is knowing the effect(s) of air pollution, especially of nitrogen deposition, on ecosystems in the monument.

Clean air is fundamental to protecting human health, the health of wildlife and plants within parks, and for protecting the aesthetic value of lands managed by the NPS (NPS 2006a). For example, air quality in Tonto NM plays an important role in maintaining the high-quality scenic vistas and clear night skies of the national monument (NPS 2003). Good visibility allows visitors to literally "visualize" their connection to nature and to the Salado culture (NPS 2017a).

In an analysis of 33 national parks across the U.S., Keiser et al. (2018) found that average annual 8-hour ozone concentrations did not differ significantly from ozone levels in major metropolitan areas. While ozone levels have improved in both parks and cities, improvements have been more modest in parks (Keiser et al. 2018). In metropolitan areas, air quality has improved since about 1990, but in national parks, air quality did not improve until after 2000. The authors speculate that this may have been the result of the 1999 USEPA Haze Rule, which called for stricter regulations to improve air quality in national parks and wilderness areas (Keiser et al. 2018). Keiser et al. (2018) also showed that on days with higher levels of ozone, visitation in parks was lower than on days with lower ozone levels, probably as a result of USEPA air quality index warnings issued by the NPS or reduced visibility, which may have discouraged visitation. Although Tonto NM was not part of the study, air quality in nearby Phoenix, Arizona is one of the poorest in the nation (Keiser et al. 2018) and likely influences air quality in the monument.

Impacts to air quality can result from pollution from urban centers both near and more distant from the national monument. In general, sources of air quality threats may include forest fires (natural or prescribed), dust created from agriculture, carbon emissions from vehicles, and copper smelters in the region (NPS 2003). The U.S. Forest Service is currently analyzing the environmental effects of the Resolution Copper Project and Land Exchange proposal (U.S. Department of Agriculture [USDA] 2018). The proposal calls for an exchange of 980 ha (2,422 ac) of public land on the

Table 20. Summary of air quality indicators, measures, and condition rationale.

Indicators	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Visibility	Haze Index		Visibility warrants moderate concern at Tonto NM. This is based on NPS ARD benchmarks and the 2011-2015 estimated visibility on mid-range days of 5.1 deciviews (dv) above estimated natural conditions. For 2006-2015, the trend improved on the 20% clearest days and on the 20% haziest days. The level of confidence is high because there is an on-site or nearby visibility monitor.
Level of Ozone	Human Health: Annual 4th-Highest 8-hour Concentration		Human health risk from ground-level ozone warrants significant concern. This status is based on NPS ARD benchmarks and the 2011-2015 estimated ozone of 74.2 parts per billion (ppb). For 2006-2015, the trend remained relatively unchanged (no statistically significant trend). The level of confidence is high because there is an on-site or nearby ozone monitor.
	Vegetation Health: 3-month maximum 12hr W126		Vegetation health risk from ground-level ozone warrants significant concern. This status is based on NPS ARD benchmarks and the 2011-2015 estimated W126 metric of 17.9 parts per million-hours (ppm-hrs). The W126 metric relates plant response to ozone exposure. A risk assessment concluded that plants in the monument were at moderate risk for ozone damage. For 2006-2015, the trend improved. The level of confidence is high because there is an on-site or nearby ozone monitor.
Wet Deposition	N in kg/ha/yr		Estimated wet nitrogen deposition of 2.1 kilograms per hectare per year (kg/ha/yr) during 2011-2015 would normally warrant moderate concern, but because ecosystems in the monument were rated as having high sensitivity to nutrient enrichment effects relative to all Inventory & Monitoring parks, the condition rating was elevated to significant concern. Trend could not be determined because there were not sufficient on-site or nearby monitoring data. The confidence level is medium because estimates are based on interpolated data from more distant deposition monitors.
	S in kg/ha/yr		Wet sulfur deposition is good. This status is based on NPS ARD benchmarks and the 2011-2015 estimated wet sulfur deposition of 0.9 kilograms per hectare per year (kg/ha/yr). Trend could not be determined because there were not sufficient on-site or nearby monitoring data. The confidence level is medium because estimates are based on interpolated data from more distant deposition monitors.
	Mercury and Predicted Methylmercury Concentration		The 2013-2015 estimated wet mercury deposition was moderate at 3.7 micrograms per square meter per year. The predicted methylmercury concentration in park surface waters during the same interval was very high (0.14 nanograms per liter). Trends could not be determined. Confidence in the measure is low because estimates were based on interpolated or modeled data rather than in-park studies; there are no park-specific studies examining contaminant levels in taxa from park ecosystems.
Overall Condition	Summary of All Measures		Overall, we consider air quality at Tonto NM to warrant significant concern because the two measures of ozone, wet deposition of nitrogen, and the mercury/toxics measures are all of significant concern. Trend data were only available for three measures. There were no trend data for the remaining four measures so overall trend is unknown. Confidence is medium.

Note: Condition summary text was primarily excerpted from NPS ARD (2018f).

Tonto National Forest, known as the Oak Flat parcel, to Resolution Copper Mining, LLC in return for 2,163 ha (5,344 ac) elsewhere (USDA 2018). If approved, the project would be the largest copper mine in the U.S. It is unknown how the mine would affect air quality in Tonto NM.

Monahan and Fisichelli (2014) found climate for the monument and surrounding region departed from the natural range of variation. One effect of climate change is an increase in wildfire activity (Abatzoglou and Williams 2016). Fires contribute a significant amount of trace gases and particles into the atmosphere that affect local and regional visibility and air quality (Kinney 2008). Wildfires have increased across the western U.S., and there is a high potential for the number of wildfires to grow as climate in the Southwest becomes warmer and drier (Abatzoglou and Williams

2016). Warmer conditions also increase the rate at which ozone and secondary particles form (Kinney 2008). Declines in precipitation may also lead to an increase in wind-blown dust (Kinney 2008). Weather patterns influence the dispersal of these atmospheric particulates. Because of their small particle size, airborne particulates from fires, motor vehicles, power plants, and wind-blown dust may remain in the atmosphere for days, traveling potentially hundreds of miles before settling out of the atmosphere (Kinney 2008).

Sources of Expertise

The NPS Air Resources Division oversees the national air resource management program for the NPS. Together with parks and NPS regional offices, they monitor air quality in park units, and provide air quality analysis and expertise related to all air quality topics. Information and text for the assessment was obtained from the NPS ARD website and provided by Jim Cheatham, Park Planning and Technical Assistance, ARD. Email NPS ARD (airresources@nps.gov) for more information. The assessment was written by Lisa Baril, biologist and science writer at Utah State University.

Geology

Background and Importance

Tonto National Monument (NM) is set in the rugged landscape of the Central Highlands Transition Zone Physiographic Province (Studd et al. 2017). The known geological record for Tonto NM dates to 1.5 to 2 billion years ago, when much of central Arizona was covered by an inland sea (NPS 2015a). During this time, a thick layer of sedimentary and volcanic rock was deposited on the sea floor. When the seas withdrew, the entire area entered a period of upheaval known as the Mazatzal Revolution (NPS 2015a). The Mazatzal Revolution culminated in "vast mountainous intrusions of granitic igneous rock" (NPS 2015a).

Over the next 100 million years, forces of erosion withered away the land surface into an almost flat plane, after which another shallow sea flooded the region (NPS 2015a). The rocks most readily observed in the monument are composed of materials deposited during this time. These rocks form the Apache Group, which is comprised of six types: (oldest to youngest) the Pioneer Formation, Barnes Conglomerate, Dripping Spring Quartzite Formation, Mescal Limestone, Basalt, and Diabase Formation (NPS 2015a). While rocks in the Pioneer Formation are more than a billion years old, the youngest materials in the Dripping Quartzite Formation and Mescal Formation are actively eroding.

It is in the highly erodible rocks of the Dripping Quartzite Formation, which formed alcoves in the rock, that the Salado constructed their homes more than 700 years ago (NPS 2015a). The caves eroded sometime between 400,000 and 50,000 years ago, and rocks that eroded from the caves were used as construction materials for the cliff dwellings. The Gila Conglomerate, a sedimentary formation deposited 0.5-15 million years ago, lies at the base of the cliffs and continues to accumulate debris eroded from above (NPS 2015a). Figure 28 shows the exposed rocks at Tonto NM.

Geologically Tonto NM is split into two sections: the southwestern part of the park with mountainous Precambrian rocks and the northeastern part of the park with a plain of Tertiary sediments (Martin 2001). These areas are separated by a Two Bar North Fault, running from northwest to southeast. The southwestern part of the park is characterized by exposed bedrock, with talus and colluvium at the base of the steep slopes, and alluvium in the canyon bottoms. Nearly vertical faults, joint and shear fractures are common throughout the bedrock formations (Raup 1959). In the northeastern part of Tonto NM, bedrock has been down-dropped by faulting along the Two Bar Fault, up to a depth of up to 488 m (1,600 ft) (Richard et al. 2007). The basin is filled with Tertiary sediments,

The Upper Cliff Dwellings in Tonto NM. Photo Credit: NPS/P. Pineda Bovin.

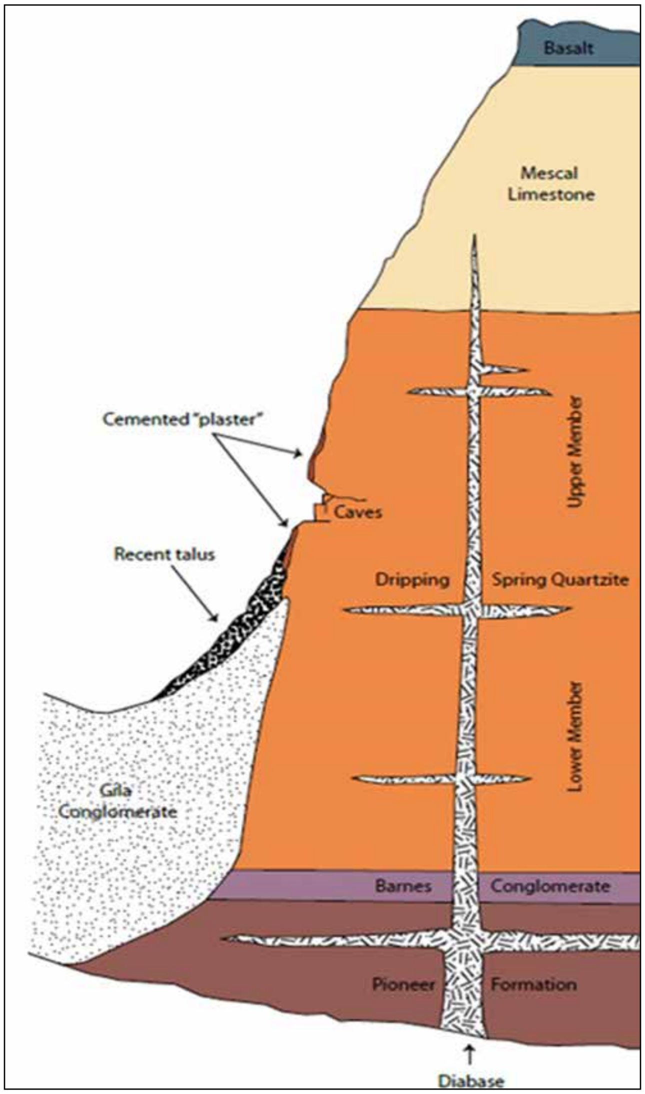


Figure 28. Rocks exposed at Tonto NM. Photo Credit: NPS.

including mudstone and fine-grained sandstone, containing some evaporate beds (Martin 2001).

It is this unique geology of Tonto NM, coupled with access to the nearby water resources of Cave Canyon and the Salt River, that enabled the Salado to occupy the region (NPS 2017a). Thus, the cultural resources of the monument are intimately connected to the monument's geology.

Data and Methods

This assessment is based on three indicators with a total of six measures. The three indicators are erosion (two measures), deterioration or loss of integral geological/paleontological/cultural features (three measures), and seismic activity (one measure). Although geological forces occur over long time scales, this assessment focuses on a snapshot in time to determine the current condition of geological resources and the cultural and paleontological resources that are embedded within the monument's geology. The indicators and measures were, in part, based on the National Park Service's (NPS) vital signs for geology (Mau-Crimmins et al. 2005) in addition to other data available for the monument.

The first measure of the erosion indicator is the percent estimated degraded area of erosion features (Nauman 2011). The three features are sheet, rill, and gullies. These three features are evidence of active erosion caused by wind or water (Pellant et al. 2005). Precursors of erosion include the presence of burrows, pedestals, terracettes, and tunnels (Pellant et al. 2005). The presence of these features are indications of the potential for future erosion.

Estimated degraded area data were collected as part of the National Park Service's (NPS) Sonoran Desert Inventory and Monitoring Network (SODN) program for upland vegetation (Hubbard et al. 2012). Nineteen plots were allocated to three strata based on elevation and soil rock fragment class. The three strata were: valley bottom (762 m [<2,500 ft]), bajada (762-1,128 m [2,501-3,700 ft]), and foothills (1,128-1,372 m [3,701-4,500 ft]). The soil rock fragment class was the same for all three strata: 35% to 90% rock fragment. Three plots were established in the valley bottom, 11 plots were established in the bajada, and five plots were established in the foothills. Plots were surveyed in December of 2009/2010 and 2014. Further sampling details are described in Hubbard et al. (2012). Raw data were provided by K. Bonebrake, SODN data manager, via e-mail on 8 December 2017.

The following describes this measure as detailed in Nauman (2011):

> Erosion features were described using a semi-quantitative scheme to estimate approximate extent (%) of affected areas [in each plot]. Estimated erosion classes were as follows: 0%, 1–5%, 6–25%, 26–50%, 51–75%, and >75%. Recorded features included tunneling, sheeting, rilling, gullying, pedestal development, terracette occurrence, and burrowing activity.

We summarized these data by the proportion of each plot comprised of a given erosion feature type. The overall degraded area by plot was calculated by summing the midpoints of sheet, rill, and gully percent erosion (Nauman 2011).

The second measure of the erosion indicator is the erosion resistance index. Plant roots growing around cultural, geological, and paleontological features can cause structural damage, displace artifacts, and increase fire hazard (McIntyre 2008). To lower the potential for these negative impacts, plants growing near important features are thinned (McIntyre 2008). However, thinning can lead to increased erosion, which can damage features, especially after rainstorms. In 2006-2007, McIntyre (2008) initiated a study "to evaluate the relative risk of site destabilization due to water erosion and ...to estimate the impact(s) of vegetation removal on water-erosion potential" at 46 backcountry archeological sites in the monument.

McIntyre (2008) computed an index score for each archaeological site "that reflected the sum of factors affecting erosion potential." The factors were either static (i.e., soil type and average % slope) or dynamic (i.e., average soil stability, percent cover of exposed bare ground, and the presence of mature biological soil crusts [BSC]). Factors meeting the standard established by McIntyre (2008) were assigned a score of "1" and those that did not meet established standard were assigned a score of "0" (Table 21). The sum of the assigned scores resulted in the index of erosion resistance for that site. The index ranged from 0 (not meeting any standards) to 5 (meeting all standards). In other words, the higher the value, the more resistance a site is to water erosion.

Table 21. Summary of factors used to determine erosion resistance in archeological sites.

Factor	Standard
Soil Type	Soils in the monument that are considered stable (Eba, Topawa, Gadwell, Whitvin)
Average % Slope	<25%
Average Soil Stability	10-25% of soil remains on sieve after five dipping cycles
Exposed Bare Ground	<20%
Biological Soil Crust Cover	Presence of mature biological soil crusts (dark cyanobacteria, lichen, moss)

Source: McIntyre (2008).

Each of the five factors were assessed at 46 backcountry archeological sites during summer 2006, prior to plant thinning. Following plant removal, 15 randomly selected sites were re-sampled in February 2007. In Autumn 2007 the 15 sites were re-sampled but soil aggregate stability could not be determined at one site. Thus, the sample size in autumn 2007 was 14. Plant thinning included "cutting away any trees and shrubs from close proximity to site architecture and applying herbicide to stumps to prevent regrowth," (McIntyre 2008). We conducted a paired t-test between means for each time period to determine if the effects of plant thinning on erosion resistance were significant.

To assess the anthropogenic and natural impacts to geological, cultural, and paleontological resources (second indicator) in the monument, we reviewed the geologic resources inventory scoping report (KellerLynn 2006), the monument's foundation document (NPS 2017a), a series of letters documenting the presence of low-flying aircraft over the monument (unpublished data), the paleontological resources inventory report (Tweet et al. 2008), and other relevant literature. We separated known incidents into two measures: anthropogenic events and natural events. Examples of anthropogenic events include vandalism, graffiti, off-trail travel, and any incidents that have or may cause damage to geological, paleontological, and cultural resources. The major natural processes that have and continue to sculpt Tonto NM include water, hillslope processes, and wind, as well as wildlife damage (KellerLynn 2006).

For the third measure of the deterioration or loss of the integral geological/paleontological/cultural features indicator, we summarized the results of the Archeological Site Management Information System (ASMIS) database, which is a tool used to evaluate the condition of archeological resources on lands managed by the NPS (NPS 2013). Information on condition was available for 93 archeological sites. All sites were surveyed at least once during 2011 through March 2019. Most sites (63) were surveyed during all seven years, and 30 sites were surveyed in only one year. Based on 10 criteria, each site is assigned an overall condition of good (>75% undisturbed), fair (50-75% undisturbed), poor (25-50% undisturbed), or destroyed (<25% undisturbed). We summarized these data by the proportion of sites within each class by year.

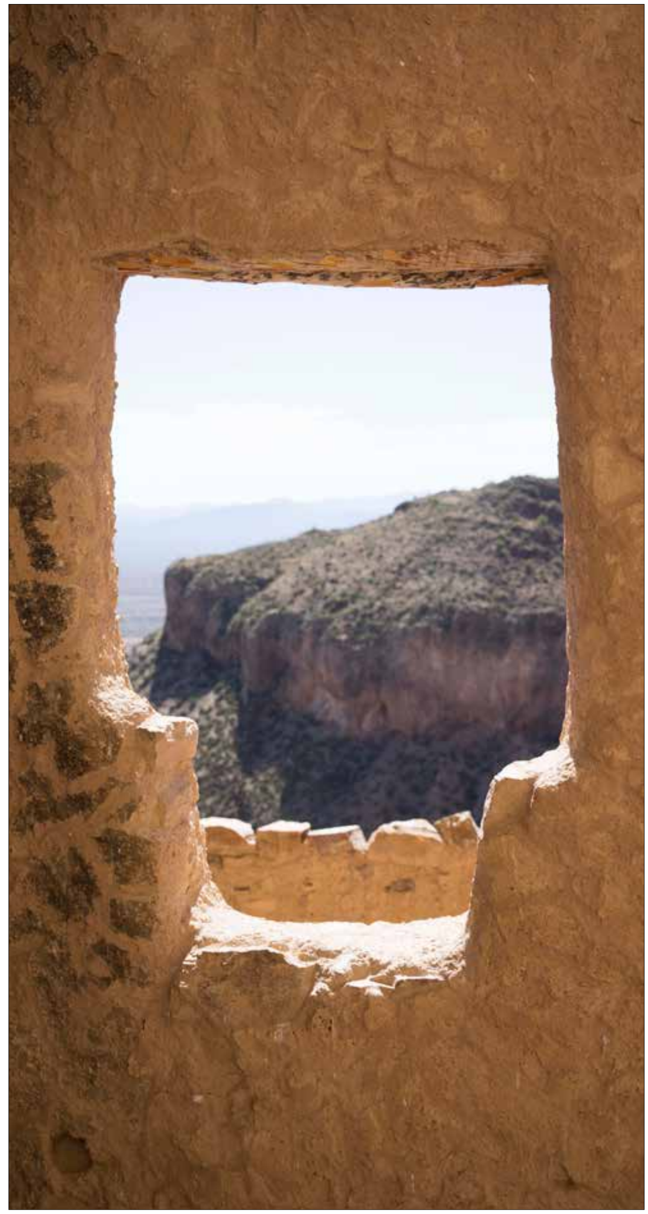
Finally, the single measure (presence/absence) of the seismic activity indicator was assessed using the U.S. Geological Survey's (USGS) Earthquake Catalog. We searched for all seismic events (i.e., earthquakes and non-earthquake events, such as sonic booms), regardless of magnitude, in a 161-km (100 mi) area surrounding the monument over a 20-year period (February 1999 - February 2019) (Worden and Wald 2016). Table 22 shows the various earthquake magnitudes and class descriptions identified by the Incorporated Research Institutions for Seismology (IRIS 2017). Although damage from earthquakes does not usually occur at magnitudes of less than 4 or 5 (light to moderate), factors such as soil type, distance from the epicenter, and sensitivity of a feature to Earth's movements also influence whether damage occurs (Worden and Wald 2016).

To account for these factors, we examined the USGS's ShakeMap Atlas for each event, if available (Worden and Wald 2016). ShakeMap provides information on the area over which a seismic event occurred using a heat map (Worden and Wald 2016). The heat map shows earthquake intensity and potential damage at various locations for the entire affected area. The potential damage scale ranges from no damage to very heavy damage (Worden and Wald 2016). The ShakeMap Atlas was available for events occurring from 1960 through 2016. Therefore, any earthquakes occurring in the area of analysis (AOA) after 2016 do not have an associated ShakeMap (Worden and Wald 2016). The ShakeMap scale does not directly correspond to magnitude because magnitude is a measure of ground-shaking at the epicenter, while the ShakeMap provides information on the degree of ground-shaking over the entire affected area (Worden and Wald 2016).

Table 22. Earthquake magnitude descriptions.

Magnitude	Description
<3.0	Micro
3.0-3.9	Minor
4.0-4.9	Light
5.0-5.9	Moderate
6.0-6.9	Strong
7.0-7.9	Major
>8.0	Great

Source: IRIS (2017).



A view from inside the Upper Cliff Dwelling. Photo Credit: NPS/P. Pineda Bovin.

Reference Conditions

Reference conditions are described for resources in good, moderate concern, and significant concern conditions for each of the six measures (Table 23). Reference conditions were initially developed by the assessment author and then reviewed by monument staffs and staffs from the Sonoran Desert Inventory and Monitoring Network (SODN) during the Natural Resource Condition Assessment (NRCA) scoping meeting on 10 May 2018 and during later reviews of this assessment.

Table 23. Reference conditions used to assess geology in Tonto NM.

Indicators	Measures	Good	Moderate Concern	Significant Concern
Erosion	Estimated Degraded Area (%)	No one plot exceeded <25% active erosion (sheet, rill, gully).	Active erosion (sheet, rill, gully) was estimated to be between 25-50% for any given plot.	Active erosion (sheet, rill, gully) was estimated at >51% for any given plot.
	Erosion Resistance Index	The index averages ≥4.0.	An average index of 3-4	An average index of ≤2.0.
Deterioration or Loss of Integral Geological/ Paleontological/ Cultural Features	Anthropogenic Events	There are no known anthropogenic incidences that affect geological/ paleontological/cultural resources.	There have been a small number of known anthropogenic incidences that affect geological/ paleontological/cultural resources.	There have been a moderate number of known anthropogenic incidences that affect geological/ paleontological/cultural resources.
	Natural Events	There have been no incidences of rockfall or slope failure along trails, roads, or overlooks, or in close proximity to cultural features within the monument. There also appear to be no areas of concern for such occurrences.	There have been a small number of incidences of rockfall or slope failure along trails, roads, or overlooks, or in close proximity to cultural features within the monument. These incidents are restricted to only a few locations and are not considered a widespread issue.	There have been a moderate number of incidences of rockfall or slope failure along trails, roads, or overlooks, or in close proximity to cultural features within the monument. These incidences are widespread across the monument.
	ASMIS Condition Rating	At least 75% of sites are listed as in good condition with the remaining sites considered fair and no sites rated as poor or destroyed.	Between 50%-74% of sites are considered good, with the remaining sites considered fair. A few sites may be listed as poor. No sites are considered destroyed.	Less than 50% of sites are considered good, with the remaining sites considered fair, poor, or destroyed.
Seismic Activity	Presence/ Absence	No earthquakes have occurred in the vicinity of the monument or the monument is not in a seismically active zone.	Earthquakes have occurred in the vicinity of the monument or the monument is within a seismically active zone. But ShakeMaps for these events have not extended into the monument.	Earthquakes have occurred in the monument's vicinity or the monument is in a seismically active zone. Further, the occurrence of earthquakes appears to be at a moderate to high level in either frequency or magnitude and at least one of the ShakeMaps produced for these events extend into the monument.

Condition and Trend

For the erosion indicator measure of estimated degraded area, there was no evidence of tunneling, pedestals, or terracettes during either sampling period in the monument's lowest elevation stratum (Table 24). Burrowing was observed in all plots and time periods except for in 2014 for plot 2, although this feature type was estimated at <5%. The summed mid-points of the estimated area of sheet, rill, and gully features was highest (9%) in 2009/2010 for plot 3 but was 0% in the second round of sampling. Since no one plot exceeded 25% degraded area, the condition is good for the valley stratum.

As with the valley stratum, none of the 11 plots in the bajada exhibited tunneling, pedestals, or terracettes (Table 25). Burrowing occurred in nearly all plots and in both sampling periods but was, in general, estimated at less than 5% in any given plot. Plot 6 during 2014 exhibited the highest degraded area at 15.5%, but no one plot exhibited greater than 25% of sheet, rill, and gully features. These results indicate good condition for the bajada.

Of the five plots in the foothills, only one exhibited some tunneling, but there were no terracettes or pedestals (Table 26). Burrowing was common across plots, but was generally estimated at <5%. Plot 4

Table 24. Extent of erosion by feature type in the valley stratum during 2009/2010 and 2014.

Plot	Year	Tunneling (% of plot)	Pedestals (% of plot)	Terracettes (% of plot)	Burrowing (% of plot)	Sheet (% of plot)	Rill (% of plot)	Gully (% of plot)	Estimated Degraded Area (% of plot)
2	2009/2010	0	0	0	<5	0	0	0	0
	2014	0	0	0	0	0	0	0	0
3	2009/2010	0	0	0	<5	<5	<5	<5	9
	2014	0	0	0	<5	0	0	0	0
4	2009/2010	0	0	0	<5	0	0	0	0
	2014	0	0	0	<5	0	<5	0	3

Note: The estimated degraded area was calculated by summing the mid-points of sheet, rill, and gully erosion.

Source: NPS, K. Bonebrake, SODN data manager, 8 December 2017.

Table 25. Extent of erosion by feature type in the bajada stratum during 2009/2010 and 2014.

Plot	Year	Tunneling (% of plot)	Pedestals (% of plot)	Terracettes (% of plot)	Burrowing (% of plot)	Sheet (% of plot)	Rill (% of plot)	Gully (% of plot)	Estimated Degraded Area (% of plot)
2	2009/2010	0	0	0	6-25	0	0	0	0
	2014	0	0	0	<5	0	0	0	0
5	2009/2010	0	0	0	<5	0	0	0	0
	2014	0	0	0	<5	0	<5	0	3
6	2009/2010	0	0	0	<5	0	0	0	0
	2014	0	0	0	<5	0	0	6-25	15.5
8	2009/2010	0	0	0	<5	0	<5	0	3
	2014	0	0	0	<5	0	<5	0	3
9	2009/2010	0	0	0	<5	0	<5	0	3
	2014	0	0	0	<5	0	0	0	0
10	2009/2010	0	0	0	<5	0	0	0	0
	2014	0	0	0	<5	0	0	0	0
13	2009/2010	0	0	0	<5	0	0	<5	3
	2014	0	0	0	<5	0	0	<5	3
14	2009/2010	0	0	0	<5	0	0	0	0
	2014	0	0	0	<5	0	0	0	0
15	2009/2010	0	0	0	0	0	0	0	0
	2014	0	0	0	0	0	<5	0	3
16	2009/2010	0	0	0	0	0	0	0	0
	2014	0	0	0	<5	0	0	0	0
17	2009/2010	0	0	0	0	<5%	<5	<5	9
	2014	0	0	0	0	0	<5	0	3

Note: The estimated degraded area was calculated by summing the mid-points of sheet, rill, and gully erosion.

Source: NPS, K. Bonebrake, SODN data manager, 8 December 2017.

exhibited 18.5% and 15.5% degraded area during 2009/2010 and 2014, respectively. All other plots exhibited degradation of 3% or less. As with the other two strata, these results indicate good condition for the foothills. The overall condition rating for all three strata is good, but confidence in the condition rating is medium because the data were last collected five years ago. Trend could not be determined based on two sampling periods.

Table 26. Extent of erosion by feature type in the foothills stratum during 2009/2010 and 2014.

Plot	Year	Tunneling (% of plot)	Pedestals (% of plot)	Terracettes (% of plot)	Burrowing (% of plot)	Sheet (% of plot)	Rill (% of plot)	Gully (% of plot)	Estimated Degraded Area (% of plot)
1	2009/2010	0	0	0	<5	0	0	0	0
	2014	0	0	0	<5	0	0	0	0
2	2009/2010	0	0	0	<5	0	0	0	0
	2014	0	0	0	<5	0	0	0	0
3	2009/2010	0	0	0	<5	0	0	0	0
	2014	0	0	0	0	0	<5	0	3
4	2009/2010	<5	0	0	6-25	0	<5	6-25	18.5
	2014	0	0	0	0	0	0	6-25	15.5
5	2009/2010	0	0	0	<5	0	0	0	0
	2014	0	0	0	<5	0	<5	0	3

Note: The estimated degraded area was calculated by summing the mid-points of sheet, rill, and gully erosion.

Source: NPS, K. Bonebrake, SODN data manager, 8 December 2017.

The erosion resistance index in summer 2006 (prior to plant thinning) averaged 3.9 ± 1.2 SD across all 46 sites. This value falls within the moderate concern condition rating but is close to the good condition rating. When considering only the 15 plots that were monitored during at least two time periods, the index averaged 4.2 ± 1.1 SD in summer 2006 (good condition). After plant thinning, the index dropped to 3.6 ± 1.5 SD (n = 15) in February 2007 and then to 3.3 ± 1.1 SD (n = 14) in autumn 2007. This suggests that the effects of plant thinning lasted at least one year, or after one growing season.

The difference in means between summer 2006 and February 2007 was significant ($n = 15, t = 2.55, p = 0.02$) as was the difference in means between summer 2006 and autumn 2007 ($n = 14, t = 4.84, p < 0.005$). However, the difference in means between February 2007 and autumn 2007 was not significant (n = 14, t = 090, p = 0.39), indicating that the greatest changes occurred immediately after plant thinning. Figure 29 shows the number of plots within each sampling period that improved, declined, or did not change.

The factors that decreased resistance to erosion varied by plot. In general, however, soil aggregate stability declined and exposed bare ground increased (McIntyre 2008). Trampling by surveyors may have also been a factor in declines in stability (McIntyre 2008). These results warrant a moderate concern condition rating, but confidence is low because the plots were sampled more than 10 years ago (2006/2007). To our knowledge, this study has not been repeated. Trend could not be determined.

For the anthropogenic impacts measure of the deterioration or loss of integral geological/paleontological/cultural features indicator, we found that vandalism has increased in recent years at both cliff dwelling sites (NPS 2017a). During Tonto NM's NRCA scoping meeting, NPS staff mentioned finding a shovel and other materials that suggested possible unauthorized artifact removals, although this could not be confirmed. Although the monument is closed and gated nightly, illegal after-hours visitation has increased (NPS 2017a). There is also evidence of "historic looting of critical sites," but most sites are inaccessible to the public and as a result are considered in pristine condition with artifacts present on the soil surface (NPS 2017a).

Key management practices have reduced the likelihood of vandalism to important features in the monument. For example, access to the Upper Cliff Dwellings is limited to weekend guided tours from November to April, and the trail to the Upper Cliff Dwelling is gated (NPS 2019). Access to the Lower Cliff Dwelling, however, is year-round and does not require a guide. Due to the steep and rugged nature of the monument, there are few trails and off-trail travel is difficult. These factors help limit the damage that visitors may cause to monument resources, purposefully or accidentally.

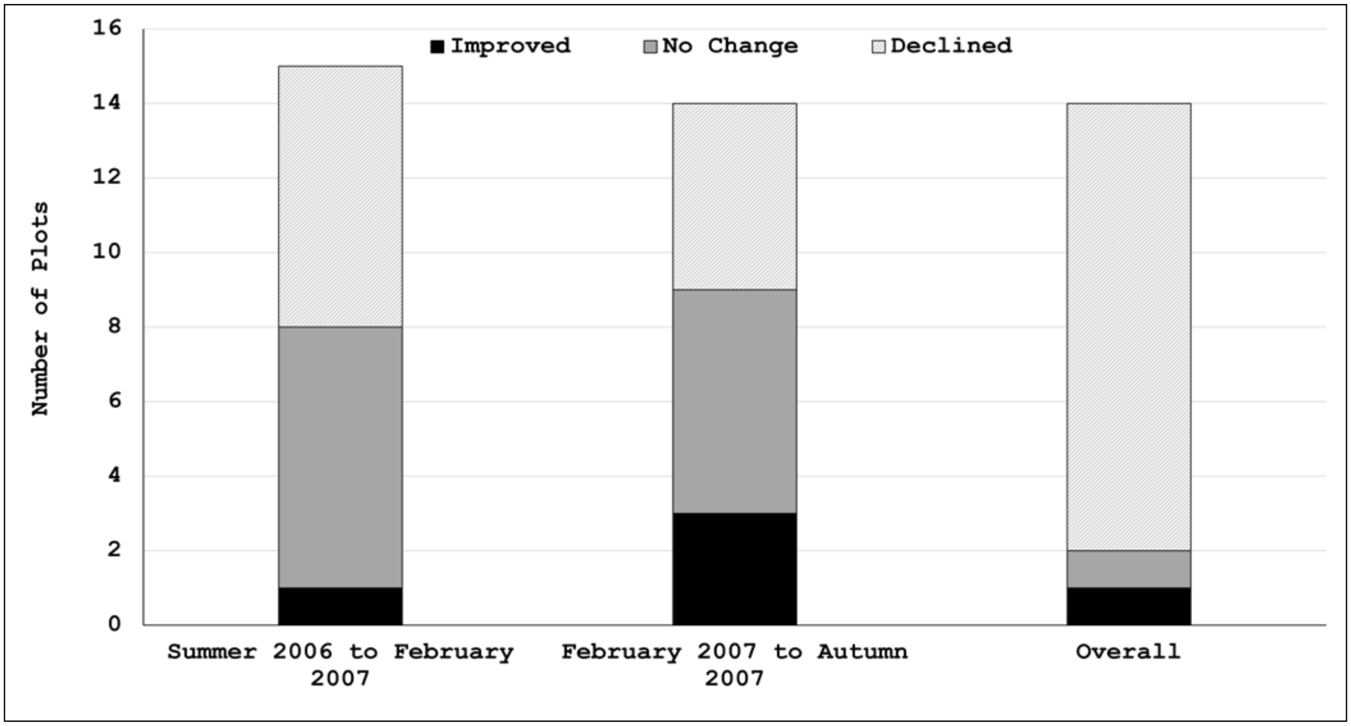


Figure 29. The number of plots that improved, declined, and did not change in erosion resistance from summer 2006 (n = 15) to autumn 2007 (n = 14).

According to the monument's foundation document, the Upper and Lower Cliff Dwellings are in good condition, and preservation and maintenance projects occur regularly at these locations, with stabilization projects occurring at key areas (NPS 2017a). Previous preservation efforts, however, have impacted site quality. For example, some of the original adobe walls were overlaid with cement, and moisture trapped between the layers may have contributed to erosion (NPS 2017a). Additionally, retaining walls constructed at the dwellings has changed drainage patterns, which also contributes to erosion. Although wildlife are noted as potentially causing damage to these features (NPS 2017a), there is no study that specifically addresses this.

Because of the sensitive nature of the cliff dwellings and caves in which they were excavated, impacts from air tours and overflights could cause damage through vibrations. According to the NPS Air Tours program, which works with the Federal Aviation Administration (FAA) to monitor and manage air tours in National Park System units, there were no reported air tours over Tonto NM from 2013 to 2017 (Lignell 2018). The interim operating authority established by the FAA allows for two overflights per year (FAA 2005). Nevertheless, aircraft are frequently observed over the monument.

In comments to the NPS Air Tours Program, Tonto NM staff stated, "We have dozens of overflight incidents per year here, but we don't get an ID on most of them" (NPS, unpublished document, 2005). The individual also commented that most air tours are by private citizens or are government aircraft. In each of these instances when the tail number was identified, a letter was sent to the owner of the aircraft requesting consideration of cultural resources and the visitor experience (Table 27). Unauthorized helicopters frequently hover above and close to the ruins, sometimes just 30 m (~100 ft) off the ground (NPS, unpublished document, 2005).

While there is no way to know whether these unauthorized overflights have affected the structural integrity of the cliff dwellings or other geological resources in the monument, the noted vandalism and the effects of negative past preservation efforts warrant moderate/significant concern condition. However, confidence in the condition rating is low since there is no database that tracks these types of events, nor is there direct evidence of damage caused by overflights.

Table 27. Summary of helicopters observed flying low over cliff dwellings in Tonto NM.

Date	Above Ground Level (m)
18 March 2004	<610
20 March 2004	<610
1 April 2004	<610
24 November 2003	<610
22 December 2003	<610
11 January 2008	<610
12 December 2017	30-152

Source: NPS unpublished data.

The natural events measure of the deterioration or loss of integral geological/paleontological/cultural features indicator was difficult to assess because Tonto NM does not maintain a database documenting rock falls, slope failures, and other natural erosional occurrences in the monument. The steep slopes coupled with the monument's highly erodible rock and soils makes Tonto NM a naturally sensitive landscape to erosional forces such as water and wind. It is the erodible nature of the caves that attracted the Salado people to the area initially. While most factors that affect these resources are natural, the monument was established to protect these features (NPS 2017a). Since the monument was established, there have been numerous projects to stabilize slopes, preserve the cliff dwellings, and maintain trails (NPS 2017a). These projects are ongoing and considered a part of routine maintenance at the monument (NPS 2017a).

There are a few places where erosion has been noted as especially concerning, namely with respect to the cliff dwellings. Erosion occurs along the retaining wall on the trail to the Lower Cliff Dwelling and the trail passes under a steep overhang, which is a concern with respect to visitor safety (KellerLynn 2006). There is also a crack in the ceiling above the alcove at the Lower Cliff Dwelling (Fisher 2009). No management activity was required when the crack was evaluated by a structural engineer in 2008, but an increase in 10 cm (4.0 in) would warrant future management action (Fisher 2009).

At the Upper Cliff Dwellings, Rutenbeck (1993) attempted to monitor several cracks from the mid-1980s to 1993, but most of the equipment failed. One monitor, however, indicated that a crack in a detached rock mass near the trail to the Upper Cliff Dwelling had actually closed by about one millimeter since it was first surveyed (Rutenbeck 1993). Rutenbeck (1985) reported that monitoring of the structural integrity of the Upper and Lower Cliff Dwellings did not suggest any evidence of progression toward failure of cliff walls or other features. Movements in rock formations and cliff dwellings are likely very slow, taking decades or even centuries to manifest as changes in structure (Rutenbeck 1985). A 25-year record of gages that measured cracks in archeological structures in Tonto NM found that minimal movements occurred over this time-frame (KellerLynn 2006).

A helicopter hovering above Tonto NM. Photo Credit: NPS.

The cumulative effects of wind, water, wildlife, and plants are difficult to monitor, and it is unclear at what pace changes in structural integrity are occurring. However, there are numerous concerns at both the Upper and Lower Cliff Dwellings and the geologic landscape in which they are embedded. Many of these concerns are mitigated through routine preservation efforts. Therefore, the condition is good, but confidence in the condition rating is low. Trend is unknown.

For the ASMIS condition rating measure of the deterioration or loss of integral geological/paleontological/cultural features indicator, we found that for the 30 sites surveyed only once, all but four were in good condition. The four remaining sites were considered in fair condition. Of the 63 sites surveyed during all seven years, 53 (84%) were rated as good. Two sites were rated as fair in all seven years (11%), and one site was rated as destroyed from 2014-2018 but good in 2011-2012 and in 2019. Whether this is an error or because the site was restored is unknown. In

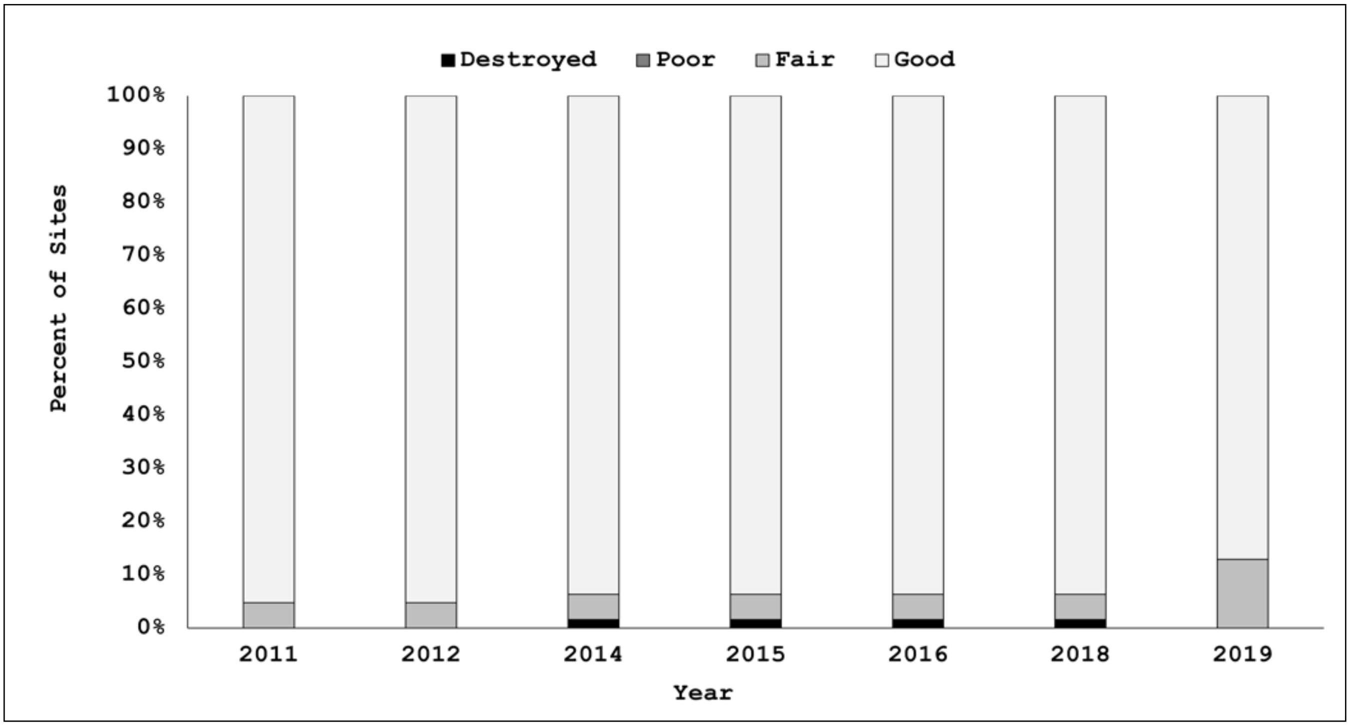
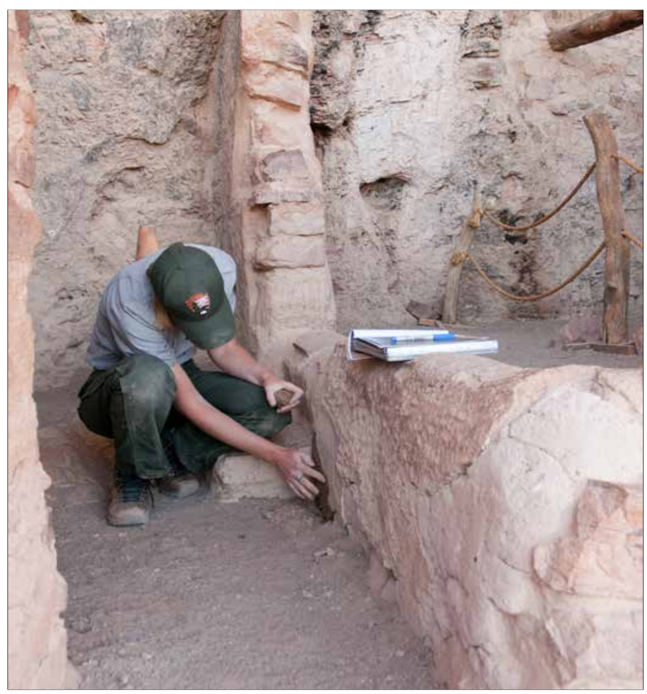


Figure 30. The proportion of archeological sites in each of four condition classes.

2019, all sites were surveyed and 88% of them were rated as good. The remaining 12% were rated as fair. Figure 30 shows the proportion of sites within each condition class by year. Based on these results, the condition for this measure is good. Confidence in the condition rating is high because of the repeated surveys and recent results.

The presence/absence measure of the seismic activity indicator revealed that 36 seismic events occurred within the AOA from February 1999 to February 2019 (Figure 31). The magnitudes of these events ranged from 2.5 (micro) to 5.1 (moderate). One of these events was the result of a mining explosion. This 3.0 magnitude (minor) event occurred 161 km (100 mi) southeast of the monument on 8 August 2018. All but three events were less than 4.0 magnitude (light), which is the minimum magnitude at which most events are felt. Five seismic events occurred around the monument but none were reported within the monument. These events ranged from 2.8 to 3.2 magnitude.

Within the AOA, there were no events with a ShakeMap that extended into the monument; however, the ShakeMap Atlas did not include the earthquake triggered by mining in 2018. Given the distance and magnitude of this event, it was unlikely to have affected the monument. No other events occurred from 2017 to February 2019. According to the USGS (USGS 2018b) and the Arizona Geological Survey (AGS) (AGS 2019), the state is seismically active. Given the number of events (more than one per



Stabilization work at the Lower Cliff Dwelling in 2012. Photo Credit: NPS.

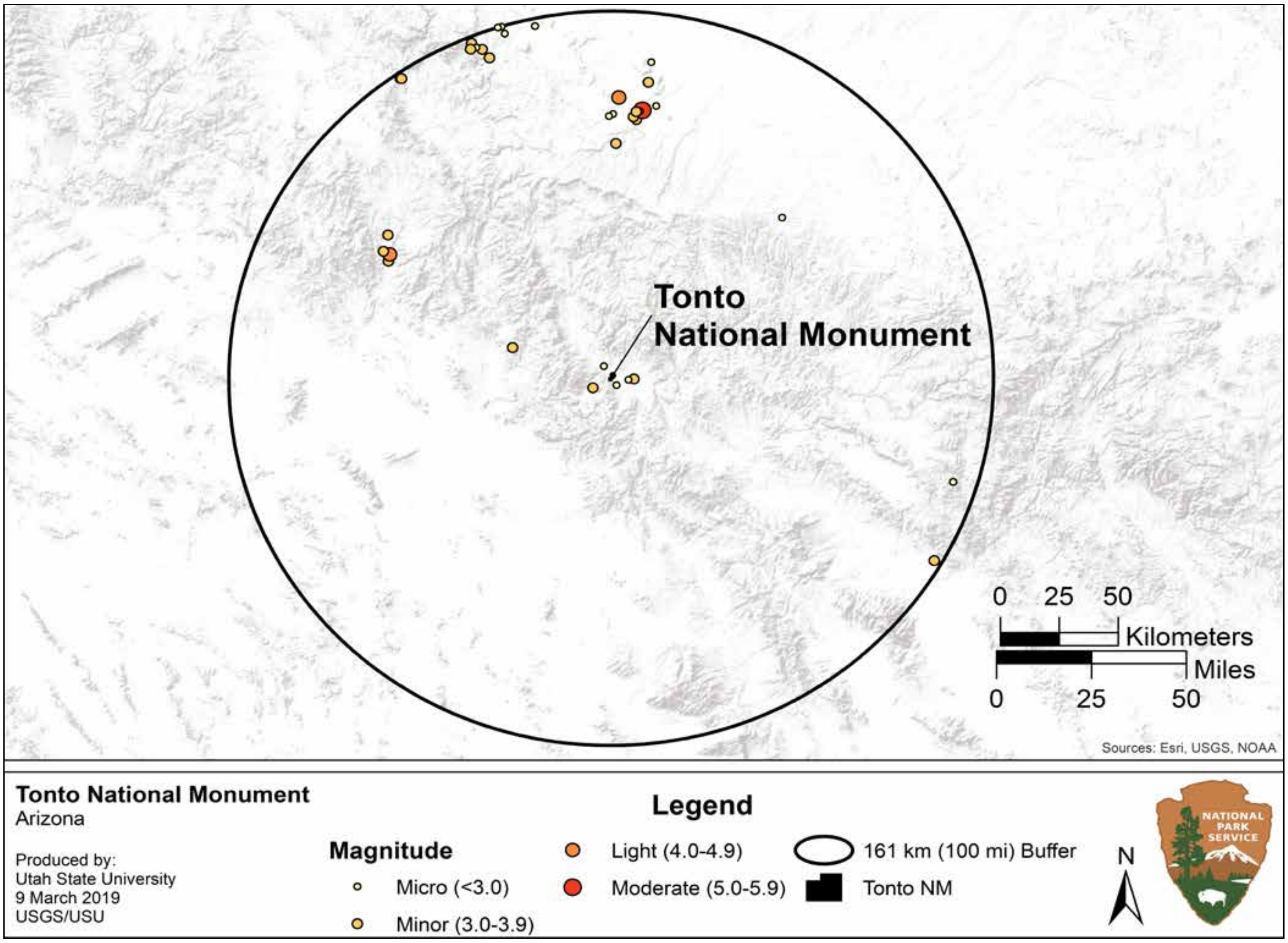


Figure 31. **Earthquakes from 1999 to 2019 in a 161 km (100 mi) radius around the monument.**

year) and the fact that Arizona is prone to earthquakes, the condition is of moderate concern. Confidence in the condition rating is medium, however, because it is unclear what impacts, if any, these earthquakes have had on features in the monument. Earthquakes by nature are unpredictable and could occur near the monument at any time.

Overall Condition, Threats, and Data Gaps

We used three indicators and six measures to assess the current condition of geological and associated resources in Tonto NM (Table 28). Three measures indicate moderate concern and three measures indicate good condition. Measures with high confidence were weighted more in the overall condition rating than measures with medium and, especially, those with low confidence. This resulted in an overall condition of good with medium confidence. For example, low erosion resistance, cracking of features, and seismic activity present numerous challenges for the preservation of geological and associated cultural features in the monument. However, ASMIS data indicate that nearly all archeological sites surveyed are in good condition and erosion features are uncommon. Trend could not be determined.

The monument protects six classified structures (Ogle 2016) and at least 180 archeological sites in addition to the natural geology of the landscape (NPS 2017a). Vandalism and illegal excavation have occurred in the monument and continue to be threats to geological and cultural resources (NPS 2017a). Illegal excavation may also be a threat to paleontological resources, although these resources are uncommon in the monument (NPS 2017a, Tweet et al. 2008).

Fossils in the monument occur in the Mescal Limestone (Tweet et al. 2008). While no fossils have been found in the Dripping Quartzite Formation, this exposed rock has the potential to contain fossils since they have been found in the same formation at nearby Roosevelt Dam (Tweet et al. 2008). The Gila

Table 28. Summary of geology indicators, measures, and condition rationale.

Indicators	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Erosion	Estimated Degraded Area (%)		No one plot during either sampling period exceeded 25%. Data exhibited similar patterns in extent and type of features across the three strata. Most features that are precursors to erosion (pedestals, terracettes, tunneling), were absent or rare. Burrowing, however, was more widespread but generally did not exceed 5% in any one plot. Of the sheet, rill, and gully features that are summed to determine overall degraded area, sheet erosion was the least commonly observed feature. Overall, though, most plots across the three strata exhibited no or minimal (<5%) degraded area.
	Erosion Resistance Index		The mean index across the 46 sites in 2006 averaged 3.9 ± 1.2 SD, which is very near the threshold for good condition. However, plant thinning reduced erosion resistance in the 15 plots experimental plots. There was a significant decline in erosion resistance after plant thinning. confidence is low because the most recent data are from 2007.
Known Deterioration or Loss of Integral Geological/ Cultural Features	Anthropogenic Impacts		While human-caused deterioration of features in the monument are largely unknown, they are likely minimal with respect to on-site visitation due to restricted access, few trails, and rugged terrain. However, each year dozens of unauthorized overflights in the monument occur with the potential for compromising the structural integrity of the cliff dwellings and the geology of the caves in which they were constructed. However, we could not determine what impacts, if any, overflights have had over time.
	Natural Events		The cumulative effects of wind, water, wildlife, and plants are difficult to monitor, and it is unclear at what pace changes in structural integrity are occurring. There are numerous concerns at both the Upper and Lower Cliff Dwellings and the geologic landscape in which they are embedded. However, many of the disturbances are mitigated through routine preservation efforts.
	ASMIS Condition Rating		Of the 30 sites surveyed only once, all but four were in good condition. The four remaining sites were rated as in fair condition. Of the 63 sites surveyed during all seven years, 53 (84%) were rated as good. Two sites were rated as fair in all seven years (11%), and one site was rated as destroyed from 2014-2018 but good in 2011-2012 and in 2019. In 2019, all sites were surveyed and 88% of them were rated as good. The remaining 12% were rated as fair.
Seismic Activity	Presence/ Absence		A total of 36 seismic events, including one related to mining, occurred within 161 km (100 mi) of the monument. None of these events had an associated ShakeMap that extended into the monument, although the mining event occurred outside the timeframe of the ShakeMap Atlas database. The USGS and the Arizona Geological Survey report that the state is very seismically active. Although several events during 1999 to 2019 occurred near the monument, no events were reported for inside the monument.
Overall Condition	Summary of All Measures		Numerous helicopter overflights along with low erosion resistance, cracking of features, and seismic activity present numerous challenges for the preservation of geological and associated cultural features in the monument. However, ASMIS data indicate that nearly all archeological sites surveyed are in good condition and erosion features are uncommon.

Conglomerate and Quaternary rocks and sediments in the monument also have the potential to bear fossils. However, there has not been a thorough survey of paleontological resources at Tonto NM. Observations of exposed cliffs, erosional bedrock, and talus piles by NPS staffs at the monument may reveal specimens in the future (Tweet et al. 2008).

Water is the major erosional force at work in Tonto NM. During high rainfall events, water drips through cracks in caves, which erodes the underlying rock—a process called spalling (KellerLynn 2006). The Salado collected this water for use in cooking, cleaning, and drinking (KellerLynn 2006). Historic preservation activities, including cementing adobe walls, may be causing erosion, and retaining walls at the cliff dwellings may be changing patterns of drainage around structures (NPS 2017a).

In addition to water, wildlife and plants can also damage these resources. Wildlife are attracted to the cliff dwellings for the shelter and shade they offer.

Birds, rodents, and bats have become a particular nuisance (NPS 2017a). These species appear to be accelerating erosion, especially when combined with high rainfall events (Rutenbeck 1993). Burrowing rodents provide tunnels through which water may flow, thereby accelerating erosion. In the 19 upland vegetation plots surveyed by SODN during 2009/2010 and 2014, evidence of burrowing, was present in most plots but low in extent. While Africanized honey bees (*Alpis mellifera*) also occur in the cliff dwellings, this species is more of a threat to visitors than it is to archeological or geological resources (NPS 2017a).

Although plant thinning protects archeological sites from damage caused by roots, it also exposes these sites to increased erosion. McIntyre (2008) suggested water diversions or other structural measures for mitigating the impacts of plant removal on erosion. Another option noted by McIntyre (2008) is to seed with native grasses in place of shrubs since shrubs tend to threaten archeological structures more than grasses. High cover of mature BSC can also limit erosion. Although BSC cover was very low across the 46 sites monitored by McIntyre (2008) in 2006, mature BSC cover averaged 16% in 2014 in the bajada during SODN's sampling of upland plots. In the foothills, BSC cover averaged 4% (SODN unpublished data). McIntyre (2008) did not indicate where the 46 plots were located, probably because of the sensitivity of archeological site information.

Mineral development and grazing in the lands surrounding the monument also pose a potential threat to Tonto NM's geological resources (KellerLynn 2006). Although a fence surrounding the monument excludes non-native ungulates, grazing on U.S. Forest Service (USFS) lands above the spring could lead to unnatural flooding of Cave Canyon, the monument's only perennial water source (Albrecht et al. 2007). However, the USFS practices rotational grazing in the Cave Canyon watershed, which allows for plants to recover (U.S. Forest Service [USFS], E. Hoskins, range manager, personal communication to K. Raymond, NPS hydrologist, received 10 December 2018). Regardless of grazing practices, intense rainfall could produce a flash flood that scours Cave Canyon.

Although southern Arizona has been in a drought since 2000 (Arizona Department of Water Resources 2018), climate projections include more intense thunderstorms along with overall drier conditions and warmer temperatures (Backlund et al. 2008). Extremes in temperature could also produce more freeze-thaw cycles, which causes the expansion and contraction of water in rocks, resulting in fractures (Santucci et al. 2009). As fractures increase in size, some may break off and cause rock falls. Rock falls may also be caused by heavy rainfall or even from vibrations caused by overflights (USFS 1992a).

The NPS has no authority over the monument's airspace, which is solely in the domain of the FAA up to an altitude of 15,240 m (50,000 ft) (FAA 2012). FAA regulations require special permits for flights below 152 m (500 ft) and advises all aircraft to maintain a distance of at least 610 m (2,000 ft) above ground level over National Park System units and other protected areas, but this is only a recommendation and is not enforced (FAA 2012).

A data gap is whether overflight vibrations impact resources in the monument. Data gaps also include an inventory of the monument's cave features, which may contain archeological resources (KellerLynn et al. 2006). While the U.S. Department of Agriculture's Natural Resources Conservation Service completed a preliminary soil survey for the monument in 1994, a more comprehensive survey is needed (KellerLynn et al. 2006). Lastly, the monument's geologic resources inventory report was never completed, and the monument is lacking an inventory of the cultural landscape (Ogle 2016). However, there is a completed digital geologic map available at the NPS Geologic Resource Inventory website and a report is expected by end of FY2019 (T. Connors, NPS geologist, pers. comm. 16 April 2019).

Sources of Expertise

This assessment was written by science writer and wildlife biologist, Lisa Baril, Utah State University. Subject matter expert reviewers for this assessment are listed in Appendix A.

Cave Canyon Riparian Area

Background and Importance

Cave Spring in Cave Canyon gives rise to a narrow riparian forest in Tonto National Monument (NM). The bedrock-dominated wash flows perennially from the spring, with the highest flows occurring during winter (Albrecht et al. 2005). Cave Spring allows for diverse riparian vegetation, which in turn provides habitat for nesting birds and other wildlife. The spring also provide breeding pools for amphibians and drinking water for mammals (Albrecht et al. 2005).Historically, a lower, connected spring located about 100 m (328 ft) downstream of Cave Spring, flowed during all but the driest periods (Albrecht et al. 2005); however, that spring has since completely dried and no longer provides surface flows (NPS, K. Raymond, hydrologist, comments to draft assessment, 10 December 2018).

During a 2001 to 2003 study of the Cave Canyon wash, 90 species of vascular plants, 18 species of amphibians and reptiles, 36 bird species, and five species of mammal were documented in this narrow corridor (Albrecht et al. 2005). At the time of these surveys, the species reported as inhabiting Cave Canyon accounted for between 40% and 86% of all species in the monument. Several species were found only within the riparian area, such as Bell's vireo (*Vireo bellii*), yellow warbler (*Setophaga petechia*), and Abert's towhee (*Melozone aberti*) (Albrecht et al. 2005).

Riparian areas are diverse environments wherever they occur, but in the arid southwestern U.S., riparian vegetation supports a disproportionately greater diversity of wildlife and plants than the surrounding habitat (Skagen et al. 1998). In Tonto NM, Sonoran desert, thornscrub, and semi-desert grasslands surround the riparian area (NPS 2018d). Rugged and steep slopes rise high above Cave Canyon to the Colorado Plateau north of the monument (NPS 2018d). Aside from Cave Canyon, Deadman and Cholla canyons provide additional but ephemeral water sources in the monument (NPS 2018d).

The Cave Canyon area with its spring, and the Salt River a few miles away, not only provided water for plants and animals, it allowed for human occupation as well. These perennial water sources drew pre-historic peoples into the region 10,000 years ago. At around A.D. 800 the Hohokam settled the region with the Salado following by the mid- 1200. Both of these cultures practiced subsistence agriculture and it was the Salado who constructed the cliff dwellings for which the monument is known. By the mid-1400s the Hohokam and Salado people abandoned the area for reasons that are still unclear to archaeologists. The area soon became occupied by today's Yavapai and Apache

Cave Canyon Wash in Tonto NM. Photo Credit: NPS SODN.

peoples until the U.S. military, due to the discovery of gold in the 1870s, pushed these people northwards (Lindauer 1997). The monument was established in 1906 just 30 years later.

Data and Methods

This assessment is based on three indicators with a total of nine measures. The indicators are water quantity (two measures), water quality (six measures), and riparian/wetland vegetation (one measure). For brevity, we provide a brief description of each measure and why it is important rather than complete sampling details, which can be found in Albrecht et al. (2005) and Hubbard and Gwilliam (2016).

For the water quantity indicator, we assessed water persistence using both *in situ* water level sensor data from August 2014 through mid-2017 (NPS 2017b) and spring discharge data from 2001 to 2003 (Albrecht et al. 2005) and 2017 (NPS 2017b). In August 2014, a water level sensor was installed below the ground surface approximately 16 m (52 ft) downstream from the spring orifice and 1 m (3 ft) from the thalweg (lowest elevation within the stream) of the spring brook. The sensor was read daily through mid-2017. These data were provided by hydrologist Colleen Filippone, NPS Intermountain Region, retired. Water level data are useful for monitoring long-term changes in groundwater recharge and storage, long-term changes in climate, and the effects of regional groundwater development, but because the sensor lies beneath the ground surface, it is not a direct indicator of water level. Rather, it is a measure of shallow groundwater adjacent to the springbrook (NPS, K. Raymond, hydrologist, comments to draft assessment, 10 December 2018).

Discharge data were collected bimonthly from October 2001 through October 2003 (n = 12) (Albrecht et al. 2005). Data were collected approximately 30 m (98 ft) downstream of Cave Spring. Discharge data were also collected near Cave Spring on 13 July 2017 (NPS 2017b). The National Park Service's (NPS) Sonoran Desert Inventory and Monitoring Network (SODN) program monitors springs, seeps, and tinajas across several of its network parks. A brief, summarizing the springs monitoring protocol, is available in Hubbard and Gwilliam (2016). While water level data are useful for persistence at a specific location in the stream channel, discharge is a good metric for conditions along the length of the flowing stream channel.

Wetted extent was the second measure of water quantity. From 2001 to 2003, Albrecht et al. (2005) measured the distance over which water flowed in the stream channel at two locations: downstream of Cave Spring and downstream of the lower spring, which is now dry. As with discharge, the distance of flowing water was collected bimonthly (n = 12). In 2017, the distance of flowing water was reported for Cave Spring on one day (13 July 2017) (NPS 2017b). NPS (2017b) also reported wetted width. Wetted extent is useful for determining the area influenced by surface water.

For the water quality indicator, data were collected on one day in 2017 (13 July) at two locations near Cave Spring. Location 1 refers to the Cave Spring orifice and location 2 refers to 7.4 m (24.3 ft) downstream of the Cave Spring orifice. Like wetted extent and discharge, water quality data were collected as part of SODN's springs monitoring program (Hubbard and Gwilliam 2016). The water quality measures were stream temperature, dissolved oxygen (% and mg/L), specific conductivity, pH, and turbidity.

Stream temperature fluctuates both daily and seasonally as well as with rates of discharge. All water quality parameters are influenced by temperature. For example, stream water with higher temperatures typically has a lower pH, which results in greater dissolution of minerals from the surrounding rock than under cooler conditions. This, in turn, influences specific conductivity (USGS 2018c). The pH determines the solubility and availability of compounds and minerals to organisms. The amount of dissolved materials, including heavy metals, rises with increasing acidity. Therefore, pH is a good indicator of change in water chemistry and pollution (USGS 2018c).

Dissolved oxygen measures the amount of gaseous oxygen dissolved in the stream (USGS 2018c). Because oxygen is required for aquatic organisms, low dissolved oxygen levels put aquatic wildlife under stress. At very low levels, oxygen may be present but unable to sustain aquatic wildlife. There are many natural causes of variability in dissolved oxygen levels, including nutrient levels, whether the stream is gaining groundwater, the time of day, and the time of year (USGS 2018c). Specific conductivity is the ability of water to conduct an electrical current and is dependent on the amount of dissolved solids in the water, such as salts (USGS 2018c). Turbidity is a measure of water clarity. It is expressed by the amount of light scattered by materials in the water (USGS 2018c). The higher the intensity of scattered light, the higher the turbidity. High concentrations of particulates in the water lessen the amount of light that penetrates the water column, which can affect plants and other aquatic life (USGS 2018c). Particles also provide attachment places for pollutants and other harmful chemicals. Therefore, turbidity can be used as an indicator of potential pollution (USGS 2018c). Turbidity is reported in Nephelometric Turbidity Units (NTU).

To assess the presence/absence of the riparian/wetland vegetation indicator, we used vegetation classification data provided in Studd et al. (2017). The purpose of the study was to map vegetation across the entire monument. Two vegetation plots measuring 10 x 100 m (33 x 328 ft) were established in the Cave Canyon riparian area. The two plots were subjectively placed because of the narrow and limited area of this habitat type in the monument. Observers estimated the percent cover in each of four vegetation layers. The four layers were as follows: field (0-0.5 m [0-1.6 ft]), subcanopy (0.5-2.0 m [1.6-6.6 ft]), canopy 1 (2.0-5.0 m [6.6-16.4 ft]), and canopy 2 (>5.0 m [>16.4 ft]). Observers also determined the dominant species in each layer, the associated species in each layer, and uncommon species found in each layer. Data were collected in March and April 2009.

For each plant species, we determined its wetland status using the U.S. Army Corps of Engineers National Wetlands Plant List for the State of Arizona arid west region (Lichvar et al. 2016). Plants were divided into five categories based on wetland status. The categories are: obligate wetland (OBL = almost always occurs in wetlands), facultative wetland (FACW = usually occurs in wetlands but may occur in non-wetlands), facultative (FAC = occurs in wetlands and non-wetlands), facultative upland (FACU = usually occurs in non-wetlands), and obligate upland (UPL = almost never occurs in wetlands). Any species not listed by the Corps is considered an upland species (Lichvar et al. 2016).

Reference Conditions

Reference conditions are described for resources in good, moderate concern, and significant concern conditions; however, reference conditions for some measures include only good and significant concern benchmarks (Table 29). Water quality reference conditions were derived from criteria developed by the State of Arizona's Department of Environmental Quality (ADEQ) (ADEQ 2017). There are no state

Table 29. Reference conditions used to assess the Cave Canyon riparian area in Tonto NM.

Indicators	Measures	Good	Moderate Concern	Significant Concern
Water Quantity	Persistence (water level sensor and discharge)	Data indicate that Cave Spring flows perennially.	Data indicate that periods of low water are occurring more frequently outside the normal low-flow season.	Data indicate a disruption in flow such that water is available intermittently.
	Wetted Extent (m)	The length of wetted area below the main spring has remained stable.	The length of wetted area below the main spring is highly variable, even outside the normal low-flow season.	The length of wetted area below the main spring is absent for parts of the year.
Water Quality	Temperature (°C)	No Reference Conditions	No Reference Conditions	No Reference Conditions
	Dissolved Oxygen (%)	≥ 90	–	< 90
	Dissolved Oxygen (mg/L)	≥ 6	–	< 6
	Specific Conductivity (μS/cm)	No Reference Conditions	No Reference Conditions	No Reference Conditions
	pH (SU)	6.5-9.0	–	<6.5 or > 9.0
	Turbidity (NTU)	No Reference Conditions	No Reference Conditions	No Reference Conditions
Riparian/Wetland Vegetation	Presence/Absence	Species present are able to stabilize the streambank and maintain wetland soil moisture characteristics.	–	Species present are not able to stabilize the streambank and maintain wetland soil moisture characteristics.

standards for temperature, specific conductivity, or turbidity. Although Arizona State standards for dissolved oxygen in surface waters are used to evaluate the condition of water quality, the standards may not be reasonable for water discharged from the ground because groundwater tends to be lower in dissolved oxygen since it is not exposed to the atmosphere nor does photosynthesis occur below ground (Hynes 1970). Reference conditions for the presence/absence of wetland vegetation was based on criteria for assessing riparian vegetation to the proper functioning of lotic systems as outlined in Dickard et al. (2015). For high-energy streams, both woody and riparian plant species that stabilize the stream bank may be required (Dickard et al. 2015). Furthermore, the wetland status of plants present indicate whether soil moisture characteristics are being maintained. In "flashy" streams like Cave Canyon, OBL and FACW are often restricted to the active channel, and shallow-rooted FAC, FACU, and even UPL species may occur alongside the stream channel (Dickard et al. 2015).

Condition and Trend

During 2014 to 2017, water level at Cave Spring's *in situ* sensor was always greater than 0 and usually greater than 0.30 m (1.0 ft) (Figure 32). Most measurements were between 0.30 m and 0.38 m (1.0-1.25 ft), but there were several temporary spikes in water level that occurred when rainfall was high. Water levels in Cave Canyon respond immediately to precipitation and recover quickly due to the steep gradient of the uplands and stream channel, which promotes rapid drainage (Albrecht et al. 2005). As noted in the data and methods section describing this measure, the sensor is located below the ground surface and is, therefore, not a direct indicator of depth of surface water, but is instead an indicator of shallow groundwater in the springbrook. Water temperature at the *in situ* sensor exhibits a typical seasonal pattern with highs occurring during the summer months and lows during the winter months.

Discharge at Cave Spring exhibited a seasonal pattern with higher flows during winter and the lowest flows during July and August (Figure 33). Over the entire period, discharge averaged 17.23 L/min (SD = 9.09)

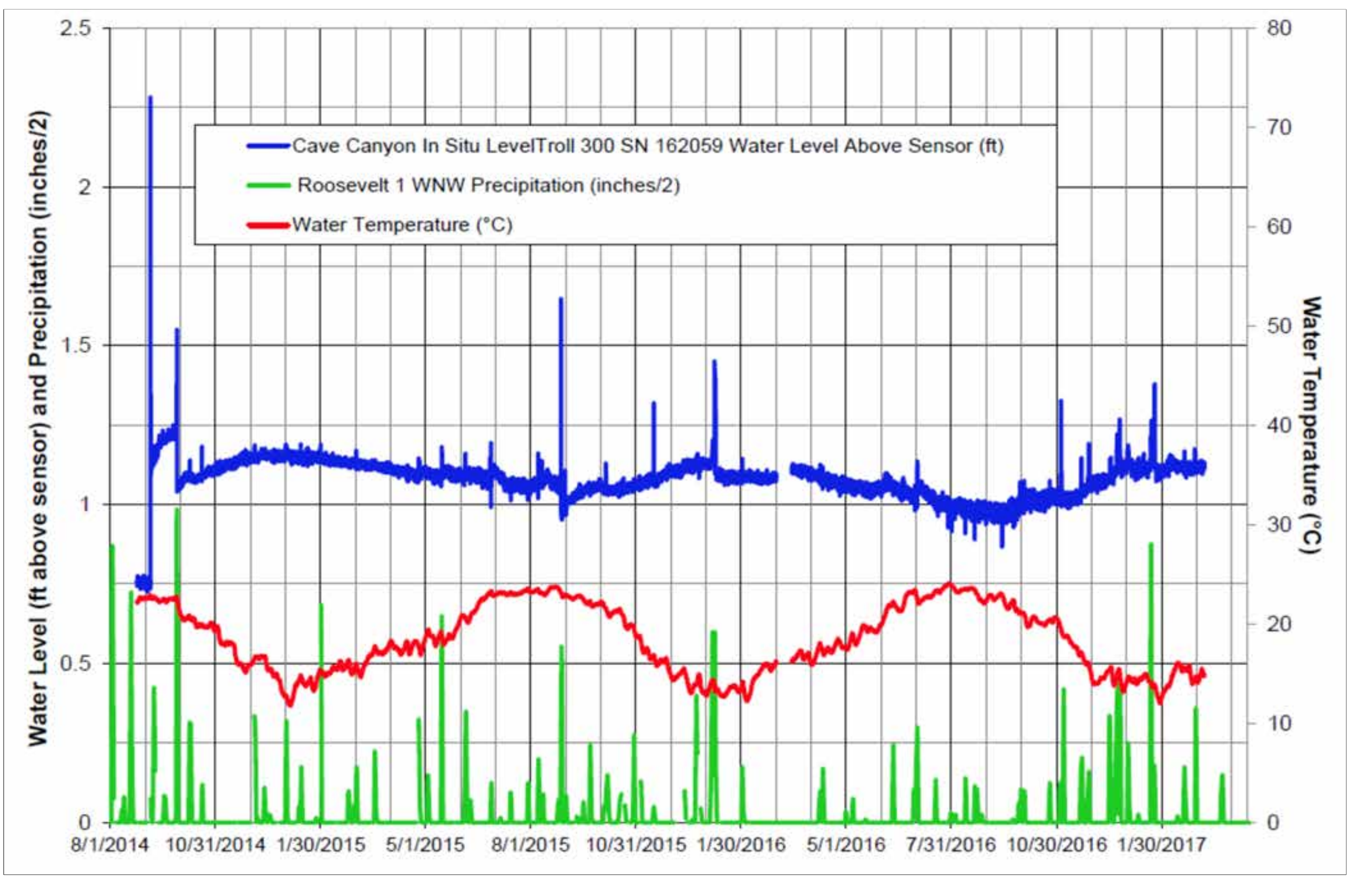


Figure 32. **Water level data at Cave Spring (2014-2017). Figure Credit: NPS.**

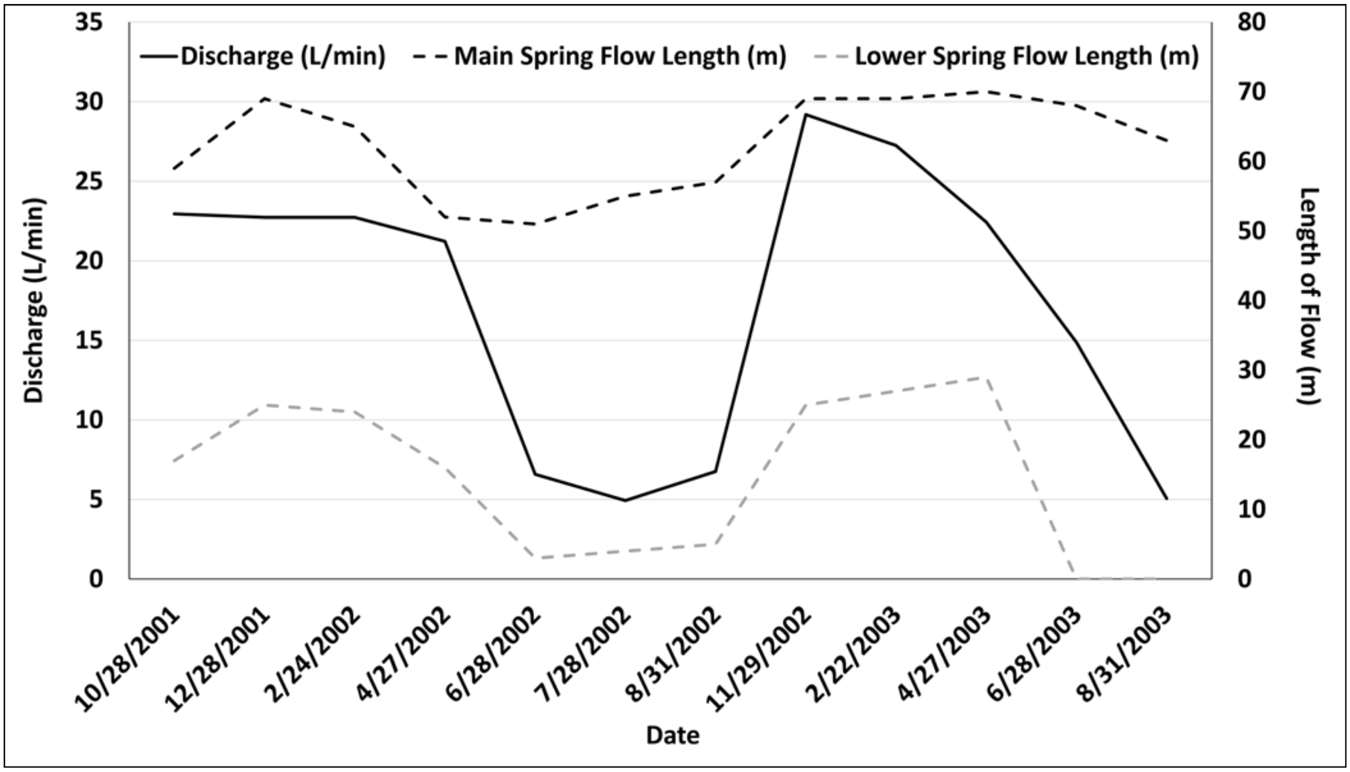


Figure 33. Main spring discharge and length of flow at main and lower spring (2001-2003).

(4.55 ± 2.40 gallons/min). Although this pattern is thought to be typical of Cave Spring, the study occurred during one of the most severe droughts on record at that time (Albrecht et al. 2005). Variability in flow was much greater at the lower spring (now dry) than at Cave Spring. Cave Spring is connected to the local aquifer, and aquifers are not typically affected by droughts, at least in the short-term. The lower spring, however, bears characteristics of a seep, which typically exhibit greater seasonal fluctuations than springs emerging from aquifers. Shallow groundwater from rainfall is the primary source of water in seeps, and the lower spring is likely recharged from Cave Spring runoff (Albrecht et al. 2005). The most recent discharge data for Cave Spring was 7.2 L/min (1.9 gallons/min) (on 13 July 2017), which exceeded discharge measurements for July 2002 and August 2003.

Although there was a large gap in discharge data from 2003 to 2017, and the spring was measured on only one day in 2017, the 13 July 2017 data are consistent with the earlier measurements for the same season. Furthermore, the *in situ* water level data indicate persistence of shallow groundwater in the springbrook in recent years (i.e., 2014-2017). For these reasons, the condition is good but confidence in the condition rating is medium due to the gap in data and the current annual, single-day monitoring schedule for the spring. There were not enough data to determine trend.

The wetted extent, or distance of flow, was greater for Cave Spring than for the lower spring (Figure 33). Flow length at Cave Spring averaged 62.3 m (SD = 7.14) (204.4 ± 23.4 ft) and 14.6 m (SD = 11.44) (47.9 ± 37.5 ft) at the lower spring. The main channel length on 13 July 2017 was 65.9 m (228.0 ft). Wetted width on 13 July 2017 averaged 42.9 cm (16.9 in). Wetted width was not measured during 2001 to 2003. These data suggest good condition for this measure, but confidence is medium because of the large gap in data and the current annual, single-day monitoring schedule for the spring. Wetted extent changes throughout the day depending on temperature and evapotranspiration, as well as by season (NPS, K. Raymond, hydrologist, comments to draft assessment, 10 December 2018). There were not enough data to determine trend.

Below we summarize the six measure of water quality. During the winters of 2014 through 2017, water temperatures were between 12°C and 15°C (54-59°F) (Figure 32). In summer, water temperatures were between about 20 °C and 25 °C (68- 77°F). The most recent water temperature readings were 22.7°C (72.9°F) and 23.1°C (73.6°F) at location 1 and location

Table 30. Water quality data for Cave Canyon.

Measure	Location 1	Location 2
Temperature (°C)	22.7	23.1
Dissolved Oxygen (%)	34	41
Dissolved Oxygen (mg/L)	2.90	3.51
Specific Conductivity (µS/cm)	566	559
pH (SU)	7.44	7.40
Turbidity (NTU)	0.32	Not Collected

Source: NPS (2017b).

2, respectively (Table 30). Because there are no reference conditions for temperature, the condition is unknown and confidence is low. Trend could not be determined for any of the water quality measures.

Neither the percent dissolved oxygen nor mg/L of dissolved oxygen met the reference benchmarks for good condition. Dissolved oxygen measured 34% and 41% at locations 1 and 2, respectively (Table 30). In mg/L, dissolved oxygen measured 2.90 and 3.51 at locations 1 and 2, respectively. However, these measurements were collected on one day in July. Summer oxygen levels are expected to be at their lowest during summer because discharge is low and temperature is high. Furthermore, dissolved oxygen is expected to be low for water that emerges from underground since it is not exposed to the atmosphere nor does photosynthesis occur below ground. Therefore, we assigned an unknown condition rating for this measure. Because the condition is unknown, confidence is low.

Specific conductivity measured 566 microsiemins/m and 559 microsiemins/cm at locations 1 and 2, respectively (Table 30). Because there are no reference conditions for specific conductivity, the condition is unknown and confidence is low.

The pH of the two locations (7.44, 7.40) indicate good condition for acidity since both values were greater than 6. However, because these data were collected on one day only, there are insufficient data to determine condition. Therefore, the condition is unknown and confidence is low.

Turbidity measured 0.32 NTU at location 1 (data were not collected at location 2). This low value indicates high water clarity, but because there are no reference conditions for turbidity, the condition is unknown and confidence is low.

Lastly, we summarize the presence/absence of riparian/wetland vegetation. Of the 22 associations mapped during Tonto NM's vegetation classification, only the Cave Canyon area supports riparian plants (Studd et al. 2017). This riparian forest comprises just 1.13 ha (2.79 ac) in one continuous patch or corridor. The riparian association is dominated by Arizona sycamore (*Platanus wrightii*) and Arizona walnut (*Juglans major*). These two tree species form a mostly closed canopy (~65%) of approximately 14 m (46 ft) in height (Table 31). Sycamore comprises roughly 26% to 33% of the total canopy cover, while walnut forms between 34% and 50% of the total canopy cover. Arizona sycamore is a FACW species and Arizona

Table 31. Plants documented along Cave Canyon riparian area.

Stratum	Cover (%)	Dominant Species	Common Associated Species	Uncommon Species
Canopy (>5m)	65	Arizona walnut, Arizona sycamore	None	None
Canopy (2-5 m)	5[1]	Netleaf hackberry, Velvet mesquite	None	None
Subcanopy (0.5-2 m)	35	Netleaf hackberry, Velvet mesquite	Fremont's desert-thorn, lotebush, jojoba, Arizona dewberry	Black elderberry[2], Gila manroot, Broom snakeweed, Globemallow sp., Tarragon, Skunkbush sumac, Cuman ragweed
Field (0-0.5 m)	30	Ripgut brome[2], annuals	Arizona dewberry, Blue wild rye	Spreading fleabane, Desert tobacco, Lemmon's ragwort, Brownplume wirelettuce, Common sowthistle[2]

[1] This value refers to netleaf hackberry and velvet mesquite cover of the tree-like growth form. The authors did not include an estimate of the tall shrub cover for these species in this layer. Therefore, the estimate is low.

[2] Non-native species.

Source: Studd et al. (2017).

walnut is a FAC species (Table 32). These two species are well-distributed throughout the small riparian area.

The subcanopy is dominated by netleaf hackberry (*Celtis laevigata*) and velvet mesquite (*Prosopis velutina*) with lesser amounts of Fremont's desert-thorn (*Lycium fremontii*), lotebush (*Ziziphus obtusifolia*), jojoba (*Simmondsia chinensis*), Arizona dewberry (*Rubus arizonensis*), and other species (Table 31). The total combined cover in the shrub layer is about 35%, with the two dominant shrubs representing a combined 11-25% cover. The two dominant species are considered FAC (netleaf hackberry) and FACU (velvet mesquite). The remaining species in the subcanopy layer are FACU or UPL species (Table 32).

Approximately 30% of the ground surface is covered by vegetation (Table 31), mostly the non-native annual ripgut brome (*Bromus diandrus*), which is considered a UPL species (Table 32). Although Arizona dewberry and blue wild rye (*Elymus glauca*) are also present, they represent only between 1% and 5% of the total cover in this layer. All species in this layer are considered either FACU or UPL species (Table 32).

NPS (2017b) describes Cave Canyon as "tightly confined to the banks of the drainage, beyond which the community rapidly transitions to a wooded shrubland dominated by velvet mesquite and creosote bush (*Larrea tridentada*)." Although many of the plant species are associated with uplands rather than wetlands, the two dominant trees are wetland species. These two species stabilize the streambank and have root masses capable of withstanding high flows while retaining soil moisture (Zaimes et al. 2007).

The stream channel in Cave Canyon is composed of surface bedrock and shallow soils, which means that runoff is expected to be high, especially after high rainfall (Albrecht et al. 2005). The stream channel gradient is also steep, which contributes to rapid runoff. For these reasons, upland species are expected to occur along the riparian area, and their presence does not necessarily indicate replacement of wetland species that would otherwise occupy the corridor. While vegetation cover is high in the field layer with little or no bare ground, it is dominated by ripgut brome. This non-native species may be a better competitor than native grasses and forbs, which likely accounts for its dominance. For these reasons, the condition of riparian vegetation is of moderate concern. However, confidence is medium because the data were collected more than five years ago (i.e., 2009) and may not reflect current conditions.

Overall Condition, Threats, and Data Gaps

We used three indicators and nine measures to assess the condition of the Cave Canyon riparian area (summarized in Table 33). Measures without a condition rating were not used to assess overall condition (six water quality measures). Two of the remaining three measures were in good condition (i.e., water quantity), but the presence/absence of riparian vegetation warrants moderate concern. Based on only three measures, the overall condition is good to moderate concern. Confidence is medium because of long gaps in data, few recent measurements, and/or short-term data of only a few years or even a single day. Trend could not be determined based on available

Table 32. Wetland status of species in the Cave Canyon riparian area by lifeform.

Lifeform	Scientific Name	Common Name	Status
Tree	*Juglans major*	Arizona walnut	FAC
	Platanus wrightii	Arizona sycamore	FACW
Shrub	*Celtis laevigata*	Netleaf hackberry	FAC
	Lycium fremontii	Fremont's desert-thorn	UPL
	Prosopis velutina	Velvet mesquite	FACU
	Rhus trilobata	Skunkbush sumac	UPL
	Rubus arizonensis	Arizona dewberry	FACU
	*Sambucus nigra**	Black elderberry	FACU
	Simmondsia chinensis	Jojoba	UPL
	Ziziphus obtusifolia	Lotebush	UPL
Forb/Herb	*Ambrosia psilostachya*	Cuman ragweed	FACU
	Artemisia dracunculus	Tarragon	UPL
	Erigeron divergens	Spreading fleabane	UPL
	Gutierrezia sarothrae	Broom snakeweed	UPL
	Marah gilensis	Gila manroot	UPL
	Nicotiana obtusifolia	Desert tobacco	FACU
	Senecio lemmonii	Lemmon's ragwort	UPL
	Sphaeralcea sp.	Globemallow sp.	N/A
	Stephanomeria pauciflora	Brownplume wirelettuce	UPL
Graminoid	*Bromus diandrus**	Ripgut brome	UPL
	Elymus glaucus	Blue wild rye	FACU

* Non-native species.

Table 33. Summary of the Cave Canyon riparian area indicators, measures, and condition rationale.

Indicators	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Water Quantity	Persistence		During 2014 to 2017, water level at the main spring's in situ sensor was always greater than 0 and usually greater than 0.30 m, which is a measure of shallow groundwater adjacent to the springbrook. From 2001 to 2003, discharge at the main spring exhibited a seasonal pattern with higher flows during winter and the lowest flows after green-up with a mean of 17.23 L/min. The most recent discharge data for Cave Spring was 7.2 L/min (on 13 July 2017), which exceeded discharge measurements for July 2002 and August 2003. Although there was a large gap in discharge data from 2003 to 2017, and the spring was measured on only one day in 2017, the 13 July 2017 data are consistent with the earlier measurements for the same season. Furthermore, the in situ water level data indicate persistence of spring discharge in recent years (i.e., 2014-2017).
	Wetted Extent (m)		Mean flow length at the main spring averaged 62.3 m and 14.6 m at the lower spring. The wetted channel length on 13 July 2017 was 65.9 m. The wetted extent of the stream channel tracks discharge, and discharge appears consistent over time.
Water Quality	Temperature (°C)		There are no reference conditions for temperature, but this measure is important for putting other water quality measures in context. Higher temperature reduces the amount of oxygen water can hold, lowers the pH, and may allow for bacterial growth, which can increase turbidity.
	Dissolved Oxygen (%)		The two dissolved oxygen measures from the single date indicate levels that may stress aquatic wildlife. However, these data were collected on a single day during July when temperatures are highest and discharge is lowest, which reduces the amount of oxygen that water can hold. Furthermore, reference conditions may not apply to water that discharges from the ground.
	Dissolved Oxygen (mg/L)		As with percent dissolved oxygen, these values also indicate potential stress to aquatic organisms. However, these data were collected on a single day during July when temperatures are highest and discharge is lowest, which reduces the amount of oxygen that water can hold. Furthermore, reference conditions may not apply to water that discharges from the ground.
	Specific Conductivity (µS/cm)		There are no reference conditions for specific conductivity, but measurements at the two locations were 566 µS/cm and 559 µS/cm. These data were collected on one day in July 2017.
	pH (SU)		pH values were 7.4 and 7.44 at the two locations sampled, which is well within the standard range for good water quality. However, these measures were collected on a single day in July 2017.
	Turbidity (NTU)		There are no reference conditions for turbidity, but the value of 0.32 NTU indicates relatively clear water.
Riparian/ Wetland Vegetation	Presence/ Absence		Arizona walnut (FAC) and Arizona sycamore (FACW) were the dominant species in the canopy layer (65% cover). The shrub layer (~35% cover) was dominated by netleaf hackberry (FAC) and velvet mesquite (FACU). The herbaceous layer (~30% cover) was dominated by the non-native annual ripgut brome. While most species were associated with uplands, this may be because the stream is naturally steep and narrow with high runoff. The high cover of ripgut brome, however, may prevent the establishment of native forbs and grasses.
Overall Condition	Summary of All Measures		Only measures with a known condition were considered in the overall condition rating. Water quantity suggests good condition, and while vegetation appears in good condition, the high cover of ripgut brome is concerning. However, plant data were collected in 2009 and water quantity data have been sporadically collected.

data. The key uncertainty is whether the assigned condition ratings reflect current conditions.

Although the condition of water quality is unknown based on the limited data available, the NPS Water Resources Division (NPS WRD) reported that the stream in Cave Canyon is not impaired according to the Clean Water Act section 303(d) (NPS WRD 2013). However, the U.S. Forest Service (USFS) considers water quality in the Cottonwood Creek-Salt River watershed to be poor (USFS 2011). The Cottonwood Creek-Salt River watershed, which includes Tonto NM, is 5,976 ha (14,766 ac) and is the finest-scale watershed recognized by the U.S. Geological Survey (USGS) (USGS 2018d).

The USFS evaluates watersheds based on 12 criteria, one of which is water quality (Potyondy and Geier 2011). In addition to water quality, soil condition, rangeland vegetation, and terrestrial invasive species were rated as poor. Only fire regime and forest health were rated as good. Aquatic biota, riparian vegetation, and road and trail conditions were rated as fair, and forest cover was not rated. Based on these results, the overall condition of the watershed is considered impaired (USFS 2011). Impaired watersheds are described as exhibiting "low geomorphic, hydrologic, and biotic integrity relative to their natural potential condition" (Potyondy and Geier 2011).

Although Tonto NM represents just a small portion of the watershed (~8%), the criteria in poor condition may result in threats to the monument's riparian area. For example, grazing on USFS lands above the spring could lead to unnatural flooding of the riparian area and water quality issues (Albrecht et al. 2007). However, the USFS practices rotational grazing in the Cave Canyon watershed. Three pastures of a nine-pasture allotment are at least partially located in the watershed, and all nine pastures are grazed for approximately two months out of every 18 month period, which allows for plants to recover (USFS, E. Hoskins, range manager, personal communication to K. Raymond, NPS hydrologist, received 10 December 2018). While current grazing practices are more sustainable than previous practices, the history of past grazing may still impact the watershed. In the monument's Foundation Document, the authors called for a study investigating grazing impacts on the watershed (NPS 2017a).

Although the Cave Canyon spring is (for now) independent of recent climate changes, there is a lag between climate and spring discharge that may not become apparent for years or even decades (Albrecht et al. 2005). Since 2000, southern Arizona has been in a drought (ADWR 2018). Continued dry conditions may eventually lead to declines in the aquifer from which Cave Spring discharges. Climate projections for the American Southwest include higher temperatures, increased drought, and more intense thunderstorms (Backlund et al. 2008). Springs are also vulnerable to changes in tectonic activity. Such a change could result in the sudden cessation of spring activity in Cave Canyon (Albrecht et al. 2005), although this change would presumably be due to natural causes.

Albrecht et al. (2005) stated that by keeping the spring open of debris, avoiding construction in the area of the spring, and working with the surrounding Tonto NF to mitigate threats to the watershed, the Cave Spring area should continue to function normally barring the effects of climate change. Staff at Tonto NM also plan to re-route the trail that traverses the riparian area, which would further reduce impacts to the stream channel and spring (NPS, B. Cockerell, Chief of Natural and Cultural Resources, NRCA scoping meeting, 10 May 2018).

Sources of Expertise

This assessment was written by science writer and wildlife biologist, Lisa Baril, Utah State University. Subject matter expert reviewers for this assessment are listed in Appendix A.

Upland Vegetation and Soils

Background and Importance

The National Park Service (NPS) Sonoran Desert Inventory and Monitoring Network (SODN) monitors upland vegetation and soils across its 11 network parks, including Tonto National Monument (NM), to better understand current condition and patterns of change over time (Hubbard et al. 2012). Tonto NM lies just below the Colorado Plateau against the Mogollon Rim at the intersection of the Apache Highlands and Sonoran Desert ecoregions (Hubbard et al. 2013, Studd et al. 2017). Because Tonto NM occurs in this transition area, it is floristically diverse. The monument's plant diversity is also partly attributed to the steep gradient along which the monument occurs; the elevation ranges from 695 m to 1,219 m (2,280-4,000 ft) across three biomes—desert, thornscrub, and semidesert grasslands (Hubbard et al. 2012). These three biomes support sparse wooded shrublands in the valley bottom, more densely wooded shrublands in the bajada, and a mixture of wooded shrublands and savannas in the foothills (Hubbard et al. 2013).

Plants in the valley bottom include yellow paloverde (*Parkinsonia microphylla*), jojoba (*Simmondsia chinensis*), velvet mesquite (*Prosopis velutina*), turpentine bush (*Ericameria laricifolia*), and a variety of annual forbs and grasses (Hubbard et al. 2013). Ascending from the valley bottom to the bajada, jojoba, globemallow (*Sphaeralcea* spp.), and perennial herbs increase, while turpentine bush, yellow paloverde, and velvet mesquite decline. The bajada is also where Saguaro cacti (*Carnegiea gigantea*) begin to grow. Above the bajada, foothills vegetation includes semidesert grasslands and wooded shrublands, including interior chaparral (Hubbard et al. 2013). Common understory plants include sideoats grama (*Bouteloua curtipendula*), globemallows, desert needlegrass (*Achnatherum speciosum*), and a variety of annual forbs and grasses. Mountain mahogany (*Cercocarpus montanus*) and crucifixion thorn (*Canotia holacantha*) comprise overstory vegetation, replacing paloverde, mesquite, and jojoba (Hubbard et al. 2013).

The foothills support the only fire-adapted plant community in the monument (Hubbard et al. 2013). Sonoran Desert vegetation is not adapted to fire, especially succulents such as Saguaro cacti. The juxtaposition of a fire-adapted habitat alongside one that is not fire-adapted, the rugged topography of the monument, and location of the monument on the border between two ecoregions allows for an unusual combination of species with a disturbance regime that is atypical of the region.

Ten soil families have been mapped in Tonto NM, which can be grouped into those that occur in drainages

Desert vegetation in the bajada with Saguaro and barrel cacti in Tonto NM. Photo Credit: NPS.

(Boedecker and Tonto soil families), those that occur in hills (Lampshire, Gadwell, Lemitar, Powerline, and Whitvin soil families), and those that occur in the bajada (Eba, Topawa, and Tubac soil families) (Lindsay et al. 1994, Hubbard et al. 2013). Tonto NM also supports a diverse community of biological soil crusts, which are composed of cyanobacteria, algae, lichens, and bryophytes. Biological soil crusts significantly reduce erosion by wind and water, in addition to providing other ecosystem services such fixing nitrogen and contributing organic matter to soils (Hubbard et al. 2013). In Tonto NM, biological soil crusts are slow to recover after disturbances as a result of high temperatures and low precipitation (Hubbard et al. 2013).

Data and Methods

This assessment is based on five indicators (erosion hazard, site resilience, Saguaro cacti recruitment, non-native plants, and fire hazard) with a total of 14 measures. Data were collected as part of SODN's upland vegetation monitoring program (Hubbard et al. 2012). SODN's protocol employs a random, spatially balanced sampling design with plots allocated to three strata based on elevation and soil rock fragment class. The three strata are: valley (762 m [<2,500 ft]), bajada (762-1,128 m [2,501-3,700 ft]), and foothills (1,128-1,372 m [3,701-4,500 ft]). The soil rock fragment class is the same for all three strata: 35% to 90% rock fragment. Three plots were established in the valley bottom, 11 plots were established in the bajada, and five plots were established in the foothills. The number of plots established in each stratum is proportional to the area of each stratum, with 11% of monument in the valley bottom, 44% of the monument in the bajada, and 5% of the monument in the foothills (Hubbard et al. 2012).

Plots were 20 x 50-m (66 x 164 ft) with six, 20-m (66-ft) transects established every 10 m (33 ft) along the plot's long edge. The transects divided the plot into five subplots. Vegetation and soils were measured in all of the following three vegetation layers: field (0-.05 m [<1.6 ft]), subcanopy (>0.5-2.0 m [1.6-6.6 ft]), and canopy (>2.0 m [6.6 ft]). The first round of sampling occurred during 2009/2010, and the second round of sampling occurred during 2014. All plots were surveyed during winter. Raw data were provided by K. Bonebrake, SODN data manager, via e-mail on 8 December 2017. Although data for 2009/2010 were published in Hubbard et al. (2013), we used data provided by K. Bonebrake because the report's data sometimes differed from data in the excel file. For brevity, we provide a brief description of each measure and why it is important rather than specific sampling details. Data collection methods for each measure are described in Hubbard et al. (2012).

The first measure of the erosion hazard indicator is bare ground cover without overhead vegetation. The amount of bare ground is a measure of erosion potential since most soil loss occurs in unprotected bare patches (Hubbard et al. 2012). As the amount of bare ground increases, the velocity of surface water flow and erosion due to wind also increases. Vegetation, soil crusts, litter, and rock cover help protect against rapid soil loss. This measure was assessed for all three strata.

The second measure of erosion hazard is soil aggregate stability. Soil aggregate stability is a measure of resistance to erosion (Hubbard et al. 2012). Soil aggregate stability was classified on a scale ranging from 1 (least stable) to 6 (most stable) (Herrick et al. 2005). "Surface soil aggregates play a critical role in the movement of water, nutrients, and gases through the soil–atmosphere interface and in resisting wind and water erosion. Soil aggregate stability provides insight into current and past site disturbance and is an efficient measure of site stability in the context of potential management actions" (Hubbard et al. 2012). This measure was assessed for all three strata at points without overhead vegetation. This is because plant roots and canopy cover increase soil stability and the

Semidesert grasslands in the foothills of Tonto NM. Photo Credit: NPS.

Paloverde is a common valley bottom plant in Tonto NM. Photo Credit: NPS.

objective of this measure is to determine soil stability without these confounding factors.

Biological soil crust (BSC) cover is the third measure of erosion hazard. BSCs are comprised of cyanobacteria, algae, lichens, and bryophytes (Hubbard et al. 2013). Soil crusts provide key ecosystem services by increasing resistance to erosion, increasing infiltration, contributing organic matter, and fixing nitrogen (Hubbard et al. 2012). Soil crust cover can be used to estimate erosion (Hubbard et al. 2012). This measure was assessed for the bajada only because this landform type is especially vulnerable to erosion owing to its steep slopes and alluvial soils (Hubbard et al. 2013).

The first two measures of the site resilience indicator are foliar cover of dead perennial plants in the field layer and foliar cover of dead perennial plants in the subcanopy layer. These two measures address the ability of plant communities to recover after a disturbance, maintain natural processes, and resist invasion by non-native plants. Dead perennial plants included only those that were still rooted in the ground (Hubbard et al. 2012). Low levels of dead plants indicate higher site resilience, especially if dead cover declines rapidly following a disturbance. This measure was assessed for all three strata.

The third measure of site resilience is the cover of trees and shrubs in the subcanopy. This measure applies to the foothills only because foothills typically support semi-desert grasslands and short-statured, open-canopy shrublands. Although some tree and shrub cover is natural, high cover of woody vegetation may indicate a shift in ecosystem structure and function if grasslands shift toward a shrubland or woodland (Miller 2005).

The Saguaro cactus is a key species of the Sonoran Desert and was evaluated using two measure—extent and cover of nurse plants. These measures only apply to the bajada since this landform type supports Sonoran Desert vegetation. The Saguaro cactus is considered an umbrella species (Mau-Crimmins et al. 2005), providing habitat for nesting birds, and food for mammals, reptiles, and insects that feed on its fruit and flowers. Monitoring the extent, or distribution, of Saguaro cacti in the monument can help biologists understand how widespread this iconic species is. The growth and survival of Saguaro cactus seedlings depend on the cool and moist microenvironment created beneath the canopy of taller vegetation, such as velvet mesquite and paloverde (Drezner and Garrity 2003). These protective plants are known as nurse plants. Monitoring nurse plant cover can help biologists understand whether the conditions exist for seedling recruitment.

The non-native plants indicator includes the measures extent, cover, and the ratio of non-native plant cover to total plant cover. Extent refers to the frequency of non-native plants encountered across monitoring plots by strata (Hubbard et al. 2012). It is an effective way to monitor changes in the spread of non-native species over time. Cover is a measure of the area over which a species or group of species occurs. In this case, it was used to monitor non-native species invasion. The ratio of non-native to total plant cover is useful for determining dominance. These measures apply to all strata.

Lastly, the fire hazard indicator includes grass and forb cover, the ratio of annual plant cover to total plant cover, and litter and duff cover. Grass and forb cover is in the bajada can be used to determine fire hazard. The greater the area of ground surface covered by plants, particularly non-native annuals, the greater the potential of fire spreading to the bajada from the upper elevation foothills. The ratio of annual cover to total plant cover in the foothills is an important measure of fire hazard because many non-native annuals are fire-adapted. Not only can non-native annuals, such as red brome (*Bromus rubens*), tolerate fire, but fire also facilitates colonization of non-natives, which further increases fire potential in a positive-feedback loop Hubbard et al. 2012). Litter and duff are fine fuels. Little is known about the historic fire regime in the Sonoran Desert, but lightning-caused fires are thought to have occurred every 250 to 300 years (NPS 2006b). The amount of fine fuels on the landscape informs fire hazard, and non-native plants can add to the fine fuel layer.

Reference Conditions

Reference conditions are described for resources in good and moderate/significant concern conditions for each of the 14 measures (Table 34). Reference conditions were based on Management Assessment Points (MAPS) developed by SODN for Tonto NM (Hubbard et al. 2013). MAPS "represent preselected points along a continuum of resource-indicator values where scientists and managers have together agreed that they want to stop and assess the status or trend of a resource relative to program goals, natural variation, or potential concerns" (Bennetts et al. 2007). MAPS do not define management goals or thresholds. Rather, MAPS "serve as a potential early warning system," where managers may consider possible actions and options (Bennetts et al. 2007).

Condition and Trend

For the following 14 measures, trend could not be determined because this assessment includes only two rounds of sampling. Confidence is medium for all measures because the data were collected five years ago and therefore may not reflect current condition; however, data collection is ongoing. The conditions apply to all strata unless otherwise noted.

Two of the three measures of erosion hazard were in good condition. In all three strata, bare ground cover was greater during 2009/2010 than during 2014 (Table 35). Bare ground cover was also greater in the valley bottom than in the bajada or foothills. The latter two strata were similar in cover during both rounds of sampling. In all cases, though, cover was less than

Table 34. Reference conditions used to assess upland vegetation and soils in Tonto NM.

Indicators	Measures	Good	Moderate Concern/Significant Concern
Erosion Hazard	Bare Ground Cover (%)	Bare ground with no overhead vegetation is ≤ 20%.	Bare ground with no overhead vegetation is > 20%
	Soil Aggregate Stability without Overhead Vegetation (Class)	Average surface soil aggregate stability is ≥ Class 3.	Average surface soil aggregate stability is < Class 3.
	Biological Soil Crust Cover in the Bajada (%)	Biological soil crust cover is ≥ 10% of available habitat.	Biological soil crust cover is < 10% of available habitat.
Site Resilience	Foliar Cover of Dead Perennial Plants in the Field Layer (%)	Foliar cover of dead perennial plants is ≤ 15%.	Foliar cover of dead perennial plants is > 15%.
	Foliar Cover of Dead Perennial Plants in the Subcanopy (%)	Foliar cover of dead perennial plants is ≤ 15%.	Foliar cover of dead perennial plants is > 15%.
	Tree and shrub cover in the Subcanopy of the Foothills (%)	Tree and shrub cover is ≤ 50%.	Tree and shrub cover is > 50%.
Saguaro Cacti Recruitment	Extent in the Bajada (%)	Extent of saguaro cacti is ≥5%	Extent of saguaro cacti is <5%
	Cover of Nurse Plants in the Bajada (%)	Cover of nurse plants (trees and shrubs in subcanopy) is ≥15%	Cover of nurse plants (trees and shrubs in subcanopy) is <15%
Non-native Plants	Extent (%)	Extent of non-native plants is ≤ 50%.	Extent of non-native plants is > 50%.
	Cover (%)	Total cover of non-native plants is ≤ 10%.	Total cover of non-native plants is > 10%.
	Ratio of Non-native Plant Cover to Total Plant Cover	Non-native plant cover: total plant cover is ≤ 1:4 (≤ 25%).	Percent of total plant cover that is non-native is > 1:4 (> 25%).
Fire Hazard	Grass and Forb Cover in the Bajada (%)	Grass and forb cover is ≤ 30%.	Grass and forb cover is > 30%.
	Ratio of Annual Plant Cover to Total Plant Cover in the Foothills	Annual plant cover: total plant cover is ≤ 1:4 (≤ 25%).	Annual plant cover: total plant cover is > 1:4 (> 25%).
	Litter and Duff Cover in the Foothills (%)	Litter and duff cover is ≤75%.	Litter and duff cover >75%.

Source: Hubbard et al. (2013).

Table 35. Erosion hazard in Tonto NM.

Measure	Stratum	2009/2010 (mean ± standard error)	2014 (mean ± standard error)
Bare Ground Cover (%)	Valley Bottom	11.1 ± 4.6	8.5 ± 0.9
	Bajada	5.3 ± 0.8	2.3 ± 0.5
	Foothills	5.8 ± 0.8	3.4 ± 1.0
Soil Aggregate Stability without Overhead Vegetation (class)	Valley Bottom	3.6 ± 0.3	2.5 ± 0.5
	Bajada	4.4 ± 0.2	2.8 ± 0.3
	Foothills	3.8 ± 0.3	1.9 ± 0.4
Biological Soil Crust Cover (%)	Bajada	14.0 ± 2.3	16.3 ± 4.2

Source: Data provided by K. Bonebrake, SODN data manager, via e-mail on 8 December 2017.

20% and did not exceed 12% in any stratum or sampling period. Therefore, the condition is good for this measure. BSC cover was also in good condition, averaging 14% in 2009/2010 and 16% in 2014 (Table 35). Soil aggregate stability condition, however, was of moderate to significant concern for all three strata. While all values during round 1 met the good reference condition, none of the values met the good reference condition in 2014.

For the foliar cover of dead perennials measure of site resilience, the condition was good for both vegetation layers. In 2009/2010, foliar cover of dead perennials was greater than during 2014, but all values were well below the 15% threshold for good condition (Table 36). In the subcanopy, dead perennial plants did not exceed 1% in any of the three strata or sampling period. For the measure of tree and shrub cover in the subcanopy of the foothills, the condition was also good because cover averaged 14.3% in 2009/2010 and 15.7% in 2014 (Table 36).

Both measures of Saguaro cacti recruitment were in good condition. During both rounds of sampling, Saguaro cacti extent was 5%, which is good but on the cusp of moderate/significant concern (Table 37). Nurse plant cover in both sampling periods was greater than 15%, which is also good (Table 37).

For the non-native plants indicator, the condition varied by meaure and straum. Extent of non-native plants increased in all three strata from 2009/2010 to 2014 (Table 38). In 2014, all strata exhibited 100% extent of non-natives. Red brome was the most widely distributed species, occurring in all three strata and 100% of plots by 2014. Other non-native species included redtop (*Agrostis gigantea*) (foothills), wild oat (*Avena fatua*) (valley bottom and bajada), Lehmann lovegrass (*Eragrostis lehmanniana*) (bajada and foothills), redstem stork's bill (*Erodium cicutarium*) (bajada and foothills), cheeseweed mallow (*Malva parviflora*) (bajada), and little hogweed (*Portulaca oleracea*) (foothills). These species, however, were not widespread. The condition for this measure is of moderate/significant concern.

In the valley bottom, two non-native species were encountered along line transects. The two species were red brome and wild oat, but only red brome increased in cover from 0.6% in 2009/2010 to 11% in 2014. The

Table 36. Site resilience in Tonto NM.

Measure	Stratum	2009/2010 (mean ± standard error)	2014 (mean ± standard error)
Foliar Cover of Dead Perennial Plants in the Field Layer (%)	Valley Bottom	2.8 ± 1.2	1.0 ± 0.6
	Bajada	5.7 ± 1.2	2.3 ± 0.3
	Foothills	4.7 ± 0.9	2.3 ± 0.6
Foliar Cover of Dead Perennial Plants in the Subcanopy (%)	Valley Bottom	0	0
	Bajada	0.5 ± 0.2	0.2 ± 0.2
	Foothills	0.2 ± 0.2	0.1 ± 0.1
Tree and Shrub Cover in the Subcanopy (%)	Foothills	14.3	15.7

Source: Data provided by K. Bonebrake, SODN data manager, via e-mail on 8 December 2017.

Table 37. Saguaro cacti recruitment in Tonto NM.

Measure	Stratum	2009/2010 (mean ± standard error)	2014 (mean ± standard error)
Extent (%)	Bajada	5	5
Cover of Nurse Plants in the Subcanopy (%)	Bajada	20.4	19.3

Source: Data provided by K. Bonebrake, SODN data manager, via e-mail on 8 December 2017.

Table 38. Non-native plants in Tonto NM.

Measure	Stratum	2009/2010 (mean ± standard error)	2014 (mean ± standard error)
Extent (%)	Valley Bottom	66.7	100
	Bajada	55	100
	Foothills	80	100
Cover in the Field Layer (%)	Valley Bottom	0.7 ± 0.4	11.0 ± 3.9
	Bajada	3.8 ± 1.6	6.7 ± 1.4
	Foothills	4.1 ± 2.0	10.2 ± 2.6
Ratio of Non-native Plant Cover to Total Plant Cover	Valley Bottom	2.7 ± 1.4	37.4 ± 9.9
	Bajada	8.2 ± 3.5	13.2 ± 3.2
	Foothills	8.0 ± 4.5	14.9 ± 3.6

Source: Data provided by K. Bonebrake, SODN data manager, via e-mail on 8 December 2017.

same pattern was observed for both the bajada and the foothills. In the bajada, red brome increased from 2.4% to 6.7% and in the foothills red brome increased from 3.0% to 8.7%. Although average cover was less than 10% in the valley bottom during 2014, cover slightly exceeded 10% in both the valley bottom and the foothills (Table 38). As a result, the condition is of moderate/significant concern for the valley bottom and foothills, and good for the bajada.

Not surprisingly based on the two previous measures, the ratio of non-native plant cover to total plant cover (expressed as a proportion) also increased over the two sampling periods (Table 38). However, all values except the valley bottom during 2014 met the reference for good condition. Therefore, the condition is good for the bajada and foothills but is of moderate/significant concern in the valley bottom.

Grass and forb cover (a measure of fire hazard) averaged about 16% in 2009/2010 and nearly 26% in 2014 (Table 39). Although grass and forb cover increased, the value in 2014 was below 30%. Therefore, this measure is in good condition. However, it's important to note that the increase to 26% in 2014 was due in large part to red brome.

The second measure of fire hazard—the ratio of annuals to total cover (expressed here as a percentage)—also increased over the two sampling periods, with the 2014 value exceeding 25% (Table 39). Again, the increase is due in large part to the annual red brome. Therefore, the condition for this measure is of moderate/significant concern.

Litter and duff cover (the third measure of fire hazard) in 2014 was about half the cover in 2009/2010, and

Table 39. Fire hazard in Tonto NM.

Measure	Stratum	2009/2010 (mean ± standard error)	2014 (mean ± standard error)
Grass and Forb Cover (%)	Bajada	16.2 ± 3.6	25.5 ± 4.7
Ratio of Annual Plant Cover to Total Plant Cover	Foothills	12.0 ± 4.7	30.4 ± 4.6
Litter and Duff Cover (%)	Foothills	30.9 ± 4.7	13.4 ± 3.1

Source: Data provided by K. Bonebrake, SODN data manager, via e-mail on 8 December 2017.

all values were well below 75% (Table 39). A note in the database provided by SODN indicates that litter was removed in 2011, which would account for the substantially reduced value for this cover type in 2014, perhaps as part of the plant thinning that occurs in and around archeological sites (SODN unpublished data). These data indicate good condition.

Overall Condition, Threats, and Data Gaps

We used five indicators and 14 measures (summarized in Table 40) to assess the condition of upland vegetation and soils at Tonto NM. In this assessment, all measures with a condition rating were assigned medium confidence. This is because the data were collected five years ago and may not reflect current conditions. However, monitoring is ongoing. Although several measures indicated shifts from good condition in 2009/2010 to moderate/significant concern condition in 2014, two data points are too few to determine trend. Therefore, trend is unknown. But the fact that several measures appeared to decline in condition between the two time periods is concerning. The measures of concern include soil stability, non-native plant extent, non-native cover in the valley bottom and foothills, ratio of non-natives to total cover in the valley bottom, and the ratio of annuals to total cover in the foothills. For these reasons, the overall condition is of moderate concern.

According to NPSpecies, there are 43 non-native plants in the monument (NPS 2018a). An additional six species have been reported as occurring in the

Table 40. Summary of upland vegetation and soils indicators, measures, and condition rationale.

Indicators	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Erosion Hazard	Bare Ground Cover (%)		In all three strata, bare ground cover was greater during 2009/2010 than during 2014. Bare ground cover was also greater in the valley bottom than in the bajada or foothills. The latter two strata were similar in cover during both rounds of sampling. In all cases, cover was less than 20% and did not exceed 12% in any stratum or sampling period.
	Soil Aggregate Stability without Overhead Vegetation (class)		As with bare ground cover, soil aggregate stability was greater during 2009/2010 than during 2014, and soil stability class was greatest for the bajada than for the other two strata. In 2014, soil stability averaged 2.5 in the valley bottom, 2.8 in the bajada, 1.9 in the foothills, all of which indicate unstable soils.
	Biological Soil Crust Cover in the Bajada (%)		Soil crust cover averaged 14% in 2009/2010 and 16% in 2014.
Site Resilience	Foliar Cover of Dead Perennial Plants in the Field Layer (%)		In 2009/2010, foliar cover of dead perennials was greater than during 2014, but all values were well below 15%.
	Foliar Cover of Dead Perennial Plants in the Subcanopy (%)		In the subcanopy, dead perennial plants did not exceed 1% in any of the three strata in either sampling period.
	Tree and shrub cover in the Subcanopy of the Foothills (%)		Tree and shrub cover in the subcanopy layer of the foothills strata averaged 14.3% in 2009.2010 and 15.7% in 2014.
Saguaro Cacti Recruitment	Extent in the Bajada (%)		During both rounds of sampling, Saguaro cactus extent was 5%. Although the condition is good, a value less than 5.0 would warrant moderate/ significant concern.
	Cover of Nurse Plants in the Bajada (%)		Nurse plant cover in both sampling periods was greater than 15%.

Table 40 continued. ***Summary of upland vegetation and soils indicators, measures, and condition rationale.***

Indicators	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Non-native Plants	Extent (%)		Extent of non-native plants increased in all three strata from 55% to 80% in 2009/2010 to 100% in 2014.
Non-native Plants *continued*	Cover (%)	Bajada Valley Bottom & Foothills	Cover of non-native plants increased between the two time periods. Although cover was less than 10% in bajada during 2014, cover slightly exceeded 10% in both the valley bottom and the foothills.
	Ratio of Non-native Plant Cover to Total Plant Cover	Bajada & Foothills Valley Bottom	The ratio of non-native plant cover to total plant cover increased over the two sampling periods. However, all values except the valley bottom (~37%) during 2014 were below 25%.
Fire Hazard	Grass and Forb Cover in the Bajada (%)		Grass and forb cover averaged about 16% in 2009/2010 and nearly 26% in 2014. Although grass and forb cover increased, the value in 2014 was below 30%.
	Ratio of Annual Plant Cover to Total Plant Cover in the Foothills		The ratio of annuals to total cover increased over the two sampling periods, with the 2014 value exceeding 25% by about 5 percentage points.
	Litter and Duff Cover in the Foothills (%)		Litter and duff cover in 2014 was about half the cover during 2009/2010 and all values were ~31% in 2009/2010 and 13% in 2014.
Overall Condition	Summary of All Measures		Several measures appeared to decline in condition between the two time periods, including soil stability, non-native plant extent, non-native cover in the valley bottom and foothills, ratio of non-natives to total cover in the valley bottom, and the ratio of annuals to total cover in the foothills.

monument, but their status is unconfirmed. Not all non-native species are problematic. Hubbard et al. (2013) noted that non-native plants invade in two phases. The first is the colonization phase, whereby a species gradually disperses and recruits into a system, competing with other plants for resources but not gaining dominance. Although much of the monument is not accessible to regular visitation, the main road to the visitor center and the powerlines in the valley bottom along Highway 188 may serve as dispersal corridors for non-native species. The second phase is asymmetrical competition, whereby a non-native species becomes dominant by gaining competitive advantage over native species, usually as the result of some sort of disturbance (Hubbard et al. 2013). This second phase may have occurred or is occurring with red brome. Red brome occurs in all three strata in the monument, but the species was lower in cover during 2009/2010 than during 2014. By 2014, red brome more than doubled in cover in all three strata. Although the spread of any non-native species is concerning, the increase in red brome may alter the natural fire regime of the monument.

Red brome is a fire-adapted species, not only withstanding fire but spreading rapidly after a fire. Accumulations of growth then serve as fuel for future fires resulting in a positive feedback loop. In June 2017, there was a 16.2 ha (40 ac) fire in the valley/bajada area of the monument. Other major fires also occurred in 1947, 1964, 1970, 1974, and 1980 (Studd et al. 2017). This is an unusually high fire frequency for the Sonoran Desert ecosystem, given the limited evolutionary history of wildfire there, even within the fire-adapted foothills region of the monument (Hubbard et al. 2013). Non-native plants are thought to have played a role in the high fire return interval in the monument (Studd et al. 2017). While portions of the uplands may have partially recovered from these fires (Studd et al. 2017), non-native annuals may invite fire into this system again in the near future.

Although the fires have rarely occurred in the lowest elevation desert scrub community—with the exception of the Schultz Fire in 1964—mid-elevations have been affected by fire, including areas where Saguaro cacti grow. Fire kills this long-lived, slow-growing species, and Tonto NM is already at the northern extent of its range (Hubbard et al. 2013). Changes to the plant community, including nurse plants, could reduce suitable habitat for this iconic Sonoran Desert species.

Tonto NM is surrounded by the Tonto National Forest, which serves as a partial buffer against threats such as development. However, the forest allows for multiple uses, including grazing, which may facilitate the spread of non-native plants (NPS 2017a). However, the USFS now practices rotational grazing in the lands adjacent to the monument, which is more sustainable than traditional grazing practices (USFS, E. Hoskins, range manager, personal communication to K. Raymond, NPS hydrologist, received 10 December 2018). Nevertheless, Lehmann lovegrass is much more common outside the monument than inside the monument (Hubbard et al. 2013). Following the 1964 Schultz Fire, the USFS reseeded the rangeland with Lehmann lovegrass, the legacy effects of which can still be seen across the monument's boundary (Hubbard et al. 2013). In contrast, the monument was reseeded with native jojoba following the Schultz Fire (Hubbard et al. 2013).

While plant thinning around archeological sites increases protection for those features, plant removals increases erosion (McIntyre 2008). A study of erosion resistance around 46 archeological sites in the monument found that resistance was low in these locations, even prior to plant thinning (McIntyre 2008). Low bare ground cover and high BSC cover both increase erosion resistance, but soil aggregate stability data indicate susceptibility to erosion. In SODN's upland monitoring plots, erosion features (rills, gullies, and sheet) estimated only a very small portion of some plots, while other plots did not exhibit these features. The geology assessment in this report provides more details regarding erosion in the monument.

All of these threats (i.e., non-native species, erosion, grazing, fire) may be exacerbated by climate change. The monument's climate is already outside the range of normal (Monahan and Fisichelli 2014). Temperatures have increased and the monument has experienced drought conditions for seven of the last 11 years (Climate Analyzer 2018). Furthermore, air pollution from vehicle exhaust, agriculture, and dust may stress native plants. In the air quality assessment in this report, ozone levels with respect to plant health warrant significant concern, although conditions have improved somewhat (NPS ARD 2018f). Nitrogen deposition is also high, especially when considering the sensitivity of the monument's flora to the effects of excess nitrogen (NPS ARD 2018f).

In 2013, Hubbard et al. (2013) stated that data collected in the uplands in Tonto NM reflected "an intact and functioning terrestrial ecosystem with species abundance and diversity within expected ranges." While this may still be the case, more recent data suggest a shift toward an increase in red brome, loss of soil stability, and an increase in fire hazard. Only continued monitoring and comparison to past monitoring results will show whether the system is changing beyond the natural range of variation.

Sources of Expertise
This assessment was written by science writer and wildlife biologist, Lisa Baril, Utah State University. Subject matter expert reviewers for this assessment are listed in Appendix A.

Birds

Background and Importance

Changes in bird population and community parameters have been identified as an important element of a comprehensive, long-term monitoring program at Tonto National Monument (NM) (Beaupré et al. 2013). In the bird monitoring protocol for the National Park Service (NPS) Sonoran Desert Inventory and Monitoring Network (SODN) and other networks, Beaupré et al. (2013) describe how landbird monitoring contributes to a basic understanding of park resources and associated habitats as follows:

> Landbirds are a conspicuous component of many ecosystems and have high body temperatures, rapid metabolisms, and occupy high trophic levels. As such, changes in landbird populations may be indicators of changes in the biotic or abiotic components of the environment upon which they depend (Canterbury et al. 2000; Bryce et al. 2002). Relative to other vertebrates, landbirds are also highly detectable and can be efficiently surveyed with the use of numerous standardized methods (Bibby et al. 2000; Buckland et al. 2001).
>
> Perhaps the most compelling reason to monitor landbird communities in parks is that birds themselves are inherently valuable. The high aesthetic and spiritual values that humans place on native wildlife is acknowledged in the agency's Organic Act: "to conserve . . . the wild life therein. . . unimpaired for the enjoyment of future generations." Bird watching, in particular, is a popular, long-standing recreational pastime in the U.S., and forms the basis of a large and sustainable industry (Sekercioglu 2002).

Although Tonto NM is part of SODN, the monument lies along the Mogollon Rim, which separates the Sonoran Desert ecoregion from the Apache Highlands ecoregion (NPS 2018d). The monument's location at the confluence of these two ecoregions is reflected in the diversity of wildlife and plants found in the monument. Furthermore, Tonto NM is located within the 11.3-million ha (2.8-million ac) Tonto National Forest (NF) (NPS 2018d). The Tonto NF provides a buffer from developed areas that fragment bird habitat elsewhere.

Data and Methods

This assessment is based on one indicator (species occurrence) with three measures. The measures are presence/absence of all species, presence of species of concern, and presence of the Mexican spotted owl (*Strix occidentalis lucida*). The Mexican spotted owl

A Gila woodpecker peering out of a nest cavity. Photo Credit: @ R. Shantz.

(hereafter referred to as MSO) is listed as threatened by the U.S. Fish and Wildlife Service's (USFWS) Endangered Species Act (USFWS 2018a).

The NPSpecies (NPS 2018a) bird list served as our foundation list for the monument. NPSpecies documents the occurrence of wildlife and plants by NPS unit and is typically updated using past surveys, such as those described in this assessment, and expert opinion. The list is included in Appendix C along with additional species reported by NPS staff and visitors and those that appear in the studies described here. For brevity, scientific names in the following tables are provided in Appendix C only. We compared the NPSpecies list to the checklist of bird species documented for Tonto NF by the U.S. Forest Service (USFS 1992b) to determine how many of the species known to occur in the forest also occur in the monument.

For the presence/absence measure, we compared two studies of breeding season birds, the first of which was part of a vascular plant and vertebrate inventory for the monument (Albrecht et al. 2007). Albrecht et al. (2007) surveyed breeding birds during 2001 to 2003 using the variable circular plot (VCP) method. Ten points were established along two transects: six points in riparian habitat and four points in upland habitat. Points were spaced a minimum of 250 m (820 ft) apart. Riparian habitat in the monument is represented by a narrow band of Arizona sycamore (*Plantanus wrightii*) and Arizona walnut (*Juglans major*) along Cave Canyon. The riparian transect covered the entire length of Cave Canyon within the monument (refer to Figure 5.1 in Albrecht et al. (2007) for point count locations).

Upland points were located within interior chaparral vegetation with some components of semidesert grasslands (Albrecht et al. 2007). Interior chaparral is dominated by alderleaf mountain mahogany (*Cercocarpus montanus*), Sonoran scrub oak (*Quercus turbinella*), desert needlegrass (*Achnatherum speciosum*), and crucifixion thorn (*Canotia holacantha*) (Albrecht et al. 2007). Interior chaparral is found in the highest elevations in the monument (roughly 1,200 m [3,937 ft]). Semidesert grasslands are dominated by Emory's globemallow (*Sphaeralcea emoryi*), brownplume wirelettuce (*Stephanomeria puciflora*), desert needlegrass, Lehman lovegrass (*Eragrostis lehmanniana*), jojoba (*Simmondsia chinensis*), common sotol (*Dasylirion wheeleri*), broom snakeweed (*Gutierrezia sarothrae*), and sideoats grama (*Bouteloua curtipendula*) (Albrecht et al. 2007).

The six riparian points were visited four times in 2001 and five times in 2002 and 2003. Upland points were visited four times in 2002 only. Surveys were conducted from April to July, and counts lasted for eight minutes at each point. Flyovers and birds beyond 75 m (246 ft) from each point count station were excluded from analysis of abundance, but since this measure focuses on presence/absence, we included total species richness. We reported species richness by year and habitat type. Because surveys began in April, the counts included migratory species in addition to breeding species, the latter of which were the focus of this study (Albrecht et al. 2007).

Albrecht et al. (2007) also conducted nocturnal owl surveys along the main road in the monument and in the riparian area at a total of six stations established 300 m (984 ft) apart (refer to Figure 5.2 in Albrecht et al. (2007) for a map of nocturnal survey locations). The six stations were surveyed three times during 2001, twice during 2002, and four times during 2003. Surveys began with a three-minute passive listening period followed by two minutes of alternating broadcast and listening periods each lasting 30 seconds for each of three owl species. The three species were elf owl (*Micrathene whitneyi*), western screech-owl (*Megascops kennicottii*), and barn owl (*Tyto alba*). Calls for MSO were not broadcast because of special permit requirements for federally threatened species (USFWS 2018a).

The second breeding season study was conducted by SODN from 2008 to 2015 (Beaupré et al. 2013). SODN established two transects: one in desert scrub habitat and one in riparian habitat (refer to Figure C.3-10 in Beaupré et al. (2013) for a map of survey locations). The riparian habitat was as described above for the inventory surveys. Desert scrub habitat is dominated by jojoba, broom snakeweed, Fremont's desert-thorn (*Lycium fremontii*), yellow paloverde (*Parkinsonia microphylla*), eastern Mojave buckwheat (*Eriogonum fasciculatum*), and Arizona spikemoss (*Selaginella arizonica*). In contrast to interior chaparral surveyed by Albrecht et al. (2007), desert scrub occurs in the monument's lowest elevations at about 430 m (1,312 ft).

Eight points were established along the riparian transect and nine points were established in desert scrub vegetation. Each point was surveyed twice per year from 2008 to 2015 (Beaupré et al. 2013). Surveys were conducted from mid-April through May. Each point count station was surveyed for six minutes. SODN's protocol was similar to the VCP method in that points were spaced 250 m (820 ft) apart, flyovers were removed, and birds beyond 75 m (246 ft) from each point count station were excluded (Beaupré et al. 2013). But because this measure focuses on presence/absence, we included a complete list of species observed in both habitat types. We reported species richness by year and habitat type. SODN data were provided by K. Bonebrake, SODN data manager on 16 November 2017 via e-mail.

Although the two studies described above used similar methods, they are not directly comparable because of differences in the upland habitat type surveyed, differences in the location of riparian point count stations, and differences in effort (i.e., length of point counts, number of visits, and years surveyed). However, we are only comparing presence/absence and not abundance.

We also summarized observations made by William Moore, a Tonto NM intern who collected bird observations from November to April 2012-2018. Observations were reported as species observed by month for each of the seven years. Although these data did not inform the current condition of presence/absence, they provide valuable information for future comparisons. Aside from early bird checklists and notes (Hargrave 1963, 1965), the only other study of birds in the monument was conducted by Hiett and Halvorson (1999) from 1992 to 1995. Unfortunately, data from this effort have been lost (Albrecht et al. 2007), although a report detailing a proposed monitoring protocol along with notes about some of their findings is available in Hiett and Halvorson (1999). Finally, although National Audubon Society (NAS) Christmas Bird Count (CBC) (NAS 2014) observations for 2018 were available, the count included species observed at Theodore Roosevelt Lake located outside of monument boundaries. Therefore, we did not include these data in this assessment.

The second measure (presence of species of concern) was evaluated using the Arizona Partners in Flight (AZ-PIF) Bird Conservation Plan (Latta et al. 1999). The plan lists 43 species of concern for the state based on 11 criteria, which included relative abundance, breeding and wintering distribution, threats, and importance of Arizona to each species (Latta et al. 1999). We cross-referenced this list with the NPSpecies list for the monument (NPS 2018a), 2001-2003 inventory data, SODN monitoring data, and with W. Moore's observations. The NPSpecies list provides a certified record of the species that have been observed in the monument over time while the other surveys/observations provide a measure of persistence over time.

For MSO occurrence, we summarized all the published information regarding MSOs in and around Tonto NM based on files obtained during the NRCA scoping meeting (10-11 May 2018) and through an exhaustive literature search on publicly available information. We also reviewed MSO habitat requirements and determined the availability and extent of appropriate breeding habitat in the monument using the NPS vegetation classification maps (Studd et al. 2017).

Reference Conditions

Reference conditions for the two measures are shown in Table 41. Reference conditions are described for resources in good, moderate concern, and significant concern conditions.

A zone-tailed hawk being chased by a western kingbird. Photo Credit: @ R. Shantz.

Table 41. Reference conditions used to assess birds.

Indicator	Measures	Good	Moderate Concern	Significant Concern
Species Occurrence	Presence/ Absence	All or nearly all of the species recorded during early surveys/ observations in the monument were recorded by SODN.	Several bird species recorded during early surveys in the monument were not recorded by SODN (particularly if the species had previously been considered common).	A substantial number of species recorded during early surveys in the monument were not recorded by SODN (particularly if the species had previously been considered common).
	Presence of Species of Concern	A moderate to substantial number of species of conservation concern occur in the monument, which indicates that the NPS unit provides important habitat for these species and contributes to their conservation.	A small number of species of conservation concern occur in the monument.	No species identified as species of conservation concern have been recorded in the monument.
	Mexican Spotted Owl	Passive observations and focused surveys indicate that this species is a persistent resident of the monument.	Passive observations and focused surveys indicate that this species is present, but occupancy appears inconsistent.	Passive observations and focused surveys indicate that the species no longer occurs in the monument.

Condition and Trend

NPSpecies lists 190 species of bird for the monument (NPS 2018a). Of the 190 species, 150 are considered "present," two species are considered "probably present," and 38 species are "unconfirmed." Three species considered "present" are non-native. The non-native species are Eurasian collared-dove (*Streptopelia decaocto*), European starling (*Sturnus vulgaris*), and house sparrow (*Passer domesticus*).

According to the 1992 checklist of birds for Tonto NF, 305 species occur in the forest and 131 (44%) of them appear on the monument's NPSpecies list. Most of the species documented for the forest but not the monument are shorebirds, waterfowl, and wading birds. Since aquatic habitat (i.e., lakes and ponds) is not available in the monument, this is not surprising. Because the list for Tonto NF is 25 years old, there are 16 species listed as "present" by NPSpecies that were not included on the Tonto NF bird checklist, including brown-crested flycatcher (*Myiarchus tyrannulus*), red-naped sapsucker (*Sphyrapicus nuchalis*), rufous-winged sparrow (*Peucaea carpalis*), and Bullock's oriole (*Icterus bullockii*). The remaining species that were not included on the Tonto NF list are either vagrants or unconfirmed for the monument according to NPSpecies. Lastly, the common black-hawk (*Buteogallus anthracinus*) and greater pewee (*Contopus pertinax*) appear on the forest's checklist but not in NPSpecies, yet they have been observed during the 2001-2003 inventory surveys (both species) or by W. Moore (common black hawk).

When excluding the roughly 75 species of shorebirds, waterfowl, and wading birds observed for the forest, the monument supports about 57% of the bird species listed for the national forest. These results indicate high bird diversity for Tonto NM considering the forest's size (11.3-million ha [2.8-million ac]) compared to the monument's size (452 ha [1,119 ac]) and the greater diversity of habitats found in the forest than in the monument. However, it's important to note that the forest's checklist has not been updated since 1992, and it's possible that species richness there has changed in the last 25 years. Below we summarize the two studies used to evaluate presence/absence.

Albrecht et al. (2007) reported 97 species during VCP surveys, nocturnal surveys, and incidental observations, including four species not previously documented in the monument (Appendix C). These four species were bushtit (*Psaltriparus minimus*), black-chinned sparrow (*Spizella atrogularis*), yellow-eyed junco (*Junco phaeonotus*), and yellow-breasted chat (*Icteria virens*). The yellow-eyed junco is still listed as "unconfirmed" in NPSpecies, however. Albrecht et al. (2007) also reported a scarlet tanager that is listed as "unconfirmed" in NPSpecies but was not considered new to the monument according to the inventory results. Considering only species listed as "present" in NPSpecies, Albrecht et al. (2007) recorded 63% of the NPSpecies bird list.

During VCP surveys observers recorded 71 species in riparian habitat and 33 species in upland habitat (Figure 34). Species richness in riparian habitat ranged

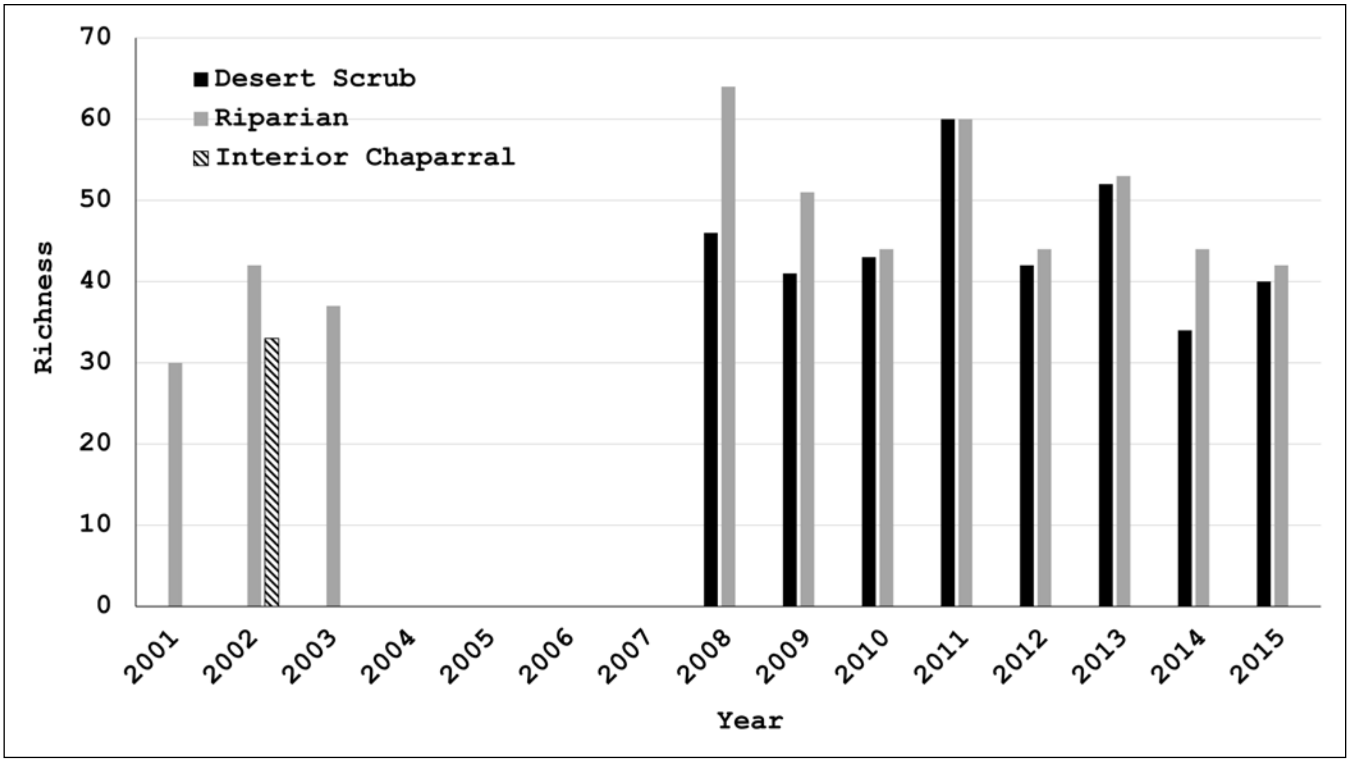


Figure 34. Bird richness by year and habitat type in Tonto NM. Data (2001-2003) were from Albrecht et al (2007). The remaining data were provided by SODN.

from 30 to 42 species per year with an average of 33 species per year. The authors note high species turnover in riparian habitat, which suggests multiple years of sampling is required to capture the full range of species (Albrecht et al. 2007). The most common species observed in riparian habitat were Bell's vireo (*Vireo bellii*), northern cardinal (*Cardinalis cardinalis*), and verdin (*Auriparus flaviceps*). In interior chaparral, the most common species were black-throated sparrow (*Amphispiza bilineata*), canyon towhee (*Melozone fuscus*), and rufous-crowned sparrow (*Aimophila ruficeps*). The only non-native species reported was the house sparrow.

During nocturnal surveys, five species were documented—four species of owl and 15 detections of common poorwill (*Phalaenoptilus nuttallii*). All three targeted owl species were detected with the elf owl being the most common (50 detections). The barn owl and western screech-owl were only detected once. In addition, one great horned owl (*Bubo virginianus*) was reported.

A total of 101 species were observed during SODN's surveys across both habitat types (Appendix C). Common black-hawk, Franklin's gull (*Leucophaeus pipixcan*), and greater pewee were three species reported during SODN surveys that are not listed by NPSpecies. All three species are represented by one detection, including a flock of 13 Franklin's gulls. Excluding these three species, SODN's observations over all years of surveys represent 65% of the species listed as "present" by NPSpecies, which is only slightly higher than the proportion of NPSpecies documented by Albrecht et al. (2007).

Surprisingly, roughly the same number of species were reported in both habitat types (87 in riparian and 85 in desert scrub). Although many of the same species were reported for both habitats, 14 species were exclusive to riparian habitat and 13 species were exclusive to desert scrub. Fewer than six occurrences were reported for most of these species with the exception of 13 summer tanager (*Piranga rubra*) detections in riparian habitat and 22 northern rough-winged swallow (*Stelgidopteryx serripennis*) detections in desert scrub. Note that we did not do this comparison for the 2001-2003 inventory data because of the uneven sampling effort between the two habitat types (one year in uplands vs. three years in riparian habitat).

In riparian habitat species richness ranged from a low of 44 to a high of 64 species with an average of 50 species observed per year (Figure 34). In desert scrub species richness ranged from a low of 34 to a high of 60 with an average of 45 species per year. Thus, although total richness was similar between the two habitat types, average annual richness was higher in riparian habitat than in desert scrub.

In riparian habitat the most common species were Bell's vireo, cactus wren (*Campylorhynchus brunneicapillus*), and black-throated sparrow. In desert scrub habitat the most common species were black-throated sparrow, Gambel's quail (*Callipepla gambelii*), and northern mockingbird (*Mimus polyglottos*).

In summary, Albrecht et al. (2007) and SODN reported 81 species in common. Sixteen species were reported exclusively by Albrecht et al. (2007) (Table 42), and 20 species were reported exclusively by SODN (Table 43) Of the 16 species observed exclusively during the earlier survey, two are unconfirmed, two are nocturnal, and three are diurnal raptors. Of the remaining nine species, only two are considered resident or breeding birds. The remainder are migratory or vagrants. Since most of these species are not adequately surveyed using point count methods (e.g., raptors), these results do not suggest a loss of species over time. Of the 20 species listed by SODN but not Albrecht et al. (2007), only seven species are listed as resident or breeding species, and of these only the lesser nighthawk (*Chordeiles acutipennis*) is considered common.

Table 42. Bird species reported during 2001-2003 that were not reported during 2008-2015.

Species	NPSpecies Abundance	NPSpecies Status
Scarlet tanager	Unconfirmed	–
Yellow–eyed junco	Unconfirmed	–
Bald eagle	Rare	Migratory
Barn owl	Uncommon	Breeder
Bushtit	Rare	Resident
Cassin's vireo	Uncommon	Migratory
Cliff swallow	Uncommon	Resident
Elf owl	Common	Breeder
Merlin	Occasional	Migratory
Olive–sided flycatcher	Rare	Migratory
Peregrine falcon	Rare	Breeder
Sharp–shinned hawk	Rare	Migratory
Spotted towhee	Occasional	Vagrant
Townsend's solitaire	Occasional	Migratory
Yellow–headed blackbird	Uncommon	Migratory
Yellow–throated vireo	Occasional	Vagrant

Table 43. Bird species reported during 2008-2015 that were not reported during 2001-2003.

Species	NPSpecies Abundance	NPSpecies Status
Common black–hawk	Not Listed	–
Franklin's gull	Not Listed	–
Greater pewee	Not Listed	–
Anna's hummingbird	Uncommon	Migratory
Cassin's kingbird	Uncommon	Breeder
Double–crested cormorant	Uncommon	Resident
Eurasian collared–dove	Occasional	–
Great blue heron	Uncommon	Migratory
Hammond's flycatcher	Rare	Migratory
Harris's hawk	Rare	Resident
House sparrow	Uncommon	Breeder
Lark sparrow	Uncommon	Migratory
Lesser nighthawk	Common	Breeder
Loggerhead shrike	Uncommon	Breeder
Northern flicker	Uncommon	Resident
Painted redstart	Occasional	Vagrant
Pine siskin	Rare	Migratory
Pyrrhuloxia	Uncommon	Breeder
Swainson's thrush	Rare	Migratory
Vaux's swift	Uncommon	Migratory

We could not compare species by habitat type because 1) Albrecht et al. (2007) did not report all species by habitat type, only those for which abundance estimates were calculated; 2) upland habitat types differed between the two surveys (i.e., interior chaparral vs. desert scrub); and 3) different sampling methods were used, including nocturnal owl surveys. Nevertheless, 54% of the species considered "present" in the monument were reported during both surveys. When considering only breeding species, which was the target group of both studies, 73% of the 82 species of breeding bird, including residents, were observed during both studies. Based on reference conditions, the presence/absence of all species is good. Confidence is medium because of differences between the two studies. We did not determine trends in presence/absence because of these differences.

NPS intern W. Moore observed 67 species from November to April of 2012-2018, including species considered rare such as bushtit (*Psaltriparus minimus*) (Appendix C). Species most often observed included Gila woodpecker (*Melanerpes uropygialis*), canyon towhee, cactus wren, northern cardinal, and common raven (*Corvus corax*).

For each season, the number of species observed increased from November to April with the onset of migration and the arrival of breeding birds. Common black-hawk was the only species observed that was not listed at all by NPSpecies. Moore also reported one species listed as "unconfirmed" by NPSpecies—Canada goose (*Branta canadensis*).Lastly, W. Moore reported four species that were not reported during point count surveys. These were Canada goose, northern harrier (*Circus hudsonius*), Hutton's vireo (*Vireo huttoni*), and Lincolns' sparrow (*Melospiza lincolnii*). Although these data were not part of a formal survey, they provide important information on the presence/absence of migratory and wintering birds in the monument; Wintering birds were not captured by SODN or Albrecht et al. (2007).

For the species of conservation concern measure, we found that of the 43 priority bird species identified by the State of Arizona, 23 (14 present and 9 unconfirmed are listed by NPSpecies (Table 44). In addition, common black-hawk is a species of concern reported for the monument but not listed in NPSpecies as previously noted. Of the species considered "present," only three are considered common. These are Brewer's sparrow (*Spizella brewri*), Costa's hummingbird (*Calypte*

Table 44. Priority bird species listed by the State of Arizona that do or may occur in Tonto NM.

Species	NPSpecies Occurrence	NPSpecies Abundance	NPSpecies Status	Inventory (2001–2002)	SODN Surveys (2008-2015)	W. Moore (Nov–April 2012–2018)
Band-tailed pigeon	Unconfirmed	–	–	–	–	–
Black-throated gray warbler	Present	Uncommon	Migratory	X	X	X
Brewer's sparrow	Present	Common	Resident	X	X	X
Common black-hawk	Not Listed	–	–	–	X	X
Cordilleran flycatcher	Unconfirmed	–	–	–	–	–
Costa's hummingbird	Present	Common	Breeder	X	X	X
Ferruginous hawk	Unconfirmed	–	–	–	–	–
Gilded flicker	Present	Uncommon	Breeder	X	X	X
Gray flycatcher	Present	Uncommon	Migratory	X	X	–
Gray vireo	Present	Uncommon	Breeder	X	X	X
Le Conte's thrasher	Unconfirmed	–	–	–	–	–
Lucy's warbler	Present	Common	Breeder	X	X	X
Macgillivray's warbler	Present	Uncommon	Migratory	X	X	–
Mexican spotted owl*	Unconfirmed	–	–	–	–	–
Northern goshawk	Unconfirmed	–	–	–	–	–
Olive-sided flycatcher	Present	Rare	Migratory	X	–	–
Pinyon jay	Unconfirmed	–	–	–	–	–
Purple martin	Present	Uncommon	Breeder	–	–	–
Red-faced warbler	Unconfirmed	–	–	–	–	–
Red-naped sapsucker	Present	Occasional	Migratory	–	–	–
Rufous-winged sparrow	Present	Uncommon	–	X	X	–
Sage thrasher	Unconfirmed	–	–	–	–	–
Swainson's thrush	Present	Rare	Migratory	–	X	–
Yellow-billed cuckoo*	Present	Occasional	Migratory	–	–	–

* Listed as threatened by the U.S. Fish and Wildlife Service under the Endangered Species Act (USFWS 2018a,b).

Sources: Latta et al. (1999), NPSpecies (NPS 2018a), Albrecht et al. (2007), and SODN unpublished data.

Note: X = species present.

costae), and Lucy's warbler (*Oreothlypis luciae*). The remaining 11 species are listed as rare, occasional, or uncommon. Furthermore, about half of the confirmed species of concern pass through the monument during migration only.

Ten species of concern were reported during the inventory, 11 species were observed during SODN's surveys, and seven species were observed by W. Moore. Six of the 24 species listed in Table 44 were observed in all three surveys or observations. These results suggest that Tonto NM not only provides breeding habitat for several species of concern, but that the monument also provides migration and winter habitat, which are equally important to the persistence of species of concern throughout their ranges. Aside from MSO, the yellow-billed cuckoo is the only other species listed under the Endangered Species Act (USFWS 2018b). The cuckoo is considered a migratory species in the monument and was not observed during any of the studies/observations included in this assessment.

Based on the NPSpecies list considered "present," 32% of Arizona's species of concern occur in the monument (53% if including "unconfirmed" species). Given reference conditions, this measure is good. Confidence is medium, however, because species of conservation concern are often uncommon to rare, have specific habitat requirements, and are difficult to survey. A more focused study on species of concern is necessary to further evaluate this measure. Nevertheless, these data provide a good baseline for occurrence. Trend was not determined.

For the MSO occurrence measure, NPSpecies lists this species as "unconfirmed" because the monument is "outside the normal range and habitat" (NPS 2018a). This was assumed to be the case until an MSO was captured on a game camera on 22 February 2010 (Cannon 2017, USFWS 2012). This is the only confirmed observation of an MSO in the monument; however, Hiett and Halvorson (1999) discovered two records of this species but did not include details of these observations in their report. Although their data have been lost (Albrecht et al. 2007), Hiett and Halvorson (1999) wrote in their report that no MSOs were detected during their 1992-1995 surveys.

Apparently, MSO surveys were conducted by monument staff during 2001-2003 (S. Hoh, personal communication as cited in Albrecht et al. (2005));

Mexican spotted owl captured by a game camera on 22 February 2010. Photo Credit: NPS.

however, those data could not be located in monument files (data for these surveys should have been included in Appendix E in Albrecht et al. 2005 but were removed from that report). Because this appendix is missing, we could not report on the results of these surveys; however, it seems unlikely that any MSOs were detected since the only reference to an MSO observed in the monument is from the 2010 game camera. Lastly, two surveys for MSOs were completed in 2017, but observers did not detect any individuals (Cannon 2017).

According to the checklist of birds for Tonto NF, MSOs are fairly common, permanent residents of coniferous and riparian habitat (USFS 1992b). A more recent report concluded that approximately 18% of Tonto NF is associated with owl use (Ganey et al. 2012). However, the monument is located at the southeastern boundary of their current range (Figure 35). Tonto NM contains somewhat marginal habitat for this species. For breeding, MSOs prefer mixed coniferous forests dominated by Douglas-fir (*Pseudotsuga menziesii*), pine (*Pinus* spp.), or true fir (*Abies* spp.) and pine-oak (*Quercus* spp.) forests (USFWS 2012), but this forest type is not present in Tonto NM (Studd et al. 2017). However, secondary breeding habitat is available in the Cave Canyon riparian area, which is a steep, narrow canyon of riparian forests with a perennial water source (i.e., Cave Canyon spring) (USFWS 2012). In winter, MSOs prefer lower elevation pinyon-juniper (*Juniperus* spp.) woodlands and open mountain-shrub habitat

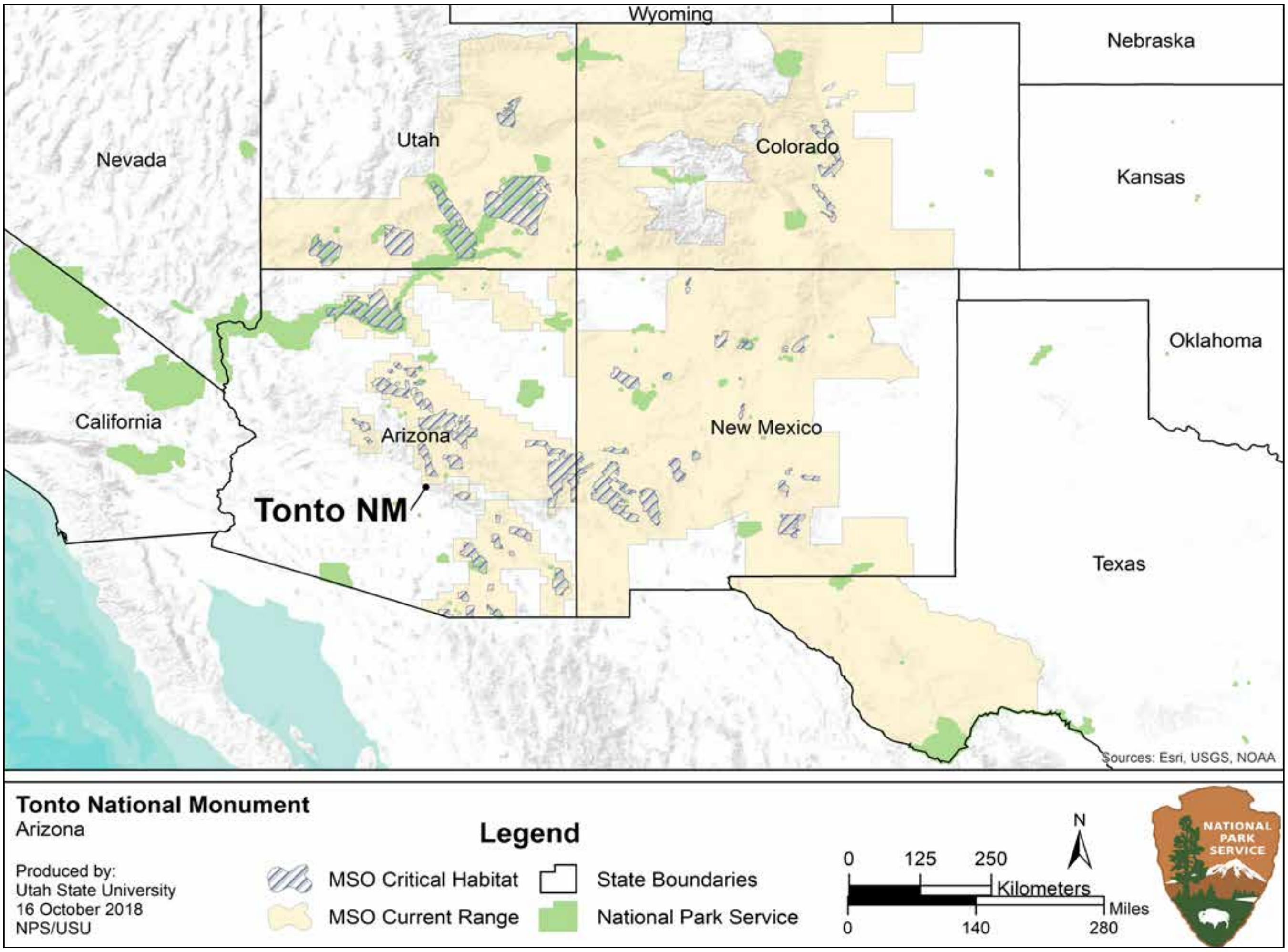


Figure 35. **The current range of the Mexican spotted owl in the southwestern U.S.**

(USFWS 2012). While pinyon-juniper woodlands are lacking in the monument, mixed shrubland habitat dominates Tonto NM (Studd et al. 2017).

In addition to vegetation and habitat characteristics, MSOs also require small to medium sized rodents such as woodrats (*Neotoma* spp.), mice (*Peromyscus* spp.), voles (*Microtus* spp.), and even bats (Family *Vespertilionidae*) (USFWS 2012). The NPSpecies list of mammals includes several potential prey species, but abundance is unknown for many of them (NPS 2018a). Because of the lack of systematic surveys and limited information regarding the occurrence of the MSO in the monument, the condition for this measure is unknown. Because of the unknown condition, confidence is low.

Overall Condition, Threats, and Data Gaps

To date there have been three formalized surveys of birds in the monument, but data for one of them (Hiett and Halvorson 1999) have been lost. The 2001-2003 inventory and the more recent surveys by SODN are somewhat comparable for the riparian area, but not for uplands since two different upland habitats were surveyed between the two studies. Nevertheless, many of the same species were observed during both studies, especially when only considering birds that breed in the monument, which were the target of both surveys. Furthermore, the monument provides habitat for both breeding and migratory species of concern, including possibly MSOs. For these reasons, the condition of birds in Tonto NM is good (Table 45). It's important to note, however, that this condition is based solely on presence/absence. While these data suggest high species richness and persistence of a subset of those species over time, the use of different survey methods in each study limit usefulness of the comparison. A key uncertainty is whether the MSOs is a regular visitor to the monument. Because of differences in survey methods we could not compare abundance

Table 45. Summary of bird indicators, measures, and condition rationale.

Indicators	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Species Occurrence	Presence/ Absence	Good condition (green circle)	NPSpecies list 190 species, 150 of which are considered "present" in the monument. Approximately 57% of species occurring in Tonto NF (excluding shorebirds, waterfowl, and wading birds), have been observed in the monument. When comparing the 2001-2003 inventory to 2008-2015 data, 54% of the species considered "present" in the monument were reported during both surveys, and 73% of the 82 species of breeding bird, including residents, were observed during both studies.
	Presence of Species of Concern	Good condition (green circle)	Twenty-three of the 43 species of concern listed for the State of Arizona occur on the NPSpecies list (14 are "present" and nine are "unconfirmed"). In addition, common black-hawk is a species of concern reported for the monument but not listed in NPSpecies for a total of 24 species. Ten species of concern were reported during the inventory, 11 species were observed during SODN's surveys, and seven species were observed by W. Moore. Six of the 24 species were observed during all three surveys or observation efforts. Based on the NPSpecies list considered "present," 32% of Arizona's species of concern occur in the monument (53% if including "unconfirmed" species).
	Mexican Spotted Owl	Unknown condition (dashed circle)	Information on Mexican spotted owls in the monument is limited. Only one observation has been confirmed to data (captured on a game camera on 22 February 2010). There were apparently two sightings as reported by Hiett and Halvorson (1999) and a survey done by monument staff during 2001-2003 as reported in Albrecht et al. 2005). However, details from these records and surveys could not be located. Formal surveys occurred in 2017, but no owls were detected.
Overall Condition	Summary of All Measures	Good condition (green circle)	To date there have been three bird surveys in the monument, but data from Hiett and Halvorson 1999 were lost. The 2001-2003 inventory and the more recent surveys by SODN are somewhat comparable for the riparian area, but not for uplands since two different habitats were surveyed. Nevertheless, many of the same species were observed during both studies, especially when considering only breeding species, which were the target of both surveys. Furthermore, the monument provides habitat for both breeding and migratory species of concern, including possibly the Mexican spotted owl.

nor did we attempt to, but this is a necessary step to more effectively monitor bird communities in the monument, and basic point count surveys represent a cost-effective way to do this.

Migratory and other bird species face threats throughout their ranges, including: loss or degradation of habitat due to development, agriculture, and forestry activities; collisions with vehicles and man-made structures (e.g., buildings, wind turbines, communication towers, and electrical lines); poisoning; and landscape changes due to climate change (USFWS 2018c). The federal Migratory Bird Treaty Act protects more than 1,000 species of bird, and many of these species are experiencing population declines because of increased threats within their range (USFWS 2018c). Also, across the U.S., free-ranging domestic cats (*Felis catus*) may be responsible for as many as 2.4 billion bird deaths each year (The Wildlife Society 2011, Loss et al. 2013). NPSpecies lists the domestic cat as present but rare at the monument (NPS 2018a).

Non-native bird species could also be problematic for native birds. The three species reported for the monument are European starling, Eurasian collared dove, and house sparrow. While the specific effects of these introduced species on native birds in the monument are unknown, these species likely compete with native birds for nesting habitat, food, and other resources as they do elsewhere (Cabe 1993, Lowther and Cink 2006, Romagosa 2012).

Aside from habitat loss and non-native species, climate change may be the biggest threat to bird species in and around the monument. The Cave Canyon riparian area is particularly rich considering its limited extent. In general, riparian vegetation in the arid southwest is rare, accounting for less than 1% of land cover but supporting as much as 50% of local bird diversity (Knopf and Samson 1994, Skagen et al. 1998). Many of the stream channels in Cave Canyon are ephemeral, but there is a small perennial stretch near the main spring (Albrecht et al. 2005). Maintenance of flowing water is vital to the persistence of riparian vegetation that supports the high bird diversity observed there. However, as the climate becomes drier, water resources in the monument may become more limited. Not only do birds respond to changes in vegetation, but they also have heat tolerance thresholds (Wu et al. 2018).

In a joint study by the NPS and the National Audubon Society, researchers found that of 274 NPS units, Tonto NM falls within the low end of projected change by 2050 (Schuurman and Wu 2018). Of the 24 species listed in Table 44, four were included in the climate change study. Climate conditions for Costa's hummingbird and Lucy's warbler are expected to improve during summer and conditions for Brewer's sparrow is expected to improve for winter. The Cordilleran flycatcher (*Empidonax occidentalis*) may colonize the monument during summer. This species is listed as "unconfirmed," by NPSpecies. In contrast, conditions may worsen for black-throated sparrow during summer; and canyon towhee, canyon wren (*Catherpes mexicanus*), and Bewick's wren (*Thryomanes bewickii*) during winter. However, these predicted changes also depend on the habitat requirements of these species. The study did not take into account how vegetation may respond to a changing climate.

Key data gaps include information about changes in abundance for birds in the monument, and aside from the observational data collected by W. Moore, there are no data on wintering birds in the monument. Data gaps also include information on species of concern.

Sources of Expertise

This assessment was written by science writer and wildlife biologist, Lisa Baril, Utah State University. Subject matter expert reviewers for this assessment are listed in Appendix A.

Mammals

Background and Importance

Tonto National Monument (NM) is nestled against the Mogollon Rim at the intersection of the Apache Highlands and Sonoran Desert ecoregions (Studd et al. 2017). The monument's topography rises abruptly from 695 m (2,280 ft) in the valley bottom to 1,219 m (4,000 ft) in the uplands over a distance of just 1.2 km (0.8 mi) (Hubbard et al. 2012). This rugged setting spans three biomes—desert, thornscrub, and semidesert grasslands (Hubbard et al. 2012). Tonto NM also includes a narrow riparian area that is supported by Cave Spring—the only perennial water source in the monument (Albrecht et al. 2005). These factors account for the monument's high floristic diversity, which in turn influences mammal species diversity, richness, and abundance.

The health, distribution, and diversity of mammals that utilize the monument and surrounding region is important because mammals serve as both predators and prey, seed dispersers, pollinators, and grazers. Mammals in general exhibit wide variation in territory size depending on the species (e.g., larger mammals require more area than smaller mammals) and the distribution of and access to resources. While the monument is relatively small at 453 ha (1,120 ac) (Hubbard et al. 2012), it is embedded within the Tonto National Forest (NF) (NPS 2017a), which serves to increase the habitat available for mammals, especially those with large home ranges.

Data and Methods

To assess the condition of mammals at Tonto NM, we used one indicator, species occurrence, with a total of three measures: species presence/absence, species nativity, and species of conservation concern. The species presence/absence measure was separated into three groups—bats, small terrestrial mammals, and medium- to large-sized mammals, due to the varying degree of inventory and monitoring efforts devoted to each group at the monument.

To evaluate the condition of the presence/absence of mammals at the monument, we compared data from two inventories (Swann et al. 1996, Albrecht et al. 2007), a bat survey (Bucci et al. 2010, 2011), a 2017 camera trapping effort (NPS, unpublished data), and the NPSpecies list (NPS 2018a). NPSpecies is a database that is maintained by the NPS and relies on previously published surveys, such as those included in this assessment, and expert opinion, to provide a record of the presence or potential presence of species in National Park System units. The NPSpecies list also serves as a reference, especially to highlight potential data gaps of unconfirmed, but likely species expected to occur within National Park System units.

A mountain lion at Tonto NM. Photo Credit: NPS.

In 1994 and 1995, Swann et al. (1996) conducted an inventory of terrestrial vertebrates at the monument. This effort was based on a combination of field surveys, museum specimens, a literature review, and unpublished reports. A second mammal inventory was conducted from 2001 to 2002 using repeatable study designs and standardized field techniques (Albrecht et al. 2007). The inventory was part of a regional vascular plant and vertebrate effort that included eight Arizona and New Mexico national parks within the National Park Service's (NPS) Sonoran Desert Inventory and Monitoring Network (SODN). Concurrent with the monument's baseline inventory, a University of Arizona graduate student surveyed bats in the monument from 2001 to 2003 (Bucci et al. 2010). Lastly, SODN initiated a camera trap study in 2017 to survey for medium and large mammals in the monument (NPS, unpublished data). We separated mammals into three groups: bats, small terrestrial mammals, and medium and large mammals. Each group is described separately below.

Swann et al. (1996) did not survey for bats during their inventory, but they reviewed the literature and museum specimens to develop an initial list in addition to reporting the results of a limited bat survey conducted by Arizona Game and Fish Department (AGFD) biologists on 14 September 1993. In October 2001, Albrecht et al. (2007) mist-netted bats at three locations in Cave Canyon (one night) and searched the rooms of the Lower and Upper Cliff Dwellings for signs of roosting (one day). Following Albrecht et al. (2007), Bucci et al. (2011) surveyed the Upper and Lower Cliff Dwellings in October 2001 (two days). At both locations, Bucci et al. (2011) also recorded bat vocalizations from May to August 2001 and 2002 (eight surveys total) and mist-netted bats during the summer of 2002 and 2003 (five nights total). Nets (35 nights) and acoustic recording devices (10 nights) were also deployed at three monitoring locations in each of three habitat types (bajada, riparian, and talus slopes) in the monument (Bucci et al. 2010).

Small terrestrial mammals (e.g., squirrels, mice, rats) were trapped using Tomahawk® (Swann et al. 1996) or Sherman® (Albrecht et al. 2007) live-traps. Swann et al. (1996) trapped for small mammals in the monument's major habitat types during the spring and summer of 1994 and 1995 for a total of 5,300 trap nights. Pitfall traps were also used to survey for shrews (in addition to reptiles) for 370 trap nights (Swann et al. 1996). Albrecht et al. (2007) trapped small mammals in October 2001 and September 2002 along the Cave Canyon riparian area (290 trap nights) and in the adjacent uplands (106 trap nights). Incidental observations were also noted during both studies.

Swann et al. (1996) surveyed medium-sized (e.g., rabbits, small cats, foxes, raccoons) mammals using Tomahawk® live traps (larger than those used for small mammals) for a total of 700 trap nights during spring and summer 1994 and 1995. As with small mammals, all major habitat types were surveyed and incidental observations were noted. To survey large mammals (e.g., big cats, ungulates, bears), Swann et al. (1996) used infrared-triggered photography. The camera was operational for 500 days (24 hours) over the two years of surveys (2001-2002). Albrecht et al. (2007) did not formally survey for medium and large mammals but reported incidental observations, including scat and tracks. Finally, SODN deployed game cameras in 2017 at nine locations throughout the monument to document medium and large mammals during 2017 (Table 46) (NPS, unpublished data).

For the species nativity measure, we used the NPSpecies 'nativeness' designation to identify non-native species in the monument (NPS 2018a). We also noted observations included in Swann et al. (1996), Albrecht et al. (2007), and the 2017 camera trapping effort (NPS, unpublished data). If any non-native species was identified, it was evaluated for its impact(s) to native species, especially those of conservation concern.

Table 46. Game camera locations during 2017 in Tonto NM.

Site Name	Description
Lower Cliff Dwelling	Along the trail
Lower Cliff Dwelling	Room 9
North 40	North of Highway 188
Bosque	Slightly south of Highway 188 in mesquite bosque
Cinda's Seep	Slightly south of Highway 188 in a clearing/seep
Upper Cliff Dwelling	At the ruins
Drinker	A man-made pond near the Administrative Building
Scat Site	Along the Upper Cliff Dwelling trail
Riparian	Riparian area along Upper Cliff Dwelling trail

Source: NPS SODN, unpublished data (2017).

For the presence of species of conservation concern measure, we compared the monument's list of 'present' species to the U.S. Fish and Wildlife Service's (USFWS) federal list of endangered and threatened species that are known to occur in Arizona (USFWS 2019a). We also reviewed species listed as those of greatest conservation need in Arizona as identified in the state's Wildlife Action Plan (AGFD 2012). Under the Wildlife Action Plan, species may be listed as Tier 1A or 1B (or 1C, although we do not consider those relatively lower-priority species here). Federally listed species and candidate species, as well as those for which a signed conservation agreement exists or those that require monitoring after delisting, are included in the Tier 1A category and are considered to be of highest conservation priority (AGFD 2012). Tier 1B species are those classified as vulnerable but did not meet the criteria of Tier 1A species (AGFD 2012).

A black bear photograph taken with a game camera in Tonto NM. Photo Credit: NPS.

Reference Conditions

Reference conditions for the three measures are shown in Table 47 and are described for resources in good, moderate concern, and significant concern conditions.

Condition and Trend

Swann et al. (1996) reported six species of bat and Bucci et al. (2010) documented 13 species of bat in the monument, for a total of 16 species between the two studies (Table 48). Albrecht et al. (2007) did not capture or detect any bats during their efforts. The six species included in Swann et al. (1996) were based on museum specimens that were collected at the monument. NPSpecies lists 25 bat species for the monument, with 11 'present', 13 'probably present,' and one 'unconfirmed' species (Table 48).

Four species that were documented by Bucci et al. (2010) were not listed by NPSpecies. The four species are Arizona myotis (*Myotis occultus*), canyon bat (*Parastrellus hesperus*), Western (bonnetted) bat (*Eumops perotis*), and western small-footed myotis (*Myotis ciliolabrum*). An additional three species

Table 47. Reference conditions used to assess mammals.

Indicators	Measures	Good	Moderate Concern	Significant Concern
Species Occurrence	Species Presence /Absence	All or nearly all of the species recorded during early surveys/ observations in the monument were recorded during later surveys.	Several species recorded during early surveys were not recorded during later surveys (particularly if the species had previously been considered common at the monument).	A substantial number of species recorded during early surveys were not recorded during later surveys (particularly if the species had previously been considered common at the monument).
	Species Nativity	Non-native species are absent.	Non-native species are present but are limited by habitat type and/or do not outcompete or negatively impact native species.	Non-native species are widespread, indicating available habitat, and/or outcompete or negatively impact native species.
	Species of Conservation Concern	A moderate to substantial number of species of conservation concern occur in the monument, which indicates that the NPS unit provides important habitat for these species and contributes to their conservation.	A small number of species of conservation concern occur in the monument.	No species identified as species of conservation concern occur in the monument.

Table 48. Bats reported at Tonto NM.

Common Name	Scientific Name	Swann et al. (1996)	Bucci et al. (2010)	NPSpecies Occurrence (NPS 2018a)
Allen's Big-eared Bat	*Idionycteris phyllotis*	–	–	Probably Present
Arizona Myotis[1,2]	*Myotis occultus*	–	X	Not Listed
Big Brown Bat	*Eptesicus fuscus*	–	X	Present
Big Free-tailed Bat	*Nyctinomops macrotis*	–	X	Probably Present
Brazilian Free-tailed Bat	*Tadarida brasiliensis*	–	X	Present
California Myotis	*Myotis californicus*	–	X	Present
Californian Leaf-nosed Bat[2]	*Macrotus californicus*	–	–	Present
Canyon Bat	Parastrellus hesperus	–	X	Not Listed
Cave Myotis[2]	Myotis velifer	X	X	Present
Eastern Red Bat	*Lasiurus borealis*	–	–	Probably Present
Eastern Small-footed Myotis	*Myotis leibii*	–	–	Present
Fringed Myotis	*Myotis thysanodes*	–	–	Probably Present
Hoary Bat	*Lasiurus cinereus*	–	–	Probably Present
Lesser (Mexican) Long-nosed Bat[3]	*Leptonycteris yerbabuenae*	–	–	Unconfirmed
Little Brown Bat	*Myotis lucifugus*	–	–	Probably Present
Long-eared Myotis	*Myotis evotis*	–	–	Probably Present
Long-legged Myotis	*Myotis volans*	–	–	Probably Present
Pallid Bat	*Antrozous pallidus*	X	X	Present
Pocketed Free-tailed Bat[2]	*Nyctinomops femorosaccus*	–	X	Probably Present
Silver-haired Bat	*Lasionycteris noctivagans*	–	–	Probably Present
Southern Yellow Bat	*Lasiurus ega*	–	–	Probably Present
Southwestern Myotis	*Myotis auriculus*	–	X	Probably Present
Spotted Bat[2]	*Euderma maculatum*	–	–	Probably Present
Townsend's Big-eared Bat[2,4]	*Corynorhinus townsendii*	X	–	Present
Western (bonnetted) Bat	*Eumops perotis*	–	X	Not Listed
Western Mastiff Bat[2,5]	*Eumops perotis*	X	–	Present
Western Pipistrelle	*Pipistrellus hesperus*	X	–	Present
Western small-footed Myotis	*Myotis ciliolabrum*	–	X	Not Listed
Yuma Myotis[2]	*Myotis yumanensis*	X	X	Present

Note: X = species present.

[1] Formerly a subspecies of the little brown bat (*Myotis lucifugus occultus*).

[2] Arizona species of conservation concern Tier 1B species (AGFD 2012).

[3] Arizona species of conservation concern Tier 1A species (AGFD 2012).

[4] The subspecies *C. t. pallescens* is considered of conservation concern. It is not known if the monument supports the subspecies.

[5] The subspecies *E. p. californicus* is considered of conservation concern. It is not known if the monument supports the subspecies.

considered 'probably present' by NPSpecies were also documented by Bucci et al. (2010). These three species are the big free-tailed bat (*Nyctinomops macrotis*), pocketed free-tailed bat (*Nyctinomops femorosaccus*), and southwestern myotis (*Myotis auriculus*). Based on specimen records in the vicinity of the monument and range maps, Swann et al. (1996) listed four species that may be present, three of which have since been confirmed according to NPSpecies. In all, there could be as many as 29 species of bat in the monument. Since Bucci et al. (2010, 2011) conducted the only formal survey of bats in the monument, we could not compare species lists over time. Therefore, the condition for bats is unknown, confidence is low, and trend could not be determined.

NPSpecies lists 35 small mammal species, with 18 species considered 'present,' 16 considered 'probably present,' and one 'unconfirmed' (Table 49). Swann et al. (1996) confirmed nine small mammal species for the monument through trapping efforts (some species were also confirmed through photo vouchers, museum specimens, and/or incidental observations). Harris's antelope squirrel (*Ammospermophilus harrisii*) was not listed by NPSpecies but was confirmed by Swann et al. (1996) using a photo voucher and a museum specimen. Swann et al. (1996) also listed an additional 10 species that may occur in the monument based

Table 49. Small mammal species recorded at Tonto NM.

Order	Common Name	Scientific Name	Swann et al. (1996)	Albrecht al. (2007)	NPSpecies Occurrence (NPS 2018a)
Rodentia	Abert's Squirrel	*Sciurus aberti*	–	–	Probably Present
	Arizona Cotton Rat	*Sigmodon arizonae*	–	–	Probably Present
	Arizona Gray Squirrel[1]	*Sciurus arizonensis*	–	–	Present
	Arizona Pocket Mouse[1]	*Perognathus amplus*	–	–	Present
	Bailey's Pocket Mouse	*Chaetodipus baileyi*	X	X	Present
	Botta's Pocket Gopher	*Thomomys bottae*	–	–	Present
	Brush Mouse	*Peromyscus boylii*	–	–	Present
	Cactus Mouse	*Peromyscus eremicus*	X	X	Present
	Cliff Chipmunk	*Tamias dorsalis*	X	X	Present
	Deer Mouse	*Peromyscus maniculatus*	–	–	Present
	Desert Kangaroo Rat	*Dipodomys deserti*	–	–	Probably Present
	Desert Pocket Mouse	*Chaetodipus penicillatus*	–	–	Present
	Gray-collared Chipmunk[1]	*Tamias cinereicollis*	–	–	Probably Present
	Harris's Antelope Squirrel[1]	*Ammospermophilus harrisii*	X	–	Not Listed
	House Mouse[2]	*Mus musculus*	–	–	Present
	Least Chipmunk[1]	*Tamias minimus*	–	–	Probably Present
	Long-tailed Pocket Mouse	*Chaetodipus formosus*	–	–	Unconfirmed
	Mantled Ground Squirrel	*Spermophilus saturatus*	–	–	Probably Present
	Merriam's Kangaroo Rat	*Dipodomys merriami*	X	–	Present
	Mexican Vole[1]	*Microtus mexicanus*	–	–	Probably Present
	Mexican Woodrat	*Neotoma mexicana*	–	–	Probably Present
	Northern Grasshopper Mouse	*Onychomys leucogaster*	–	–	Probably Present
	Ord's Kangaroo Rat	*Dipodomys ordii*	–	–	Probably Present
	Red Squirrel	*Tamiasciurus hudsonicus*	–	–	Probably Present
	Rock Pocket Mouse	*Chaetodipus intermedius*	–	–	Present
	Rock Squirrel	*Spermophilus variegatus*	X	X	Present
	Round-tailed Ground Squirrel	*Spermophilus tereticaudus*	–	–	Probably Present
	Silky Pocket Mouse	*Perognathus flavus*	–	–	Probably Present
	Southern Grasshopper Mouse	*Onychomys torridus*	X	–	Present
	Stephen's Woodrat[1]	*Neotoma stephensi*	–	–	Probably Present
	Western Harvest Mouse	*Reithrodontomys megalotis*	–	–	Present
	White-footed Deermouse	*Peromyscus leucopus*	–	–	Probably Present
	White-throated Woodrat	*Neotoma albigula*	X	X	Present
	Yuma Antelope Squirrel	*Ammospermophilus harrisii*	–	–	Present
Soricomorpha	Desert Shrew	*Notiosorex crawfordi*	X	–	Present
	Merriam's Shrew	*Sorex merriami*	–	–	Probably Present

Note: X = species present.

[1] Arizona species of conservation concern Tier 1B species (AGFD 2012).

[2] Non-native species.

on range maps and sightings reported nearby the monument. All but two of the 10 species have since been confirmed according to NPSpecies. The two species that may occur in the monument but have not yet been confirmed are the Ord's kangaroo rat (*Dipodomys ordii*) and northern grasshopper mouse (*Onychomys leucogaster*).

Albrecht et al. (2007) trapped five small mammal species during 2001 and 2002, all of which were captured during the Swann et al. (1996) study. The desert shrew (*Notiosorex crawfordi*), Harris's antelope squirrel, Merriam's kangaroo rat (*Dipodomys merriami*), and southern grasshopper mouse (*Onychomys torridus*) were species confirmed by Swann et al. (1996) but not trapped or observed by Albrecht et al. (2007). Lastly, two small mammals, cliff chipmunk (*Tamias dorsalis*) and rock squirrel (*Spermophilus variegatus*), were documented via the wildlife game camera during 2017. However, game camera photos of small mammals are generally rare because this survey technique is designed for medium and large mammals.

In summary, 56% of the small mammals captured or observed during 1994 and 1995 were captured or observed during 2001 and 2002. The desert shrew was not captured during the second study, probably because pitfall traps were not deployed along with ground traps. Differences in the timing of surveys (summer vs. autumn), trapping effort (5,300 trap nights vs. 396 trap nights), and extent of habitat types surveyed (all major habitats vs. riparian and uplands), and methods used likely contributed to the fewer number of small mammal species trapped in 2001/2002. Because of these differences, we could not determine condition. Therefore, confidence is low and trend is unknown.

Swann et al. (1996) reported 17 medium and large mammal species through either photographs, incidental observations, trapping efforts, and/or museum specimens (Table 50). Albrecht et al. (2007) reported six medium and large mammals during their study, all of which were also recorded by Swann et al. (1996). However, Albrecht et al.'s (2007) list is based entirely on incidental observations.

A total of 15 medium- to large-sized mammal species were photographed with the game cameras during 2017. The American badger (*Taxidea taxus*), hog-nosed skunk (*Conepatus mesoleucus*), and desert cottontail (*Sylvilagus audubonii*) were photographed or observed by Swann et al. (1996) but not during the 2017 camera trapping effort. However, one photograph of a cottontail rabbit (*Sylvilagus* spp.) recorded in 2017 could not be identified to species. Among the most commonly photographed species during 2017 were the collared peccary (*Pecari tajacu*), gray fox (*Urocyon cinereoargenteus*), and white-tailed deer (*Odocoileus virginianus*). NPSpecies listed 35 species of medium and large mammal. Of these, 23 are considered 'present,' seven are considered 'probably present,' and five are 'unconfirmed.'

In summary, these results indicate good condition for medium and large mammals in the monument since 82% of species reported in 1994-1995 were reported in 2017 (excluding the rabbit). Confidence in the condition rating is medium because of differences in methods between the two studies. Trend could not be determined.

Three non-native species have been reported for the monument. The three species are the house mouse (*Mus musculus*), feral cat (*Felis catus*), and donkey (*Equus asinus*). No non-native mammals were reported by Albrecht et al. (2007) nor were any non-native mammals recorded during the 2017 camera trap study. Swann et al. (1996), however, reported a feral cat during their study.

According to NPSpecies, donkeys (or wild burros) are confined to the Wild Burro Management Territory located north of Saguaro Lake, which is roughly 32 km (20 mi) west of the monument (NPS 2018a). Despite the NPSpecies note that this species is confined to the management area, NPSpecies also lists donkeys as breeding in the monument (NPS 2018a). While there are no studies of the ecological effects of wild burros in the Salt River ecosystem, a review of wild horses (*Equus caballus*) suggests that equids may be more destructive to semi-arid ecosystems than other non-native ungulates (e.g., cattle) because horses, burros, and mules are less selective foragers, consume more forage overall, and roam over larger and more heterogenous landscapes than cattle (Beever 2003). This results in impacts to both natural and cultural resources. Prior to their removal in the 1970s, for example, feral burros in Grand Canyon National Park were thought to have threatened native bighorn sheep by competing with them for forage (Stortz et al. 2018). Other studies documented the impacts to small

Table 50. Medium and large mammal species recorded at Tonto NM.

Order	Common Name	Scientific Name	Swann et al. (1996)	Albrecht et al. (2007)	SODN Camera Trap Study (2017)	NPSpecies Occurrence (NPS 2018a)
Artiodactyla	Bighorn Sheep	*Ovis canadensis*	–	–	–	Present
	Collared Peccary	*Pecari tajacu*	X	X	X	Present
	Mule Deer	*Odocoileus hemionus*	X	X	X	Present
	Pronghorn	*Antilocapra americana*	–	–	–	Probably Present
	White-tailed Deer	*Odocoileus virginianus*	X	X	X	Present
Carnivora	American Badger	*Taxidea taxus*	X	–	–	Present
	American Black Bear	*Ursus americanus*	–	–	X	Present
	Bobcat	*Lynx rufus*	X	–	X	Present
	Coyote	*Canis latrans*	X	–	X	Present
	Feral cat[1]	*Felis catus*	X	–	–	Present
	Gray Fox	*Urocyon cinereoargenteus*	X	X	X	Present
	Gray Wolf	*Canis lupus*	–	–	–	Unconfirmed
	Grizzly Bear	*Ursus arctos*	–	–	–	Unconfirmed
	Hog-nosed Skunk	*Conepatus mesoleucus*	X	–	–	Present
	Hooded Skunk	*Mephitis macroura*	X	–	X	Present
	Jaguar[2,4]	*Panthera onca*	–	–	–	Unconfirmed
	Kit Fox[3]	*Vulpes macrotis*	–	–	–	Present
	Long-tailed Weasel	*Mustela frenata*	–	–	–	Probably Present
	Mountain Lion	*Puma concolor*	X	–	X	Present
	North American River Otter	*Lontra canadensis*	–	–	–	Unconfirmed
	Ocelot[2,4]	*Leopardus pardalis*	–	–	–	Unconfirmed
	Raccoon	*Procyon lotor*	X	–	X	Present
	Ringtail	*Bassariscus astutus*	X	X	X	Present
	South American Coati	*Nasua nasua*	–	–	–	Probably Present
	Spotted Skunk	*Spilogale putorius*	X	–	X	Present
	Striped Skunk	*Mephitis mephitis*	X	–	X	Present
	White-nosed Coati	*Nasua narica*	–	–	X	Present
Lagomorpha	Antelope Jackrabbit[3]	*Lepus alleni*	–	–	–	Probably Present
	Black-tailed Jackrabbit	*Lepus californicus*	X	–	X	Present
	Desert Cottontail	*Sylvilagus audubonii*	X	X	–	Present
	Eastern Cottontail	*Sylvilagus floridanus*	–	–	–	Present
Perissodactyla	Donkey[1]	*Equus asinus*	–	–	–	Present
Rodentia	American Beaver[3]	*Castor canadensis*	–	–	–	Probably Present
	Muskrat	*Ondatra zibethicus*	–	–	–	Probably Present
	Porcupine	*Erethizon dorsatum*	–	–	–	Probably Present

Note: X = species present.

[1] Non-native species.

[2] Arizona species of conservation concern Tier 1A species (AGFD 2012).

[3] Arizona species of conservation concern Tier 1B species (AGFD 2012).

[4] U.S. Fish and Wildlife endangered species (2019a).

mammals; noted accelerated erosion and damaged soil crusts; changes to riparian vegetation; and the create of trails that often misled visitors (Stortz et al. 2018).

As with donkeys, there are no studies of how domestic cats or house mice have specifically affected the monument's wildlife. However, their presence in other areas has caused substantial disturbance to native species. Throughout the U.S., free-ranging domestic cats may be responsible for more than one billion bird deaths each year (Loss et al. 2013). For small mammals, the predation rate from domestic cats is much higher, ranging between 6.3 and 22.3 billion deaths annually (Loss et al. 2013). There are few studies that address the effects of house mice on native mammal populations, but the studies available show that mice transmit disease (Wittmer and Pitt 2012), alter trophic interactions (Strong and Leroux 2014). While information on the influence of house mice on native mammals is limited (Doherty et al. 2016), their tendency to occupy developed areas and agricultural fields may reduce their influence on native species in the monument due to its largely wilderness setting and modest human footprint. For these reasons, the condition of non-native species is of moderate concern but confidence is low since there are no monument-specific studies. There were no data to evaluate trend.

The Arizona State Wildlife Action Plan (AGFD 2012) lists a total of 19 Tier 1A and Tier 1B species that are known to occur, are suspected to occur, or that historically occurred in the monument (Table 51). These include one Tier 1A and six Tier 1B bat species. The lesser (Mexican) long-nosed bat (*Leptonycteris yerbabuenae*), a Tier 1A species, has not been confirmed at the monument according to NPSpecies. The Arizona myotis, a Tier 1B species, was not listed by NPSpecies but was detected by Bucci et al. (2011). The pocketed free-tailed bat and the spotted bat (*Euderma maculatum*), Tier 1B species, are listed as 'probably present' by NPSpecies, with the former species documented by Bucci et al. (2011). In addition, the plan lists two subspecies that may also occur in the monument, but this could not be confirmed since they were listed at the species level in NPSpecies. These two subspecies are the pale Townsend's big-eared bat (*Corynorhinus townsendii pallescens*) and the greater western mastiff bat (*Eumops perotis californicus*).

Table 51. Species of conservation concern known to occur in Tonto NM.

Status	Group	Species
1A[1]	Bats (1)	Lesser (Mexican) long-nosed bat
	Large Mammals (2)	Jaguar, Ocelot
1B[2]	Bats (6)	Arizona myotis, California leaf-nosed bat, Cave myotis, Pocketed free-tailed bat, Spotted bat, Yuma myotis
	Small Terrestrial Mammals (7)	Arizona gray squirrel, Arizona pocket mouse, Gray-collared chipmunk, Harris's antelope squirrel, Least chipmunk, Mexican vole, Stephen's woodrat
	Medium Mammals (3)	American beaver, Antelope jackrabbit, Kit fox

[1] Tier 1A = species of highest conservation priority because they are either those listed as federally threatened or endangered; are candidate species for federal listing; those with a signed conservation agreement; and/or those that require monitoring after delisting (AGFD 2012).

[2] Tier 1B = species classified as vulnerable but do not meet the criteria of Tier 1A species (AGFD 2012).

Seven small mammal species were listed as Tier 1B species, four of which are considered 'probably present' by NPSpecies. These are the gray-collared chipmunk (*Tamias cinereicollis*), least chipmunk (*Tamias minimus*), Mexican vole (*Microtus mexicanus*), and Stephen's woodrat (*Neotoma stephensi*). The Harris's antelope squirrel was not listed by NPSpecies but was confirmed by Swann et al. (1996). Three medium-sized mammals were listed as Tier 1B, two of which are considered 'probably present.' These are the American beaver (*Castor canadensis*) and antelope jackrabbit (*Lepus alleni*). Lastly, two large mammals were listed as Tier 1A due to their federally endangered status (USFWS 2019a). The two endangered species are the ocelot (*Leopardus pardalis*) and jaguar (*Panthera onca*), both of which have been extirpated from the monument and surrounding national forest.

Overall, only eight of the 19 Tier 1A and 1B species listed by the state wildlife action plan are considered present at the monument by NPSpecies or by one of the studies included in this assessment. However, species of concern are often rare, and rare species can be difficult to detect, especially without surveys that specifically target them. Tonto NF considers many of these species of concern to be rare in the forest (USFS, no date). Given that there are at least eight and as many as 16 species of concern in the monument, these results indicate good condition. Confidence in the condition rating is low because there are no recent studies of mammals in the monument nor are there studies that specifically address species of conservation concern.

Overall Condition, Threats, and Data Gaps

To assess the condition of mammals at Tonto NM, we used one indicator with three measures, which are summarized in Table 52. There were few data with which to compare presence/absence over time. For small terrestrial mammals and bats, this resulted in an unknown condition rating. The most recent survey for small mammals, including bats, occurred in 2001-2003. Medium-sized mammals were last trapped in 1994 and 1995, but were surveyed in 2017 using game cameras, as were large mammals. While both studies used game cameras, the earlier study also trapped medium-sized mammals, making direct comparisons difficult. Despite these differences, 86% of medium and large mammals observed in 1994-1995 were observed in 2017, resulting in a good condition rating. The presence of three non-native species warrants concern, but their effects on the monument's mammals are unknown. While the inventories included in this assessment and the NPSpecies list suggest that the monument supports a relatively large number of species of concern, their current status is unknown. As a result, the overall condition rating for mammals at Tonto NM is unknown to good, with an unknown trend.

Table 52. Summary of mammal indicators, measures, and condition rationale.

Indicators	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Species Occurrence	Species Presence / Absence	Bats/Small Mammals Medium/Large Mammals	Sixteen species of bat were reported between the two studies, but these efforts could not be compared because the earlier study was based on museum specimens and previous reports. Four of these species were not included in NPSpecies, which lists 25 bat species for the monument. A total of 56% of the small terrestrial mammals captured or observed during 1994 and 1995 were captured or observed during 2001 and 2002. Differences in the timing of surveys (summer vs. autumn), trapping effort (5,300 trap nights vs. 396 trap nights), and extent of habitat types surveyed (all major habitats vs. riparian and uplands) make comparisons between these two studies difficult. Fourteen of 17 species (82%) of medium and large mammals reported during 1994-1995 were reported during 2017. Confidence in the condition rating is medium because of differences in methods and timing between the two studies. Trend could not be determined.
	Species Nativity		Three non-native mammals have been documented at the park (house mouse, feral cat, and donkey). Although no studies of the influence of these species on the monument's native mammal community are available, their impact to native fauna elsewhere is well documented. Because of the uncertainty regarding monument-specific effects, the confidence is low. There are no data to evaluate trends. As a result, we consider this measure to be of moderate concern with an unknown trend and medium confidence in the current condition rating.
	Species of Conservation Concern		Eight Tier 1A and 1B species are present at the monument, although an additional 11 Tier 1A and 1B species are included in NPSpecies as unconfirmed, probably present, or are historical observations (e.g., ocelot and jaguar). These results indicate good condition, but confidence in the condition rating is low because there are no recent studies of mammals in the monument nor are there studies that specifically address species of conservation concern.
Overall Condition	Summary of All Measures		While the monument appears to support a high diversity of small mammals and bats, we could not compare presence/absence over time. For medium and large mammals, most have been observed recently. The presence of three non-native species warrants concern, but their effects on the monument's mammals are unknown. While the inventories included in this assessment and the NPSpecies list suggest that the monument supports a relatively large number of species of concern, the current status of these species is unknown. As a result, the overall condition rating for mammals is unknown to good, with an unknown trend and low confidence in the condition rating.

Most native mammals are susceptible to human development, harassment, habitat loss, poor water quality, and human-influenced mortality. Medium-to large-sized mammals are more prone to stressors related to an accumulation of human activity because their home ranges most likely extend beyond the monument's boundary. Due to the limited distance of small mammals' home ranges, which most likely confines this group of mammals, managers have greater control of eliminating stressors that originate from within the monument. Currently, there are few threats to mammals that originate within Tonto NM, but potential threats include human-wildlife encounters, habitat fragmentation, vehicular mortality along roadways, disease, and possibly poaching. Although there have not been any confirmed instances of poaching in the monument, staff have found spent shotgun shells within its boundaries (NPS, B. Cockrell, Chief of Resources, NRCA scoping meeting, 10 May 2018).

Although not currently present in Arizona, white-nose syndrome—a fungus (*Pseudogymnoascus destructans*) that causes behavioral changes in bats, ultimately leading to their death—is a potential threat to the monument's diverse bat community (USFWS 2019b). The fungus was discovered in 2006 in Albany, New York and has since spread rapidly across the U.S. (USFWS 2019b). White-nose syndrome has affected bats as far west as north-central Texas and southwestern Wyoming, but there is also a pocket of bats infected with white-nose syndrome in eastern Washington state (USFWS 2019b). Restricted access to roost sites may help reduce the risk of this disease occurring in the monument.

Disease is also a threat to bighorn sheep (*Ovis canadensis*). Ovine pneumonia, caused by the pathogens *Pasteurella* spp. and *Mannheimia ovipeumoniae*, and pinkeye caused by *Mycoplasma* spp., are diseases that were introduced to wild sheep through domestic sheep at the turn of the 20th century (Jansen et al. 2007, Besser et al. 2013). These diseases can be transmitted between groups that range together, even with no physical contact between infected animals and healthy wild sheep (Jansen et al. 2007, Besser et al. 2013). Disease, along with over-harvesting at the turn of the 20th century and current barriers to movement, have led to declines in bighorn sheep throughout their range (Beier et al. 2006). Wildlife agencies in Arizona and other western states have been reintroducing sheep since the 1920s in an effort to restore wild populations to their former ranges (Wild Sheep Working Group 2015). Today, all bighorn sheep occurring in and around Tonto NM are the result of the AGFD reintroduction and management efforts (USFS 2018).

Most bighorn sheep in Tonto NF are located in wilderness areas, including the Superstition Wilderness south of the monument, which supports the desert subspecies (*O. c. nelsoni*), and the Four Peaks Wilderness west and north of the monument, which supports the Rocky Mountain subspecies (*O. c. canadensis*) (USFS 2018). In the Superstition Mountains, 157 individuals were released from 1983 to 1995 (AGFD 2019). Nineteen years later, the population was considered established by AGFD (AGFD 2019). Since becoming established, sheep from the Tonto NF have been translocated to establish other populations in Arizona (Wild Sheep Working Group 2015). Although the monument is not within the current distribution of bighorn sheep, the steep topography and plant community that occurs there is suitable for this species.

Slopes in the monument range up to 90% (KellerLynn 2006), and bighorn sheep prefer slopes >80% while avoiding slopes <40% (Beier et al. 2006). The monument's elevation range (695-1,219 m [2,280-4,000 ft] also includes that preferred by bighorn sheep (0-3,660 m [0-12,000 ft]) (Beier et al. 2006). Furthermore, the desert subspecies of bighorn sheep (*O. c. nelsoni*) prefer mesquite (*Prosopis* spp.), paloverde (*Parkinsonia* spp.), catclaw acacia (*Senegalia greggii*), and bush muhly (*Muhlenbergia porteri*), which all occur in the monument (Beier et al. 2006, Studd et al. 2017). And Cave Spring provides a perennial source of water in addition to water gained from food sources such as Saguaro fruits (*Carnegia gigantea*), prickly pear (*Opuntia* spp.), cholla (*Opuntia* spp.), and agave (*Agave* spp.) (Beier et al. 2006).

Most of the monument is contained within the Sierra Ancha-Superstition Mountains potential linkage zone, and 97% of this zone is USFS lands with 2% allocated to the NPS (AWLW 2006). The remaining 1% is private. Mammals included as potentially benefitting from this linkage zone are bighorn sheep, black bear (*Ursus americanus*), bobcat (*Lynx rufus*), California leaf-nosed bat (*Macrotus californicus*), cave myotis (*Myotis velifer*), collared peccary, pocketed free-tailed bat, mountain lion (*Puma concolor*), and white-tailed deer (AWLW 2006). With the exception of bighorn sheep and California leaf-nosed bat, all of the mammals included in this linkage zone have been documented by at least one of the studies in this assessment. According to HabiMap™ Arizona, a tool developed by AGFD to display spatial data described in the State Wildlife Action Plan, wild sheep in the Superstition Wilderness are connected to the Sierra Ancha-Superstition Mountains potential linkage zone as are small pockets of sheep found in the Four Peaks Wilderness Area (AGDF 2015). Thus, there is potential for wild sheep to disperse into Tonto NM through this wildlife corridor.

The Sierra Ancha-Superstition Mountains potential linkage zone was mapped in 2004, when a group of concerned land managers and biologists from federal, state, and regional agencies, along with researchers from Northern Arizona University, formed the Arizona Wildlife Linkages Workgroup (AWLW). The workgroup identified critical areas that would help preserve Arizona's diverse natural resources in the midst of the state's rapid population growth. They identified and mapped large areas of protected habitat (i.e., habitat blocks) and the potential linkages (i.e., matrix) between these protected areas. This effort became known as the Arizona Missing Linkages project, identifying 152 statewide coarse-level linkage zones (Beier et al. 2007).

The US-60 from Superior to Globe linkage, which includes Tonto NM, was one of the first priority areas identified for further evaluation (Beier et al. 2006). Connectivity in this area is threatened by the realignment of U.S. Highway 60, mining, and urban development (Beier et al. 2006). Many species are reluctant to or do not cross roads or pass through developments. Furthermore, the road corridor itself represents a loss of habitat that extends beyond just the paved surface. Lighting along roads, noise, and vibrations all contribute to the area over which roads may influence wildlife behavior (Beier et al. 2006). Identifying and protecting high quality habitat is critical for continuing to protect species survival needs.

Within the last 100 years, four species that have likely occurred at Tonto NM (in addition to bighorn sheep) have been extirpated from the monument. These species are grizzly bear (*Ursus arctos*), Mexican gray wolf (*Canis lupus baileyi*), ocelot, and jaguar (NPS 2018a). The current range of the Mexican gray wolf is just 80 km (50 mi) north of the monument (USFWS 2019c). The current range of the ocelot extends north from Mexico along a narrow band that terminates at the southern end of Theodore Roosevelt Lake just outside the monument (USFWS 2019d). Given the close proximity of the monument to the ocelot's current range, this species could pass through the monument in the future, especially since the monument is located within a potential wildlife corridor. In contrast, the current range of the jaguar is restricted to the southern Arizona to just north of Tucson (USFWS 2019e). Maintaining ecosystem connectivity, however, may allow for range expansion of this species.

Despite these losses, Tonto NM supports just over half (51%) of all mammal species that occur in the Tonto NF yet the monument is 0.04% the size of the forest. the Tonto NF checklist of mammals includes 92 species, 47 of which are listed by NPSpecies as 'present' or were confirmed by one of the studies included in this assessment. This suggests remarkable mammalian diversity for the monument. The monument's diversity is attributed in part to the surrounding national forest and preservation of native habitat types within the monument.

With continued camera trap monitoring for medium- and larger-sized mammals and an excellent baseline inventory of small mammals, periodic sampling of "indicator" species within each habitat type may assist managers and scientists develop status and trends of the mammal community at and around the monument over time. Unfortunately, small mammals can also be a nuisance to the cultural resources at the monument by burrowing in the ground impacting archeological resources and roosting (bats) in the cliff dwellings (NPS 2017a).

Sources of Expertise

This assessment was written by science writer and wildlife biologist, Lisa Baril, Utah State University. Subject matter expert reviewers for this assessment are listed in Appendix A.

Herpetofauna

Background and Importance

Herpetofauna inhabit aquatic and terrestrial habitats worldwide and are an important part of the global food web. Reptiles (e.g., snakes, lizards, turtles, and tortoises) and amphibians (e.g., frogs, toads, salamanders, and newts) serve as prey for many animals, including mammals, birds, and other herpetofauna. Reptiles are important consumers of arthropods and small vertebrates; some of these prey species are considered agricultural or industrial pests (e.g., rodents; NPS 2015b). Amphibians are sensitive to a variety of threats due to their permeable skin and complex life histories. As a result, they can serve as early indicators of wetland ecosystem health and environmental change when monitored over time. And because reptiles are only active within a narrow range of temperatures, they can serve as indicators of climate change (NPS 2015b).

The Sonoran Desert supports approximately 100 reptile and at least 20 amphibian species (NPS 2015b). Although small in size relative to many NPS units, Tonto National Monument (NM) is located at the intersection of the Sonoran Desert and Apache Highlands ecoregions, providing varied habitats in which many reptile and amphibian species depend. Steep elevation with slopes ranging from 2% to 90% (KellerLynn 2006) support a variety of plant associations broadly described as Sonoran desert scrub and semi-desert grasslands with small pockets of interior chaparral (Studd et al. 2017). While water is limited in the monument, the perennial flowing Cave Spring supports a narrow band of riparian deciduous woodlands and riparian scrub communities (Studd et al. 2017). Various soils and rock types also allow for a variety of microhabitats that are important to ectotherms in regulating body temperature.

Unfortunately, reptiles and amphibians have experienced declines worldwide owing to loss of wetlands, urban development, fragmentation, disease, and other factors (NPS 2015b). Because of these declines, the importance of protected areas such as Tonto NM have increased (NPS 2015b). Although protected areas have grown in importance for many wildlife species, they are also vulnerable to outside influences, such as climate change and invasive species encroachment (NPS 2015b).

Data and Methods

To assess the condition of herpetofauna at Tonto NM, we used two indicators (species occurrence and Arizona black rattlesnake [*Crotalus cerberus*]), with two measures each. The two species occurrence measures are presence/absence and the presence/ absence of species of conservation/management

A lizard in Tonto NM. Photo Credit: NPS.

concern. The two measures of the Arizona black rattlesnake indicator are persistence and habitat availability. Each of the monument's herpetofauna surveys used to evaluate condition of these measures are described below.

The presence/absence measure was evaluated using two inventories and one pilot study that tested the efficacy of using camera traps to survey reptiles. The first was an inventory of terrestrial invertebrates conducted in the monument from 1993 to 1995 (Swann et al. 1996). This effort was based on a combination of field surveys, research of museum specimens, a literature review, and unpublished reports. Field surveys included 30 hours of time-constrained search and cover-turning for lizards and snakes, road cruising for nocturnal snakes (54 hours), searches during and after summer rains for toads (15 hours), pitfall trapping for fossorial lizards and snakes (370 trap-nights), and incidental observations (Swann et al. 1996).

The second herpetofauna inventory was conducted from 2001 to 2002 using visual encounter surveys that were not constrained by area or time (Albrecht et al. 2007). This inventory was part of a regional vascular plant and vertebrate effort that included eight Arizona and New Mexico national parks within the National Park Service's (NPS) Sonoran Desert Inventory and Monitoring Network (SODN). In this survey, two observers searched the Cave Spring riparian area on two days in September 2001 and one day in July 2002. In 2002, observers also searched the area between the Visitor Center and the Lower Cliff Dwelling, as well as a small area of the monument located north of Route 188 that supports a small pond in some years (Albrecht et al. 2007). Incidental observations were also noted.

Lastly, SODN initiated a pilot study in 2017 to determine the efficacy of using passively-triggered remote cameras to monitor herpetofauna (NPS, unpublished data). An array of three cameras were co-located with SODN's upland vegetation monitoring plots (see Hubbard et al. 2013 for locations). Cameras were setup from mid-May to mid-October, which includes the peak monsoon season when herpetofauna are most active (NPS, unpublished data).

We compared and contrasted the species documented between these various survey efforts to evaluate the presence/absence of herpetofauna over time. We also reviewed the monument's herpetofauna NPSpecies list (NPS 2018a). NPSpecies is an online database maintained by the NPS. Credible species sightings and/or vouchers are added to each park's species list through a rigorous quality control/quality assurance procedure, with the goal of maintaining valid species accounts. The NPSpecies list served as a reference, especially to highlight potential data gaps of unconfirmed but probable species that are expected to occur at the monument. Scientific names were updated to reflect current taxonomy according to the 8th (2017) edition checklist produced by the Society for the Study of Amphibians and Reptiles (SSAR) (SSAR 2019).

For the species of conservation and management concern measure, we compared the monument's list of 'present' species to the U.S. Fish and Wildlife Service's (USFWS) federal list of endangered and threatened species that are known to occur in Arizona (USFWS 2019a). We also reviewed species listed as those of greatest conservation need in Arizona as identified in the state's Wildlife Action Plan (Arizona Game and Fish Department [AGFD] 2012). Under the Wildlife Action Plan, species may be listed as Tier 1A or 1B (or 1C, although we do not consider those relatively lower-priority species here). Federally listed species and candidate species, as well as those for which a signed conservation agreement exists or those that require monitoring after delisting, are included in the Tier 1A category and are considered to be of highest conservation priority (AGFD 2012). Tier 1B species are those classified as vulnerable but did not meet the criteria of Tier 1A species (AGFD 2012).

The Arizona black rattlesnake was recognized as a distinct species in the early 2000s (formerly *C. viridis [oreganus] cerberus*). This species is restricted to Arizona and extreme western New Mexico (Nowak 2009). Habitat includes chaparral, desert scrub, and pine-oak woodlands (van Riper et al. 2014). Although this species is of conservation and management concern at Tonto NM, it was separated out from that measure because of its particular importance to managers at the monument as discussed during the scoping meeting (NPS, B. Cockrell, Chief of Resources, NRCA scoping meeting, 10 May 2018).

In addition to information provided in Swann et al. (1996) and Albrecht et al. (2007), we relied on a 2002–2007 study of the habitat associations, diet, and temporal and spatial ecology of the Arizona

An Arizona black rattlesnake. Photo Credit: NPS.

black rattlesnake (and other venomous reptiles) in Tonto NM (Nowak 2009). Together these studies provided a 14-year period over which we could determine persistence. Swann et al. (1996) also noted reliable earlier observations and the monument's website offered more recent observations through photographs.

Finally, Nowak (2009) described the habitat characteristics, including slope, aspect, and plant community types, that Arizona black rattlesnakes were most often associated with in Tonto NM. This description was based on radio tagging and tracking individual snakes in the monument from 2004 to 2007. We used this information to develop a Tonto NM potential habitat map for this species. Using the 2008 NPS plant inventory and mapping data (Studd et al. 2017), we extracted the plant communities that were described by Nowak (2009) as rattlesnake habitat. Although Nowak (2009) reports slope and aspect data for this species, the scale of the digital elevation model available for the monument was 10 m (32.8 ft), which was too coarse to accurately map habitat based on these characteristics. Therefore, we only used plant associations to map habitat and describe other characteristics reported by Nowak (2009).

Reference Conditions

Table 53 shows the reference conditions used to evaluate the four measures of herpetofauna in the monument and are described for resources in good, moderate concern, and significant concern conditions.

Condition and Trend

NPSpecies lists 77 amphibians (Table 54) and reptiles (Table 55), of which 41 are considered 'present,' 10 are considered 'probably present,' 17 are 'unconfirmed,'

Table 53. Reference conditions used to assess herpetofauna.

Indicators	Measures	Good	Moderate Concern	Significant Concern
Species Occurrence	Presence/Absence	All or nearly all of the species recorded during early surveys/ observations in the monument were recorded during later surveys.	Several species recorded during early surveys were not recorded during later surveys (particularly if the species had previously been considered common at the monument).	A substantial number of species recorded during early surveys were not recorded during later surveys (particularly if the species had previously been considered common at the monument).
	Species of Conservation/ Management Concern	A moderate to substantial number of species of conservation concern occur in the monument, which indicates that the NPS unit provides important habitat for these species and contributes to their conservation.	A small number of species of conservation concern occur in the monument.	No species identified as species of conservation concern occur in the monument.
Arizona Black Rattlesnake	Persistence	Rattlesnakes have been consistently observed during all or most of the observation/ monitoring efforts in the monument.	Rattlesnakes have been observed during most monitoring efforts, but appear to be less common in more recent monitoring efforts.	Rattlesnakes were observed during earlier efforts, but have not been observed during more recent efforts.
	Habitat Availability	No reference conditions were developed for this measure.	No reference conditions were developed for this measure.	No reference conditions were developed for this measure.

Table 54. Amphibian species at Tonto NM.

Group	Common Name	Scientific Name	Swann et al. (1996)	Albrecht et al. (2007)	2017 Camera Trap Study	NPSpecies Occurrence
Frogs and Toads	American bullfrog[1]	*Lithobates catesbeiana*	–	–	–	Historical
	Arizona toad	*Anaxyrus microscaphus*	–	–	–	Present
	Arizona treefrog	*Hyla wrightorum*	–	–	–	Unconfirmed
	Canyon treefrog	*Hyla arenicolor*	X	–	–	Present
	Chiricahua leopard frog[2]	*Lithobates chiricahuensis*	–	–	–	Unconfirmed
	Couch's spadefoot	*Scaphiopus couchii*	X	–	–	Present
	Great plains toad	*Anaxyrus cognatus*	X	–	–	Present
	Lowland leopard frog[2]	*Lithobates yavapaiensis*	–	–	–	Probably Present
	Mexican spadefoot toad	*Spea multiplicata*	–	–	–	Historical
	Northern leopard frog[2]	*Lithobates pipiens*	–	–	–	Unconfirmed
	Red-spotted toad	*Anaxyrus punctatus*	X	–	–	Present
	Sonoran Desert toad[3]	*Incilius alvarius*	X	–	–	Present
	Western chorus frog	*Pseudacris triseriata*	–	–	–	Unconfirmed
	Woodhouse's toad	*Anaxyrus woodhousii*	X	X	–	Present
Salamanders	Eastern tiger salamander	*Ambystoma tigrinum*	–	–	–	Probably Present

Note: X = species present.

[1] Non-native species.

[2] Tier 1A = species of highest conservation priority because they are either those listed as federally threatened or endangered; are candidate species for federal listing; those with a signed conservation agreement; and/or those that require monitoring after delisting (AGFD 2012).

[3] Tier 1B = species classified as vulnerable but do not meet the criteria of Tier 1A species (AGFD 2012).

and nine are 'historical' observations. One non-native amphibian (American bullfrog [*Lithobates catesbeiana*]) and one non-native reptile (Spiny softshell [*Apalone spinifera*]) have been reported for the monument. However, the American bullfrog is listed as a historical observation and is no longer considered present.

The Arizona black rattlesnake was not listed by NPSpecies, but the former species (western rattlesnake [*C. oreganus*]) was listed. We replaced western rattlesnake with the Arizona black rattlesnake in Table 55. Of the three surveys used for comparison, Swann et al. (1996) documented the most species (38), while Albrecht et al. (2007) documented 18 species, and camera traps recorded seven species, although for this latter survey we could only identify five of the seven species based on photographs provided by SODN (NPS, unpublished data). The Gila monster (*Heloderma suspectum)*, side-blotched lizard (*Uta stansburiana*), Sonoran whipsnake (*Masticophis bilineatus*), Texas greater earless lizard (*Cophosaurus texanus*), and western diamondback rattlesnake (*Crotalus atrox*) were the five species documented during all three efforts.

During the 1993-1995 surveys, the red-spotted toad (*Bufo puntatus*), canyon treefrog (*Hyla arenicolor*), western banded gecko (*Coleonyx variegatus*), tiger whiptail (*Aspidoscelis tigris*), Texas greater earless lizard, Clark's spiny lizard (*Sceloporus clarkii*), ornate tree lizard (*Urosaurus ornatus*), side-blotched lizard (*Uta stansburiana*), Sonoran whipsnake, and western diamondback rattlesnake were some of the most commonly encountered species (Swann et al. 1996). During the 2001-2002 bioinventory, the most common species were the side-blotched lizard, ornate tree lizard, and western whiptail (Albrecht et al. 2007). Relative abundance could not be determined using game camera data. Furthermore, equipment failures and technician errors reduced the number of cameras recording images during this pilot survey (NPS, unpublished data).

The nine 'historical' species were listed by Swann et al. (1996) as those that have been reported for the

Table 55. Reptile species at Tonto NM.

Group	Common Name	Scientific Name	Swann et al. (1996)	Albrecht et al. (2007)	2017 Camera Trap Study	NPSpecies Occurrence
Lizards	Arizona alligator lizard	*Elgaria kingii*	X	X	–	Present
	Clark's spiny lizard	*Sceloporus clarkii*	X	–	–	Present
	Common chuckwalla	*Sauromalus ater*	–	–	–	Unconfirmed
	Common lesser earless lizard	*Holbrookia maculata*	–	–	–	Historical
	Common side-blotched lizard	*Uta stansburiana*	X	X	X	Present
	Desert grassland whiptail	*Aspidoscelis uniparens*	–	–	–	Probably Present
	Desert iguana	*Dipsosaurus dorsalis*	–	–	–	Unconfirmed
	Desert night lizard	*Xantusia vigilis*	X	–	–	Present
	Desert spiny lizard	*Sceloporus magister*	X	X	–	Present
	Eastern collared lizard	*Crotaphytus collaris*	X	–	–	Present
	Gila monster[1]	*Heloderma suspectum*	X	X	X	Present
	Gila spotted whiptail[2]	*Aspidoscelis flagellicauda*	X	–	–	Present
	Great plains skink	*Plestiodon obsoletus*	X	–	–	Present
	Greater short-horned Lizard	*Phrynosoma hernandesi*	–	–	–	Unconfirmed
	Little striped whiptail	*Aspidoscelis inornata*	–	–	–	Unconfirmed
	Long-nosed leopard lizard	*Gambelia wislizenii*	–	–	–	Present
	Long-tailed brush lizard	*Urosaurus graciosus*	–	–	–	Unconfirmed
	Many-lined skink	*Plestiodon multivirgatus*	–	–	–	Unconfirmed
	Ornate tree lizard	*Urosaurus ornatus*	X	X	–	Present
	Plateau fence lizard	*Sceloporus tristichus*	–	–	–	Unconfirmed
	Plateau striped whiptail	*Aspidoscelis velox*	–	–	–	Probably Present
	Regal horned lizard[2]	*Phrynosoma solare*	X	–	–	Present
	Sonoran spotted whiptail	*Aspidoscelis sonorae*	X	X	–	Present
	Texas greater earless lizard	*Cophosaurus texanus*	X	X	X	Present
	Tiger whiptail	*Aspidoscelis tigris*	X	X	–	Present
	Western banded gecko	*Coleonyx variegatus*	X	X	–	Present
	Zebra-tailed lizard	*Callisaurus draconoides*	X	X	–	Present
Snakes	Arizona black rattlesnake[2,3]	*Crotalus cerberus*	–	–	–	Present
	Arizona mountain kingsnake	*Lampropeltis pyromelana*	–	–	–	Probably Present
	Black-necked gartersnake	*Thamnophis cyrtopsis*	X	–	–	Present
	California kingsnake	*Lampropeltis californiae*	X	X	–	Present
	Checkered gartersnake	*Thamnophis marcianus*	–	–	–	Probably Present
	Coachwhip	*Coluber flagellum*	X	–	–	Present
	Desert nightsnake	*Hypsiglena chlorophaea (formerly torquata)*	X	–	–	Present
	Eastern patch-nosed snake	*Salvadora grahamiae*	–	–	–	Historical

Note: X = species present.

[1] Tier 1A = species of highest conservation priority because they are either those listed as federally threatened or endangered; are candidate species for federal listing; those with a signed conservation agreement; and/or those that require monitoring after delisting (AGFD 2012).

[2] Tier 1B = species classified as vulnerable but do not meet the criteria of Tier 1A species (AGFD 2012).

[3] Arizona black rattlesnake (*C. cereberus*) was split *C. oreganus,* which does not occur in the monument but is listed by NPSpecies and earlier reports. Due to the change, we removed *C. oreganus* from this table.

[4] Federally threatened (USFWS 2019a).

[5] Non-native species.

Table 55 continued. Reptile species at Tonto NM.

Group	Common Name	Scientific Name	Swann et al. (1996)	Albrecht et al. (2007)	2017 Camera Trap Study	NPSpecies Occurrence
Snakes *continued*	Glossy snake	*Arizona elegans*	–	–	–	Historical
	Gophersnake	*Pituophis catenifer*	X	X	–	Present
	Long-nosed snake	*Rhinocheilus lecontei*	X	–	–	Present
	Mexican gartersnake[1,4]	*Thamnophis eques*	–	–	–	Unconfirmed
	Mojave rattlesnake	*Crotalus scutulatus*	–	–	–	Historical
	Narrow-headed garter snake[1,4]	*Thamnophis rufipunctatus*	–	–	–	Unconfirmed
	Plains black-headed snake	*Tantilla nigriceps*	–	–	–	Unconfirmed
	Ring-necked snake	*Diadophis punctatus*	X	–	–	Present
	Saddled leaf-nosed snake[2]	*Phyllorhynchus browni*	–	–	–	Unconfirmed
	Sidewinder	*Crotalus cerastes*	–	–	–	Unconfirmed
	Smith's black-headed snake	*Tantilla hobartsmithi*	X	–	–	Present
	Sonoran lyresnake	*Trimorphodon lambda* (formerly *biscutatus)*	X	X	–	Present
	Sonoran whipsnake	*Coluber bilineatus*	X	X	X	Present
	Southwestern speckled rattlesnake	*Crotalus pyrrhus* (formerly *mitchellii)*	–	–	–	Probably Present
	Striped whipsnake	*Coluber taeniatus*	–	–	–	Historical
	Terrestrial gartersnake	*Thamnophis elegans*	–	–	–	Unconfirmed
	Tiger rattlesnake[2]	*Crotalus tigris*	–	–	–	Historical
	Variable sandsnake[2]	*Chilomeniscus stramineus*	–	–	–	Probably Present
	Western snake (Sonoran coralsnake[2]	*Micruroides euryxanthus*	X	X	–	Present
	Western black-tailed rattlesnake	*Crotalus molossus*	X	X	–	Present
	Western diamond-backed rattlesnake	*Crotalus atrox*	X	X	X	Present
	Western groundsnake	*Sonora semiannulata*	X	–	–	Present
	Western patch-nosed snake	*Salvadora hexalepis*	X	–	–	Present
	Western slender blind snake (or western threadsnake)	*Rena humilis*	–	–	–	Probably Present
Turtles and Tortoises	Sonora mud turtle[1]	*Kinosternon sonoriense*	X	–	–	Present
	Sonoran Desert tortoise[1,4]	*Gopherus morafkai*	–	–	–	Historical
	Spiny softshell[5]	*Apalone spinifera*	–	–	–	Probably Present

Note: X = species present.

[1] Tier 1A = species of highest conservation priority because they are either those listed as federally threatened or endangered; are candidate species for federal listing; those with a signed conservation agreement; and/or those that require monitoring after delisting (AGFD 2012).

[2] Tier 1B = species classified as vulnerable but do not meet the criteria of Tier 1A species (AGFD 2012).

[3] Arizona black rattlesnake (*C. cereberus*) was split *C. oreganus,* which does not occur in the monument but is listed by NPSpecies and earlier reports. Due to the change, we removed *C. oreganus* from this table.

[4] Federally threatened (USFWS 2019a).

[5] Non-native species.

monument but for which no specimens or photo vouchers exist. Swann et al. (1996) included five additional historical species, two of which were not included in NPSpecies. These two species are the short-horned lizard (*Phrynosoma douglasii*) and the southern plateau (eastern fence) lizard (*Sceloporus undulatus*). The remaining three species are considered either 'unconfirmed,' 'present,' or 'probably present' by NPSpecies.

Because of substantial differences in effort and methods between the three surveys, we could not directly compare species presence/absence over time. However, these surveys provide an excellent baseline inventory for the monument. Continued camera trapping efforts may help confirm the persistence of species known to occur in the monument as well as document species that are listed as 'probably present' and 'unconfirmed' by NPSpecies. Based on reference conditions, the condition of presence/absence is unknown. Because of the unknown condition, confidence is low and trend could not be determined.

For the species of conservation concern measure, we found that seven species of reptile and amphibian that occur in Tonto NM (i.e., listed as 'present' by NPSpecies) are considered either Tier 1A or Tier 1B species by AGFD (Table 56). Only the Gila monster was considered a Tier 1A, or highest conservation priority species. In addition, the lowland leopard frog (*Lithobates yavapaiensis*) (Tier 1A) and variable sandsnake (*Chilomeniscus stramineus*) (Tier 1B) are considered 'probably present,' which means that there is high confidence that these species occur in the monument but verification is needed.

Several other 'unconfirmed' species (i.e., those for which evidence is weak or absent) listed by AGFD as those of concern include the narrow-headed gartersnake (*Thamnophis rufipunctatus*), Mexican gartersnake (*Thamnophis eques*), saddled leaf-nosed snake (*Phyllorhynchus browni*), Arizona treefrog (*Hyla wrightorum*), Chiricahua leopard frog (*Lithobates chiricahuensis*), and northern leopard frog (*Lithobates pipiens*). Lastly, the tiger rattlesnake (*Crotalus tigris*) and Mojave Desert tortoise (*Gopherus agassizii*) are both species of concern but are considered 'historical' observations and are no longer considered present at the monument.

Table 56. Species of conservation concern known to occur in Tonto NM.

Status	Group	Species
1A	Reptiles	Gila monster
1B	Amphibians	Sonoran Desert toad
	Reptiles	Arizona black rattlesnake, Gila spotted whiptail, Regal horned lizard, Sonora mud turtle, Western (Sonoran) coral snake

Gila monsters are one of only a handful of venomous lizards in the world. Photo Credit: NPS.

The USFWS (2019a) lists seven threatened and endangered species of reptile and amphibian for Arizona. Of these, only two may occur in the monument. The federally threatened narrow-headed gartersnake is listed as 'unconfirmed,' but the monument lies along the southern extent of this species range (USFWS 2019a). The monument is also on the boundary of the federally threatened northern subspecies of the Mexican gartersnake (*T. e. megalops*) (USFWS 2019a). Although NPSpecies did not indicate whether the threatened subspecies occurs in the monument, based on range maps, it's possible this subspecies occurs in Tonto NM.

The Gila monster is considered a Tier 1A species by AGFD owing to its large but fragmented population within Arizona and limited global distribution (AGFD 2012). According to the International Union for the Conservation of Species (IUCN), the Gila monster is listed as 'near threatened' with a declining population trend (IUCN 2007). Within Tonto NM, this species is fairly widespread and was the second most common of four reptiles studied in the monument during 2004 to 2007 (Nowak 2009). During Nowak's (2009) study, 27 individuals were captured, and from 1993 to 1995, 16 individuals were identified (mostly in Cave Canyon) (Swann et al. 1996). During their visual encounter surveys, Albrecht et al. (2007) documented the Gila monster only incidentally in two of the three years. This latter effort, however, was not as intensive as the surveys done by Swann et al. (1996) and Nowak (2009).

Based on location data from 13 individuals with transmitters, they were most common in Arizona sycamore (P*lantanus wrightii*) and jojoba (*Simmondsia chinensis*) mixed scrub habitats (Nowak 2009). Within the jojoba-mixed scrub association, Gila monsters were more commonly found in jojoba-brittlebush-broom snakeweed (*Encelia farinosa-Gutierrzia sarothrae*) and jojoba-foothill paloverde-threeawn (*Parkinsonia* spp.-*Aristida* spp.) communities (Nowak 2009). And during hibernation (October-March), Gila monsters were most often associated with upland jojoba-mixed scrub or mixed grass-mixed scrub vegetation types. They were also commonly found in developed areas, particularly during spring. According to Nowak (2009), the future existence of the Gila monster in the monument is likely secure.

In summary, at least seven, and possibly nine, species of conservation/management concern occur in the monument. Based on reference conditions, the presence of species of conservation and management concern is in good condition. But trend is unknown and confidence in the condition rating is low since only one comprehensive survey (Swann et al. 1996) has been done to date.

During 1993 to 1995, only nine observations of the Arizona black rattlesnake were documented in the monument (Swann et al. 1996). These observations were made during road-cruising surveys. The abundance during this study was estimated at just one individual (Swann et al. 1996), although a lack of observations does not necessarily indicate a small population. According to Swann et al. (1996), historical records show that this species (known as a subspecies of *C. viridis [oerganus]*) at the time, was present on lists published in 1960, 1962, and 1980. Swann et al. (1996) also stated that this species is rarely encountered outside of Cave Canyon. The Arizona black rattlesnake was not observed by Albrecht et al. (2007), although the effort during this study was low as previously mentioned.

During the most recent study (2002-2007), 10 individuals were captured (6 adult males, 3 adult females, and 1 neonate) (Nowak 2009). Although no surveys for Arizona black rattlesnakes have been conducted since that time, at least one adult and a juvenile Arizona black rattlesnake were photographed in the monument in May 2012 (NPS/M. Stewart), although there were four observations in total (2 juveniles and 2 adults) (NPS, S. Mack, e-mail message to K. Struthers, 29 May 2019). Finally, one observation was reported on 28 April 2018 and another on 1 May 2019 according to an observations database maintained by monument staff (NPS, S. Mack, e-mail message to K. Struthers, 29 May 2019). Both were observed along the Lower Cliff Dwelling trail. Although the database also contains sightings for 2002, we relied on Nowak (2009) data for that year.

The absence of consistent observations in the database may be due to lack of reporting, difficulty in identifying species, and infrequency encounters with rattlesnakes by staff and visitors (NPS, S. Mack, e-mail message to K. Struthers, 29 May 2019). Nevertheless, these results suggest that the Arizona black rattlesnake has persisted in the monument since at least 1962. However, its persistence is not secure (Nowak 2009). The rattlesnake appears to be at the limits of its thermal tolerance in the monument (Nowak 2009). Therefore, the condition for persistence appears good, but confidence is low.

Seven adult Arizona black rattlesnakes were fitted with radio transmitters, which yielded 28 locations during 2004 to 2007 (Nowak 2009). Based on these locations, Nowak (2009) determined the core habitat characteristics of this species. Locations were concentrated in the southern portion of the monument at higher elevations and on steep slopes. In Tonto NM, slopes averaged 24% ± 2% during active periods and 22.33% ± 1.94% during hibernation. Eastern aspects were more common during the active period, but north and west aspects were more common during hibernation. Habitat during the active period comprised riparian woodlands and riparian scrub habitat as well as jojoba-mixed scrub. Rattlesnakes were almost never located in bajada habitats or mountain mahogany communities.

Within the jojoba-mixed scrub plant community, rattlesnakes were most frequently observed in desert needlegrass (*Achnatherum speciosum*)-jojoba-side-oats grama (*Bouteloua curtipendula*) and in jojoba-foothill paloverde-three-awn habitats (Nowak 2009). Hibernation sites were typically in jojoba-mixed scrub or mixed grass-mixed scrub vegetation (Nowak 2009). Based on plant associations, 182 ha (450 ac), or 40%, of the monument is potential rattlesnake habitat (Figure 36). The actual extent of suitable habitat in the monument, however, is also influenced by factors not considered here (i.e., slope and aspect). Furthermore, the map is based on the locations of only seven individuals. Since no reference conditions were developed for the habitat availability measure, the condition and trend are unknown and confidence is low.

Overall Condition, Threats, and Data Gaps

To assess the condition of herpetofauna at Tonto NM, we used two indicators with two measures each (Table 57). There have been three survey efforts for reptiles and amphibians to date. However, differing efforts and methods between these studies made comparing presence/absence over time difficult. This resulted in an unknown condition rating for presence/absence. However, there are seven confirmed species of concern (possibly two additional species) in the monument. Of those, only the Gila monster was detected during previous survey efforts. But species of concern tend to be uncommon and/or restricted to specific habitat types (e.g., Arizona black rattlesnake), which makes them more difficult to observe. The Arizona black rattlesnake has persisted in the monument and 40% of the monument was mapped as potential habitat. Because of the age of the data coupled with lower effort during more recent surveys, the overall condition is unknown to good with low confidence and an unknown trend.

Herpetofauna are susceptible to climate change, changes in water resources, habitat loss and fragmentation, introduction of exotic species, pollution, and disease (NPS 2015b). Increased development of roads, traffic, and domesticated animals also contribute to the mortality of herpetofauna (NPS 2015b). Of all the factors affecting herpetofauna, climate change is a major concern. Herpetofauna may be more susceptible to the effects of climate change than other taxa because they are only active within a narrow range of temperatures, rely on terrestrial and/

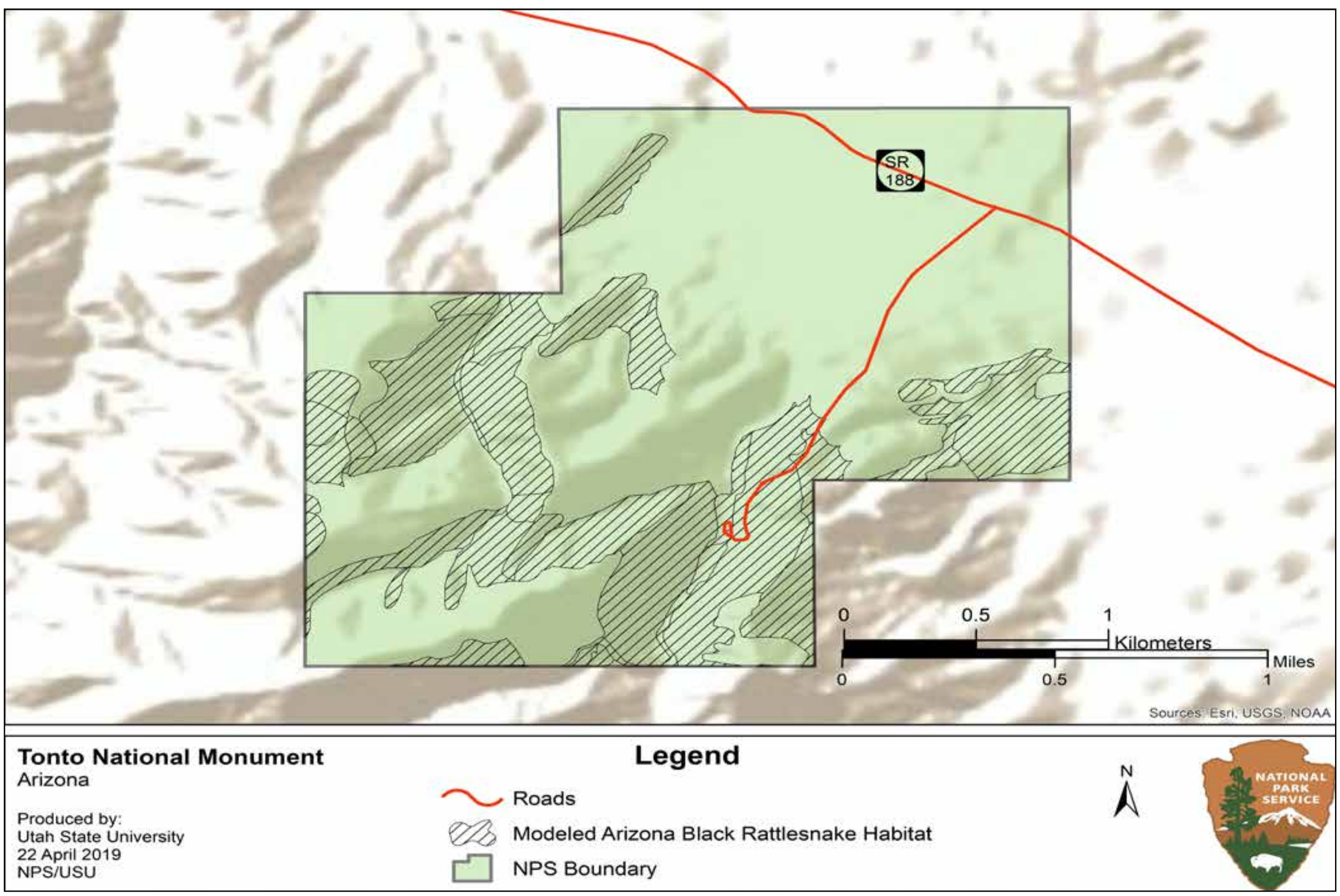


Figure 36. **Modeled habitat of the Arizona black rattlesnake in Tonto NM.**

Table 57. Summary of herpetofauna indicators, measures, and condition rationale.

Indicators	Measures	Condition/Trend/ Confidence	Rationale for Condition
Species Occurrence	Species Presence/ Absence		NPSpecies lists 77 reptiles and amphibians, of which 41 are considered 'present,' 10 are considered 'probably present,' 17 are 'unconfirmed,' and nine are 'historical' observations. Five species were observed during all three efforts. However, because of differences in effort and methods between the three surveys, we could not directly compare species presence/absence over time.
	Species of Conservation/ Management Concern		At least seven and possibly nine species of conservation/management concern occur in the monument. Based on reference conditions, this measure is in good condition. Trend is unknown and confidence in the condition rating is low since the most recent inventory/surveys were done in 2001 and 2002 but were limited in scope.
Arizona Black Rattlesnake	Persistence		Although this species appears to be rare at the monument, it has been documented on several checklists and observed during two of the three most recent studies from 1962 to 2007. In 2012, at least one adult and one juvenile were photographed in the monument. However, no observations/studies have been done since and its persistence in the monument is questionable.
	Habitat Availability		Approximately 40% of the monument was mapped as potential habitat. Arizona black rattlesnakes were most associated with riparian woodlands, riparian scrub, and jojoba-mixed scrub-grassland plant communities. Furthermore, this species occurs in uplands on moderate east-facing slopes during the active period and north- and west-facing slopes during hibernation. The condition for this measure is unknown because no reference conditions were developed for this measure.
Overall Condition	Summary of All Measures		There have been three survey efforts for reptiles and amphibians to date. However, differing effort and methods made comparing presence/absence over time difficult. NPSpecies lists 41 species as 'present,' including several species of concern such as the Gila monster and Arizona black rattlesnake. The data used in this assessment suggest that the monument provides important habitat for species of concern, that Arizona black rattlesnakes persist in the monument, and that diversity is good. But we could not determine species presence/absence over time. Continued camera trap monitoring effort will help fill in some of these gaps.

or aquatic environments, and have limited dispersal abilities (Flesch and Rosen 2017). Furthermore, rising temperatures may incur high metabolic costs (Flesch and Rosen 2017). Unfortunately, climate projections for the American Southwest include higher temperatures, increased drought, and more intense thunderstorms (Backlund et al. 2008).

Reptiles and amphibians are likely to differ in their responses to climate change based on individual species' life history traits (Flesch and Rosen 2017). In a 25-year study of five lizard species common in the Sonoran Desert, researchers found that as temperature increased and precipitation decreased those species that were either arboreal (shade-dwelling) or bred during winter/spring increased in abundance by 237-285%, while spring/summer breeding species or those that were associated with more open habitats declined by as much as 64% (Flesch and Rosen 2017). Early breeding and/or preference for shaded habitats are traits that protect individuals against rising temperatures, while summer breeding and selecting open habitats are traits that increase exposure to rising temperatures (Flesch and Rosen 2017). These results suggest that species associated with the Cave Canyon riparian area (e.g., Arizona black rattlesnake and ornate tree lizard) in Tonto NM may fare better under a warming climate than species associated with open habitats (e.g., Great Plains toad [*Anaxyrus cognatus*]).

Interestingly, Flesch and Rosen (2017) also found that rising minimum temperatures had a greater effect on abundance than maximum temperatures. The authors speculated that this was because cool refugia may be more difficult to find under warmer minimum temperatures or that rising minimum temperatures are more likely to stimulate early emergence from winter dormancy (Flesch and Rosen 2017). While herpetofauna can change microhabitat in response to rising temperatures during the active period, they are less able to do so during hibernation.

Similarly, van Riper et al. (2014) found that the most important factor affecting suitable habitat for the Arizona black rattlesnake was minimum winter temperature (October-April), which explained more than 30% of the variability in habitat suitability across its range. In order of importance following minimum winter temperature were terrain ruggedness, total summer precipitation (May-September), rock type, insolation (i.e., solar radiation) during May, geology, and the distribution of Gambel oak (*Quercus gambelii*) (van Riper et al. 2014). Based on these factors and climate change scenarios, the Arizona black rattlesnake is predicted to undergo a 40% to 45% range contraction by 2039 (van Riper et al. 2014). However, Tonto NM is predicted to remain within its range through at least 2099 (van Riper et al. 2014).

At the end of the Pleistocene approximately 12,000 years ago, the rattlesnake's range was substantially larger than it is today (Douglas et al. 2016). As the climate naturally warmed and the topography changed, its range contracted, resulting in a population composed of five genetically distinct groups isolated by landscape features (Douglas et al. 2016). The most formidable natural barrier to dispersal today is the Grand Canyon, especially since this species range is expected to move northwest under current climate change scenarios (Douglas et al. 2016).

Wildfire has reduced the forested niche of the Arizona black rattlesnake by more than 27% (Douglas et al. 2016). In Tonto NM, wildfires could affect rattlesnake habitat since they typically occur in the fire-adapted upland areas of the monument (Studd et al. 2017). However, in June 2017, there was a 16.2 ha (40 ac) fire in the valley/bajada area of the monument. Other major fires also occurred in 1947, 1964, 1970, 1974, and 1980 (Studd et al. 2017). This is an unusually high fire frequency for the Sonoran Desert ecosystem, given the limited evolutionary history of wildfire there, even within the fire-adapted foothills region of the monument (Hubbard et al. 2013). Non-native plants are thought to have played a role in the high fire return interval in the monument (Studd et al. 2017). While portions of the uplands may have partially recovered from these fires (Studd et al. 2017), the introduction and spread of non-native annuals such as red brome (*Bromus rubens*) may increase fire frequency in this system.

Although Arizona has been in a drought since 2000 (Gwilliam et al. 2017), for the time being, discharge at Cave Spring appears good (see the Cave Canyon assessment in this report). Cave Spring is connected to the local aquifer, and aquifers are not typically affected by droughts, at least in the short-term. The persistence of water and a well-developed plant canopy along Cave Canyon is important for Arizona black rattlesnakes as well as for many other species of amphibian and reptile that depend on riparian communities. Lastly, although Arizona black rattlesnakes were mostly absent in developed areas, other venomous reptiles were present (Nowak 2009, Nowak and Arundel 2009). Venomous reptiles pose a threat to visitors but are also at risk of poaching for their rattles or captivity in the black market. Also of concern to managers at the monument is mortality of herpetofauna when being handled during studies, which can be avoided if voucher photos are used for identification rather than capture.

A better understanding of how herpetofauna respond to changes in ecological processes will enable managers to identify and respond to declines in populations. Further investigation on species of interest, underrepresented species, and rare species may inform management approaches to restoring altered landscapes and monitoring indicators in the future. Furthermore, updates to the NPSpecies list may be necessary based on range maps (NPS, D. Martin, Wildlife Program Manager, comments to draft assessment, email to K. Struthers, 3 June 2019). Standardized inventory and monitoring studies of herpetofauna in the monument are necessary to update and refine the species list and determine population sizes and persistence over time, especially given a changing climate and resulting shifts in habitat suitability.

Sources of Expertise

This assessment was written by science writer and wildlife biologist, Lisa Baril, Utah State University. Subject matter expert reviewers are listed in Appendix A.

Cliff dwellings at Tonto NM. Photo Credit: NPS.

Discussion

The overall conditions of Tonto National Monument's (NM) nine selected focal natural resources are summarized in Table 58. With the exception of air quality, which is considered to be of significant concern, the majority of the monument's resources are found to be in good condition. Some unknowns exist, especially pertaining to the wildlife topics due to the lack of repeat, comparable surveys from which to make comparisons. Additionally, aspects of the upland vegetation and soils, Cave Canyon riparian area, and night sky assessments warrant moderate concern. The associated threats and stressors (at the time of writing this report) for each of the nine natural resources are listed in Table 59.

The conditions reported for Tonto NM represent 'a snapshot in time' based on the best available data during the time of writing this report (June 2018–May 2019). Unfortunately, as of June 2019, a major wildfire, the Woodbury Fire, has burned 50,111 ha (123,827 ac) throughout the Tonto National Forest, which includes the national monument. While the full effects of the fire's impact to the monument's and surrounding region's resources are currently unknown, the fire has undoubtedly created natural resource conditions that are vastly different from those delivered in this report. As a result, this document serves as a summary of pre-fire resource conditions from which future comparisons can be made.

As described in Chapter 2, temperatures are becoming warmer and conditions are becoming drier due to the changing climate (Monahan and Fisichelli 2014), especially in the Southwest (Garfin et al. 2014). Couple these changes with increasing flashy fuels, such as rapidly growing non-native annuals like red brome (*Bromus rubens*), and the risk of fire increases. Not only do annual grasses like brome tolerate fire, but they also facilitate the colonization of other non-natives, which further increases fire potential in a positive-feedback loop (Hubbard et al. 2012). Not only does fire have the ability to decimate natural resources, but can be devastating to cultural resources as well.

Table 58. Natural resource condition summary for Tonto NM.

Resource	Overall Condition
Viewshed	[green circle]
Night Sky	[yellow circle]
Air Quality	[red circle]
Geology	[green circle]
Cave Canyon	[green circle] [yellow circle]
Upland Vegetation and Soils	[yellow circle]
Birds	[green circle]
Mammals	[dashed empty circle] [dashed green circle]
Herpetofauna	[dashed empty circle] [dashed green circle]

Due to the fact that the monument's physical and biological conditions influence its cultural conditions, the original purpose of Tonto NM's Chapter 5 discussion was to develop a cultural risk matrix. This would be accomplished by ranking and analyzing the attributes of the monument's natural features. These features, such as rocky substrates or steep slopes, heavily influence the present-day archaeological resource conditions throughout the monument. For example, varying degrees of erosion potential depend on the steepness of a slope (the greater the slope, the greater the erosion potential), the substrate (rocky soils are more prone to the effects of water erosion), type of vegetation, presence of burrowing rodent activity, or whether fire has occurred in an area, etc.

By ranking and reclassifying the physical and biological features and associated attributes from datasets like soils, vegetation, and digital elevation model-derived slope, a Geographic Information System (GIS) predictive model of risk to the monument's archeological sites could be developed. ArcGIS Raster Calculator would be used to create weighted overlays, which would be combined into one raster and shown as a graduated color scheme, representing areas on the ground predicted to be of varying degrees of erosion risk.

Staff could corroborate the predictive ability of the model by overlaying their spatial layer of archeological site condition locations onto the risk analysis raster. This would assist managers with identifying locations of high vulnerability that need attention or reveal areas of discrepancy between high risk for erosion locations that actually contain archeological resources evaluated to be in good condition, warranting further investigation (with the converse warranting field investigation also). Based on this iterative process, the model could then eventually serve as a robust planning tool that would inform management actions necessary to continue preserving the monument's archeological resources.

However, due to the current unknown impacts of the recent Woodbury Fire, additional and/or different datasets may be required to develop a useful model. Monument staff intend to work with various scientists and resource managers over the next several months to years to determine the post-fire effects. Currently though, the highest priority identified by monument staff is the protection of human health and safety.

Juvenile Arizona black rattlesnakes are lighter in color than adults. Photo Credit: NPS.

Table 59. Resource condition assessment topic threats and stressors.

Resources	Threat/Stressor
Viewshed	Fire, both from an air quality and burned vegetation perspective Mining Powerplants Commercial recreation on Roosevelt Lake Campground on the U.S. Forest Open pit mine
Night Sky	Encroaching lights from nearby communities (e.g., Globe) as well as larger, more distant cities (e.g., Phoenix) Dust Smoke from fires Mines
Air Quality	Air pollution from vehicle exhaust, agriculture, and dust Open pit mine when its constructed Smelter
Cave Canyon Riparian Area	Grazing in watershed may affect water quality, flooding, and siltation Climate change may alter water quantity Non-native plants Trail impact through riparian area (short-term since staff are building a bridge) Erosion poential through steep drainages
Geologic Resources	Freeze/thaw cycles Changes in patterns of precipitation Wildlife and pests cause damage to cultural structures Retaining walls may be altering drainage and damaging archaeological structures Overflights causing vibrations Flash floods in Cave Canyon Disturbed lands including mineral development near the monument in addition to grazing. Cement over adobe substrate traps moisture and increases the potential for erosion of walls Vandalism and illegal excavation Rockfalls Non-native plants threat to archaeological resources – removing and thinning vegetation helps protect archaeological structures, but it also causes problems with erosion, especially after intense rainstorms
Upland Sonoran Desert Vegetation and Soils	Floods may damage vegetation and soil crusts Climate change (reduced water availability, increase in temperature) Non-native plants (powerlines as pathways) Grazing outside park may create erosion issues and/or contribute to the spread of non-native species Increase in fire return intervals because of non-native grasses Air pollution from vehicle exhaust, agriculture, and dust Climate change could cause loss of Saguaro cactus
Birds	Non-native species Climate change Declines in riparian habitat with diminishing water resources Unknown impacts of human presence on avian nesting activities
Mammals	Habitat fragmentation (decreasing connectivity and corridors) Human / wildlife encounters Species extirpation Potential of white-nose syndrome Lack of repeat surveys to evaluate conditions
Herpetofauna	Climate change (Arizona black rattlesnake is typically found at higher, cooler elevations) Relocation around park housing Declining spring water due to climate change Some poaching (i.e., killing to obtain rattle) Lack of repeat surveys to evaluate conditions

Literature Cited

Abatzoglou, J. T. and A. P. Williams. 2016. Impact of anthropogenic climate change on wildfire across western US forests. Proceedings of the National Academy of Sciences 113: 11770-11775. Available at: http://www.pnas.org/content/113/42/11770 (accessed 16 August 2018).

Albrecht, E. W., W. L. Halvorson, P. P. Guertin, B. F. Powell, and C. A. Schmidt. 2005. A biological inventory and hydrological assessment of the Cave Springs riparian area, Tonto National Monument, Arizona. Final Report: January 28, 2005. Sonoran Desert Research Station of the USGS Southwest Biological Science Center and School of Natural Resources, University of Arizona. Tucson, Arizona.

Albrecht, E. W., Powell, B. F., Halvorson, W. L., and Schmidt, C. A. 2007. Vascular plant and vertebrate inventory of Tonto National Monument: U.S. Geological Survey Open-File Report 2007-1295. Available at: http://pubs.usgs.gov/of/2007/1295/ (accessed 19 October 2018).

Allen, E.B., L.E. Rao, R.J. Steers, A. Bytnerowicz, and M.E. Fenn. 2009. Impacts of atmospheric nitrogen deposition on vegetation and soils in Joshua Tree National Park. Pages 78–100 in R.H. Webb, L.F. Fenstermaker, J.S. Heaton, D.L. Hughson, E.V. McDonald, and D.M. Miller, editors. The Mojave Desert: Ecosystem processes and sustainability. University of Nevada Press, Las Vegas, Nevada. Available at: https://www.fs.usda.gov/treesearch/pubs/37082 (accessed 16 August 2018).

American Ornithological Society (AOS). 2018. Checklist of North and Middle American birds. Available at: http://www.americanornithology.org/content/checklist-north-and-middle-american-birds (accessed 3 October 2018).

Arizona Department of Environmental Quality (ADEQ). 2017. Chapter 11. Department of Environmental Quality - water standards. Available at: https://www.epa.gov/sites/production/files/2014-12/documents/az-chapter11.pdf (accessed 2 January 2019).

Arizona Department of Water Resources (ADWR). 2018. Drought status. Available at: https://new.azwater.gov/drought/drought-status (accessed 19 November 2018).

Arizona Game and Fish Department (AGFD). 2012. Arizona's state wildlife action plan: 2012-2022. Arizona Game and Fish Department, Phoenix, Arizona. Available at: https://www.azgfd.com/PortalImages/files/wildlife/2012-2022_Arizona_State_Wildlife_Action_Plan.pdf (accessed 25 January 2019).

Arizona Game and Fish Department (AGFD). 2015. HabiMap™. Available at: http://habimap.org/ (accessed 29 January 2019).

Arizona Game and Fish Department (AGFD). 2019. Summary of bighorn sheep translocation efforts in Arizona. Available at: https://s3.amazonaws.com/azgfd-portal-wordpress/PortalImages/files/SummaryofBHSReleasestable.pdf. accessed 8 April 2019).

Arizona Geological Survey (AGS). 2019. Earthquakes. Available at: https://azgs.arizona.edu/center-natural-hazards/earthquakes (accessed 10 March 2019).

Arizona Wildlife Linkages Workgroup (AWLW). 2006. Wildlife linkages. Available at: https://www.azdot.gov/business/environmental-planning/programs/wildlife-linkages (accessed 20 March 2019).

Backlund, P., A. Janetos, and D. Schimel. 2008. The effects of climate change on agriculture, land resources, water resources, and biodiversity in the United States. Final Report, Synthesis and Assessment Product 4.3. U.S. Climate Change Science Program. University Corporation for Atmospheric Research. Available at: http://www.sap43.ucar.edu/ (accessed 8 August 2018).

Barentine, J.C., C. E. Walker, M. Kocifaj, F. Kundracik, A. Juan, J. Kanemoto, and C. K. Monrad. 2018. Skyglow changes over Tucson, Arizona resulting from a municipal LED street lighting conversion.

Journal of Quantitative Spectroscopy and Radiative Transfer 212: 10-23.

Baron, J.S., C.T. Driscoll, J.L. Stoddard, and E.E. Richer. 2011. Empirical critical loads of atmospheric nitrogen deposition for nutrient enrichment and acidification of sensitive U.S. lakes. Bioscience. American Institute of Biological Sciences, 61(8):602-613. Available at: https://academic.oup.com/bioscience/article/61/8/602/337131 (accessed 16 August 2018).

Beaupré, K., R. E. Bennetts, J. A. Blakesley, K Gallo, D. Hanni, A. Hubbard, R. Lock, B. F. Powell, H. Sosinski, P. Valentine-Darby, C. White and M. Wilson. 2013. Landbird monitoring protocol and standard operating procedures for the Chihuahuan Desert, Northern Great Plains, Sonoran Desert, and Southern Plains Networks: Version 1.00. Natural Resource Report NPS/SOPN/NRR—2013/729. National Park Service, Fort Collins, Colorado. Available at: https://irma.nps.gov/DataStore/DownloadFile/484922 (accessed 19 October 2018).

Beever, E. 2003. Management implications of the ecology of free-roaming horses in semi-arid ecosystems of the Western United States. Wildlife Society Bulletin 31: 887-895. Available at: https://www.jstor.org/stable/3784615?seq=1#metadata_info_tab_contents (accessed 20 March 2019).

Beier, P., D. Majka, and T. Bayless. 2006. Arizona Missing Linkages: US-60 Superior to Globe Linkage Design. Report to Arizona Game and Fish Department. School of Forestry, Northern Arizona University. Available at: http://corridordesign.org/dl/linkages/reports/US60-Superior-to-Globe_LinkageDesign.pdf (accessed 20 March).

Bell, M.D. In Review. Ozone Sensitive Plant Species on National Park Service and U.S. Fish and Wildlife Service Lands: An Update to Results from the 2003 Baltimore Ozone Workshop. Natural Resource Report NPS/NRARD/NRR-X/Y. Available at: https://irma.nps.gov/NPSpecies/Reports/Systemwide/Ozone-Sensitive%20Species%20in%20a%20Park (accessed 16 August 2018).

Bennetts, R. E., J. E. Gross, K. Cahill, C. L. McIntyre, B. B. Bingham, J. A. Hubbard, L. Cameron, and S. L. Carter. 2007. Linking monitoring to management and planning: Assessments points as a generalized approach. The George Wright Forum 24(2):59–77. Available at: http://www.georgewright.org/242bennetts1.pdf (accessed 27 November 2018).

Besser, T. E., E. F. Cassirer, M. A. Highland, P. Wolff, A. Justice-Allen, K. Mansfield, M. A. Davis, and W. Foreyt. 2013. Bighorn sheep pneumonia: sorting out the cause of a polymicrobial disease. Preventive Veterinary Medicine 108: 85-93. Available at: https://pdfs.semanticscholar.org/2234/12a51aeb387db96fc9783dad633860c850ae.pdf (accessed 14 April 2019).

Bibby, C. J, N. D. Burgess, D. A. Hill, and S. Mustoe. 2000. Bird census techniques. Second ed. London: Academic Press.

Brush, R. O.. and Palmer, J. F. 1979. Measuring the impact of urbanization on scenic quality: land use change in the northeast. In: Elsner, Gary H., and Richard C. Smardon, technical coordinators. 1979. Proceedings of our national landscape: a conference on applied techniques for analysis and management of the visual resource [Incline Village, Nev., April 23-25, 1979]. Gen. Tech. Rep. PSW-GTR-35. Berkeley, CA. Pacific Southwest Forest and Range Exp. Stn., Forest Service, U.S. Department of Agriculture. Available at: https://www.fs.fed.us/psw/publications/documents/psw_gtr035/psw_gtr035_08_brush.pdf (accessed 5 July 2018).

Bryce, S. A., R. M. Hughes, and P. R. Kaufmann. 2002. Development of a bird integrity index: Using bird assemblages as indicators of riparian condition. Environmental Management 30:294–310. Available at: https://pdfs.semanticscholar.org/9ada/9eac7c0698695ae41484567ae1154cc5bbeb.pdf (accessed 19 October 2018).

Bucci, M., Y. Petryszyn, and P. R. Krausman. 2010. Occurrence and activity of bats at three national monuments in Central Arizona. The Southwestern Naturalist 55: 207-216. Available at: https://www.jstor.org/stable/pdf/40801009.pdf (accessed 19 March 2019).

Bucci, M., Y. Petryszyn, and P. R. Krausman. 2011. Bat occurrence and use of archaeological sites at three national monuments in Central Arizona. Journal of the Arizona-Nevada Academy of Science 43: 1-5. Available at: https://www.jstor.org/stable/pdf/41510539.pdf?refreqid=excelsior%3Ab4f793db50d055373dff3df3823b3ddd (accessed 19 March 2019).

Buckland, S. T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers, and L. Thomas. 2001. Introduction to distance sampling: Estimating abundance of biological populations. Oxford, U.K.: Oxford University Press.

Bureau of Land Management (BLM). 2016. Visual Resource Management. U.S. Department of the Interior, Bureau of Land Management. Washington, DC. Available at: https://www.blm.gov/programs/recreation/recreation-programs/visual-resource-management (accessed 6 July 2017).

Cabe, P. R. 1993. European starling (*Sturnus vulgaris*), The Birds of North America (P. G. Rodewald, Ed.). Ithaca: Cornell Lab of Ornithology. Available at: https://birdsna.org/Species-Account/bna/species/eurstaDOI: 10.2173/bna.48 (accessed 25 October 2018).

Cannon, J. 2017. Mexican spotted owl monitoring, Tonto National Monument. Annual report to the U.S. Fish and Wildlife Service. Research and Recovery Permit #TE18891C-0.

Canterbury, G. E., T. E. Martin, D. R. Petit, L. J. Petit, and D. F. Bradford. 2000. Bird communities and habitat as ecological indicators of forest condition in regional monitoring. Conservation Biology 14:544–558. Available at: https://www.umt.edu/mcwru/documents/Martin_Publications/Reprint574.pdf (accessed 19 October 2018).

Carles, L. J., I. L. Barrio, and J. Vicente de Lucio. 1999. Sound influence on landscape values. Landscape and Urban Planning 43:191-200. Available at: https://ac.els-cdn.com/S0169204698001121/1-s2.0-S0169204698001121-main.pdf?_tid=db9a3788-c9d0-49df-bc29-fa115ad3d80e&acdnat=1530830332_6d15f1cea9bfbe41ec65e32e5f95be18 (accessed 5 July 2018).

Climate Analyzer. 2018. Tonto - Repeater Ridge. Gardiner, Montana. Available at: http://www.climateanalyzer.org/sonoran_desert/raws/KG7KID-2/ (accessed 11 December 2018).

Coggins, G.C. 1987. Protecting the wildlife resources of national parks from external threats. Land and Water Law Review, 22, 1-27 as cited in Monahan et al. 2012.

Dickard, M., M. Gonzalez, W. Elmore, S. Leonard, D. Smith, S. Smith, J. Staats, P. Summers, D. Weixelman, S. Wyman. 2015. Riparian area management: Proper functioning condition assessment for lotic areas. Technical Reference 1737-15. U.S. Department of the Interior, Bureau of Land Management, National Operations Center, Denver, CO. Available at: http://www.remarkableriparian.org/pdfs/pubs/TR_1737-15.pdf (accessed 19 November 2018).

Doherty, T. S., A. S. Glen, D. G. Nimmo, E. G. Ritchie, and C. R. Dickman. 2016. Invasive predators and global biodiversity loss. Proceedings of the National Academy of Sciences 113: 11261-11265. Available at: https://www.pnas.org/content/113/40/11261 (accessed 6 February 2019).

Douglas, M. A. Davis, M. Amarello, J. J. Smith, G. W. Schuett, H-W Herrmann, A. T. Holycross, and M. E. Douglas. 2016. Anthropogenic impacts drive niche and conservation metrics of a cryptic rattlesnake on the Colorado Plateau of western North America. Royal Society Open Science 3: 160047. Available at: http://dx.doi.org/10.1098/rsos.160047 (accessed 27 April 2019).

Drezner, T. D. and C. M. Garrity. 2003. Saguaro distribution under nurse plants in Arizona's Sonoran Desert: directional and microclimate influences. The Professional Geographer 55: 505-512.

Duriscoe, D., C. B. Luginbuhl, and C. A. Moore. 2007. Measuring night sky brightness with a wide-field CCD camera. Publications of the Astronomical Society of the Pacific 119:192-213. Available at: https://arxiv.org/ftp/astro-ph/papers/0702/0702721.pdf (accessed 17 May 2018).

E&S Environmental Chemistry, Inc. 2009. Nitrogen screening project - sensitive vegetation. Available at: https://irma.nps.gov/DataStore/Reference/Profile/2170016 (accessed 16 August 2018).

ESRI. 2016. Using viewshed and observer points for visibility analysis. Available at: http://desktop.arcgis.com/en/arcmap/10.3/tools/spatial-analyst-toolbox/using-viewshed-and-observer-points-for-visibility.htm (accessed 12 July 2018).

Federal Aviation Administration (FAA). 2005. Notice of interim operating authority granted to commercial air tour operators over national parks and tribal lands within or abutting national parks. 70 FR 36456. Available at: https://www.federalregister.gov/documents/2005/06/23/05-12380/notice-of-interim-operating-authority-granted-to-commercial-air-tour-operators-over-national-parks (accessed 7 March 2019).

Federal Aviation Administration (FAA). 2012. Minimum safe altitudes: general. Docket No. 18334, 54 FR 34294, Aug. 18, 1989, as amended by Amdt. 91-311, 75 FR 5223, Feb. 1, 2010. Available at: https://www.govinfo.gov/content/pkg/CFR-2012-title14-vol2/pdf/CFR-2012-title14-vol2-sec91-119.pdf (accessed 7 March 2019).

Fisher, P. 2009. Preliminary recommendations for minor cracking, Tonto National Monument, Arizona. National Park Service, Vanishing Treasures Program.

Flesch, A. D. and P. C. Rosen. 2017. Long-term changes in abundances of Sonoran Desert lizards reveal complex responses to climatic variation. Global Change Biology DOI: 10.1111/gcb.13813.

Fowler, D., J.A. Pyle, J.A. Raven, and M.A. Sutton. 2013. The global nitrogen cycle in the twenty-first century: Introduction. Philosophical Transactions of the Royal Society B: Biological Sciences, 368(1621), 20130165. Available at: http://doi.org/10.1098/rstb.2013.0165 (accessed 16 August 2018).

Ganey, J. L., J. P. Ward Jr., D. W. Willey. 2012. Status and ecology of Mexican spotted owls in the Upper Gila Mountains recovery unit, Arizona and New Mexico. General Technical Report RMRS-GTR-256WWW. Fort Collins, Colorado, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. Available at: https://www.fs.fed.us/rm/pubs/rmrs_gtr256.pdf (accessed 19 October 2018).

Garfin, G., G. Franco, H. Blanco, A. Comrie, P. Gonzalez, T. Piechota, R. Smyth, and R. Waskom. 2014. Ch. 20: Southwest, in J. M. Melillo, T. C. Richmond, and G. W. Yohe, eds. Climate Change Impacts in the United States: The Third National Climate Assessment. U.S. Global Change Research Program, 462-486. doi:10.7930/J08G8HMN. Available at: http://nca2014.globalchange.gov/report/regions/southwest%0D (accessed 9 January 2019).

Gobster, P. H. 1999. An ecological aesthetic for forest landscape management. Landscape Journal 18: 54-64. Available at: https://www.nrs.fs.fed.us/pubs/jrnl/1999/nc_1999_Gobster_001.pdf (accessed 5 July 2018).

Gwilliam, E. L., K. Raymond, and L. Palacios. 2017. Status of climate and water resources at Montezuma Castle and Tuzigoot national monuments: Water year 2016. Natural Resource Report NPS/SODN/NRR—2017/1551. National Park Service, Fort Collins, Colorado. Available at: https://irma.nps.gov/DataStore/DownloadFile/604575 (accessed 27 April 2019).

Han, K. T. 2010. An exploration of relationships among responses to natural scenes: Scenic beauty, preference and restoration. Environment and Behavior 42:243-270. Available at: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.882.5743&rep=rep1&type=pdf (accessed 3 September 2018).

Hargrave, L. L. 1963. Revised checklist of birds: Tonto National Monument, June 30, 1963.

Hargrave, L. L. 1965. Bird skin collection, Tonto National Monument, December 1964. Memo to the NPS Superintendent at Tonto National Monument.

Herrick, J. E., J. W. Van Zee, K. M. Havstad, J. M. Burkett, and W. G. Whitford. 2005. Monitoring manual for grassland, shrubland and savanna ecosystems. Volume II: Design, supplementary methods and interpretation. USDA-ARS Jornada Experimental Range, Las Cruces, New Mexico. Available at: https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1044179.pdf (accessed 7 November 2018).

Hetherington, J., T.C. Daniel. and T.C. Brown. 1993. Is motion more important than it sounds?: The medium of presentation in environmental perception research. J. Environmental Psychology. 13: 283-291. Available at: https://ac.els-cdn.com/S0272494405802518/1-s2.0-S0272494405802518-main.pdf?_tid=2851786c-8346-417a-9654-9913b8c9b225&acdnat=1530830238_fde03d2306e4288fc7de1cf3ef359410 (accessed 5 July 2018).

Hiett, K. L. and W. L. Halvorson. 1999. Inventory and assessment of avifauna and a monitoring protocol proposal for Tonto National Monument, Arizona. Technical Report No. 62. US. Geological Survey, Cooperative Park Studies Unit, School of Renewable Natural Resources, University of Arizona, Tucson, Arizona.

Hubbard, A. and E. Gwilliam. 2016. Monitoring seeps, springs, and tinajas in the Sonoran and Chihuahuan Deserts. National Park Service, Sonoran Desert Inventory and Monitoring Network, Tucson, Arizona. Available at: https://www.nps.gov/articles/monitoring-seeps-springs-and-tinajas.htm (accessed 15 November 2018).

Hubbard, J. A., C. L. McIntyre, and S. E. Studd. 2013. Status of terrestrial vegetation and soils at Tonto National Monument, 2009–2010. Natural Resource Technical Report NPS/SODN/NRTR—2013/833. National Park Service, Fort Collins, Colorado. Available at: https://irma.nps.gov/DataStore/DownloadFile/486761 (accessed 6 March 2019).

Hubbard, J. A., C. L. McIntyre, S. E. Studd, T. Nauman, D. Angell, K. Beaupré, B. Vance, and M. K. Connor. 2012. Terrestrial vegetation and soils monitoring protocol and standard operating procedures: Sonoran Desert and Chihuahuan Desert networks, version 1.1. Natural Resource Report NPS/SODN/NRR—2012/509. National Park Service, Fort Collins, Colorado. Available at: https://irma.nps.gov/DataStore/DownloadFile/447961 (accessed 27 November 2018).

Hynes, H.B.N. 1970. The Ecology of Running Waters. University of Toronto Press, Toronto.

Incorporated Research Institutions for Seismology (IRIS). 2017. Frequently answered questions: how do I interpret magnitudes and magnitude types? Available at: (accessed 9 March 2019).

Inouye, R.S. 2006. Effects of shrub removal and nitrogen addition on soil moisture in sagebrush steppe. Journal of Arid Environments. 65: 604–618.

International Dark Sky Association (IDA). 2018. International Dark Sky Places. Available at: http://darksky.org/idsp/ (accessed 17 May 2018).

International Union for Conservation of Nature (IUCN). 2007. Gila monster. Available at: https://www.iucnredlist.org/species/9865/13022716 (accessed 25 April 2019).

Jansen, B. D., P. R. Krausman, J. R. Heffelfinger, T. H. Noon, J. C. Devos. 2007. Population dynamics and behavior of bighorn sheep with infectious keratoconjunctivitis. The Journal of Wildlife Management 71: 571-575. Available at: https://www.jstor.org/stable/pdf/4495217.pdf? (accessed 14 April 2019).

Johnson, G. W., J. D. Anderson, and D. Godwin. 2008. A guidebook for the Blue Ridge Parkway Scenery Conservation Haas G.E., and T.J. Wakefield. 1998. National parks and the American public: a summary report of the National Parks Conservation Association, conducted by Colorado State University, Fort Collins, Colorado.

Kaltenborn, B. P. and T. Bjerke. 2002. Associations between environmental value orientations and landscape preferences. Landscape and Urban Planning 59:1-11. Available at: https://ac.els-cdn.com/S0169204601002432/1-s2.0-S0169204601002432-main.pdf?_tid=89c687e3-6bfb-4617-8ad8-8d7efb67a1f8&acdnat=1530828329_

db6c0b2e07a444376c8b0abe1c15b2cd (accessed 5 July 2018).

Kaplan, R. and S. Kaplan. 1989. The experience of nature: A Psychological Perspective. Cambridge University Press, Cambridge, UK.

Kearney, A. R., G. A. Bradley, C. H. Petrich, R. Kaplan, S. Kaplan, and D. Simpson-Colebank. 2008. Public perception as support for scenic quality regulation in a nationally treasured landscape. Landscape and Urban Planning 87:117-128. Available at:https://ac.els-cdn.com/S0169204608000819/1-s2.0-S0169204608000819-main.pdf?_tid=e581bcc6-712a-425b-84d6-8bf743193a38&acdnat=1530827814_0eeffcfc5d7207cbd79fc97fc65505d6 (accessed 5 July 2018).

Keiser, D., G. Lade, and I. Rudik. 2018. Air pollution and visitation at U.S. national parks. Science Advances eaat1616. Available at: http://advances.sciencemag.org/content/advances/4/7/eaat1613.full.pdf (accessed 28 August 2018).

KellerLynn. 2006. Geologic resources evaluation scoping summary, Tonto National Monument, Arizona. National Park Service, Geologic Resources Division. Available at: https://irma.nps.gov/DataStore/DownloadFile/597769 (accessed 7 March 2019).

Kinney, P. L. 2008. Climate change, air quality, and human health. American Journal of Preventative Medicine 35: 459-467. Available at: http://www.ajpmonline.org/article/S0749-3797(08)00690-9/abstract (accessed 24 August 2018).

Knopf, F. L., and F. B. Samson. 1994. Scale perspectives on avian diversity in western riparian ecosystems. Conservation Biology 8:669–676.

Kunkel, K. E, L. E. Stevens, S. E. Stevens, L. Sun, E. Janssen, D. Wuebbles, K. T. Redmond, and J. G. Dobson. 2013. Regional climate trends and scenarios for the U.S. national climate assessment. Part 5. Climate of the Southwest U.S. National Oceanic and Atmospheric Administration, Technical Report NESDIS 142-5, Washington, DC. Available at: https://www.ncdc.noaa.gov/news/us-regional-climate-trends-and-scenarios (accessed 7 July 2017).

Kyba, C. C. M., T. Kuester, A. Sanchez de Miguel, K. Baugh, A. Jechow, F. Holker, J. Bennie, C. D. Elvidge, K. J. Gaston, and L. Guanter. 2017. Artificially lit surface of Earth at night increasing in radiance and extent. Science Advances. Available at: http://advances.sciencemag.org/content/3/11/e1701528 (accessed 15 May 2018).

Latta, M. J., C. J. Beardmore, and T. E. Corman. 1999. Arizona Partners in Flight Bird Conservation Plan. Version 1.0. Nongame and Endangered Wildlife Program Technical Report 142. Arizona Game and Fish Department, Phoenix, Arizona. Available at: https://www.partnersinflight.org/wp-content/uploads/2017/03/Arizona-State-Plan-v-1-1999-1.pdf (accessed 19 October 2018).

Lichvar, R. W., D. L. Banks, W. N. Kirchner, and N. C. Melvin. 2016. The National Wetland Plant List: 2016 wetland ratings. Phytoneuron 2016-30: 1-17. Published 28 April 2016. ISSN 2153 733X. Available at: http://wetland-plants.usace.army.mil/nwpl_static/data/DOC/lists_2016/States/pdf/AZ_2016v1.pdf (accessed 18 September 2018).

Lignell, B. W. 2018. Reporting information for commercial air tour operations over units of the national park system: 2017 annual report. Natural Resource Report NPS/NRSS/NSNSD/NRR—2018/1694. National Park Service, Fort Collins, Colorado. Available at: https://www.nps.gov/subjects/sound/upload/NRSS_NRR_2017_Air_Tour_Report_Final508.pdf (accessed 7 March 2019).

Lindauer. O. 1997. The Archaeology of Schoolhouse Point Mesa, Roosevelt Platform Mound Study: Report on the Schoolhouse Point Mesa Sites, Schoolhouse Management Group, Pinto Creek Complex. Roosevelt Monograph Series, 8. Tempe, Arizona, Department of Anthropology, Arizona State University.

Lindsay, B. A., D. G. Robinett, and F. R. Toupal. 1994. Soil survey of Tonto National Monument. U.S. Department of Agriculture, Soil Conservation Service, Tucson, Arizona.

Longcore, T. and C. Rich. 2004. Ecological light pollution. Frontiers in Ecology and the Environment 2: 191-198. Available at: https://

esajournals.onlinelibrary.wiley.com/doi/abs/10.1890/1540-9295%282004%29002%5B0191%3AELP%5D2.0.CO%3B2 (accessed 15 May 2018).

Loss, S.R., T. Will, and P.P Marra. 2013. The impact of free-ranging domestic cats on wildlife of the United States. Nature Communications 4, Article 1396, doi:10.1038/ncomms2380. Available at: https://www.nature.com/articles/ncomms2380.pdf (accessed 19 October 2018).

Lowther, P. E. and C. L. Cink. 2006. House sparrow (*Passer domesticus*), version 2.0. The Birds of North America (P. G. Rodewald, editor). Cornell Lab of Ornithology, Ithaca, New York, USA. Available at: https://doi.org/10.2173/bna.12 (accessed 19 October 2018).

Martin, L. 2001. Hydrogeology and potable water supply Tonto National Monument. Technical Report NPS/NRWRD/NRTR-2001/294. 10pp.

Mau-Crimmins, T., A. Hubbard, D. Angell, C. Filippone, N. Kline. September 2005. Sonoran Desert Network Vital Signs Monitoring Plan. Technical Report NPS/IMR/SODN-003. National Park Service. Denver, Colorado. Available at: https://irma.nps.gov/DataStore/DownloadFile/516150 (accessed 15 May 2018).

McIntyre, C. 2008. Erosion assessment of cultural resource sites using an index method. Project Report. Available at: https://sonoraninstitute.org/files/pdf/erosion-assessment-of-cultural-resource-sites-using-an-index-method-tonto-national-monument-04222008.pdf (accessed 6 March 2019).

Miller, M. E. 2005. The structure and functioning of dryland ecosystems—conceptual models to inform long-term ecological monitoring: U.S. Geological Survey Scientific Investigations Report 2005-5197, 73 p. Available at: https://pubs.usgs.gov/sir/2005/5197/pdf/SIR-5197.pdf (accessed 7 November 2018).

Monahan, W. B. and N. A. Fisichelli. 2014. Recent climate change exposure of Tonto National Monument. Available at: https://irma.nps.gov/DataStore/DownloadFile/497117 (accessed 24 August 2018).

Monahan, W. B., J. E. Gross, L. K. Svancara, and T. Philippi. 2012. A guide to interpreting NPScape data and analyses. Natural Resource Technical Report NPS/NRSS/NRTR—2012/578. National Park Service, Fort Collins, Colorado. Available at: http://science.nature.nps.gov/im/monitor/npscape/interpguide.cfm (accessed 8 May, 2018).

Moore, C. A., J. M. White, and F. Turina. 2013. Recommended indicators of night sky quality for NPS state of the park reports, interim guidance. Natural Sounds and Night Skies Division, WASO-Natural Resource Stewardship and Science. July 10, 2013.

National Aeronautics and Space Administration (NASA). 2018. MODIS: Moderate Resolution Imaging Spectroradiometer. Available at: https://modis.gsfc.nasa.gov/about/specifications.php (accessed 15 May 2018).

National Atmospheric Deposition Program (NRSP-3) (NADP). 2018a. NADP Program Office, Wisconsin State Laboratory of Hygiene, 465 Henry Mall, Madison, WI 53706. Available at: http://nadp.slh.wisc.edu/data/animaps.aspx (accessed 27 February 2019).

National Atmospheric Deposition Program (NRSP-3) (NADP). 2018b. NADP Program Office, Wisconsin State Laboratory of Hygiene, 465 Henry Mall, Madison, WI 53706. Available at: http://nadp.slh.wisc.edu/amon/ (accessed 27 September 2018).

National Audubon Society (NAS). 2014. Christmas Bird Count compiler's manual. Available at: http://docs.audubon.org/sites/default/files/documents/compilers_manual_oct_2014_0.pdf (accessed 2 October 2018).

National Park Service (NPS). 2003. Tonto National Monument, General Management Plan, Final Impact Statement. Available at: https://www.nps.gov/tont/learn/management/upload/GMP.pdf (accessed 5 July 2018).

National Park Service (NPS). 2004. Natural Resource Management Reference Manual #77. Available at: http://www.nature.nps.gov/rm77/(accessed 16 May 2018).

National Park Service (NPS). 2005. NPS ecological monitoring framework. Available at: https://www.nps.gov/orgs/1439/nrca-framework.htm#framework (accessed 15 May 2018).

National Park Service (NPS). 2006a. Management Policies 2006: The guide to managing the National Park System. Washington, DsC. 180 pp. Available at: https://www.nps.gov/policy/mp/Index2006.htm (accessed 2 February 2018).

National Park Service (NPS). 2006b. Tonto National Monument fire management plan. Available at: https://www.nps.gov/tont/learn/management/upload/FMP-2.pdf (accessed 11 December 2018).

National Park Service (NPS). 2010a. Standard NRCA report outline – annotated version 3.1. 5p. Available at: https://www.nps.gov/orgs/1439/upload/NRCA_Report_Outline_annotated_ver3-1_508.pdf (accessed 29 April 2018).

National Park Service (NPS). 2010b. Stargazing in parks. NPS Natural Resource Program Center Air Resources Division Night Sky Program. Available at: http://www.nature.nps.gov/night (accessed 20 June 2018).

National Park Service (NPS). 2011. Program brief: Inventory and monitoring program. U.S. Department of the Interior, National Park Service, Natural Resource Program Center, Inventory and Monitoring Division, Fort Collins, Colorado.

National Park Service (NPS). 2012. A call to action: preparing for a second century of stewardship and engagement. Washington, D.C. Available at: https://www.nps.gov/calltoaction/ (accessed 29 April 2018).

National Park Service (NPS). 2013. Caring for sites-ASMIS. NCR regional archeology program. Washington, D.C. Available at: https://www.nps.gov/rap/archeology/asmis.htm (accessed 10 March 2019).

National Park Service (NPS). 2014a. NPScape standard operating procedure: housing measure – current and projected housing density. Version 2015-04-14. National Park Service, Natural Resource Stewardship and Science. Fort Collins, Colorado. Available at: http://science.nature.nps.gov/im/monitor/npscape/methods_sops.cfm (accessed 22 September 2016).

National Park Service (NPS). 2014b. NPScape standard operating procedure: roads measure – road density, distance from roads, and area without roads. Version 2015-04-23. National Park Service, Natural Resource Stewardship and Science. Fort Collins, Colorado. Available at: http://science.nature.nps.gov/im/monitor/npscape/methods_sops.cfm (accessed 22 September 2016).

National Park Service (NPS). 2014c. NPScape standard operating procedure: conservation status measure – protected area and ownership/governance. Version 2014-01-06. National Park Service, Natural Resource Stewardship and Science. Fort Collins, Colorado. Available at: http://science.nature.nps.gov/im/monitor/npscape/methods_sops.cfm (accessed 5 July 2018).

National Park Service (NPS). 2015a. Geology at Tonto National Monument. Available at: https://www.nps.gov/articles/tonto-geology.htm (accessed 6 March 2019).

National Park Service (NPS). 2015b. Reptiles and amphibians of the American Southwest. Available at: https://www.nps.gov/articles/series.htm?id=DF30F97C-D1A7-3773-F4C04F52B6905191 (accessed 25 April 2019).

National Park Service (NPS). 2016. NPScape: monitoring landscape dynamics of U.S. National Parks. Natural Resource Program Center, Inventory and Monitoring Division. Fort Collins, Colorado. Available at: http://science.nature.nps.gov/im/monitor/npscape/(accessed 5 July 2018).

National Park Service (NPS). 2017a. Foundation Document: Tonto National Monument. National Park Service, Denver, Colorado.

National Park Service (NPS). 2017b. Field season summary report - 13 July 2017. National Park Service, Sonoran Desert Inventory and Monitoring Network. Tucson, Arizona.

National Park Service (NPS). 2018a. NPSpecies list. Available at: https://irma.nps.gov/NPSpecies/ (accessed 15 May 2018).

National Park Service (NPS). 2018b. Tonto National Monument, Arizona. Available at: http://www.nps.gov/tont/learn/ nature/index.htm. (accessed 2 January 2018).

National Park Service (NPS). 2018c. Tonto National Monument "Park after Dark" event series 2018. Available at: https://www.nps.gov/tont/learn/news/tonto-national-monument-park-after-dark-event-series-2018.htm (accessed 17 June 2018).

National Park Service (NPS). 2018d. Natural resources monitoring at Tonto National Monument. Available at: https://www.nps.gov/im/sodn/tont.htm (accessed 19 October 2018).

National Park Service (NPS). 2019. Plan your visit. Available at: https://www.nps.gov/tont/planyourvisit/index.htm (accessed 10 March 2019).

National Park Service Air Resources Division (NPS ARD). 2002. Air quality in the national parks, second edition. Lakewood, Colorado. Available at: https://nature.nps.gov/air/Pubs/pdf/aqNps/aqnps.pdf (accessed 24 August 2018).

National Park Service Air Resources Division (NPS ARD). 2005. Redesignation of clean air areas. Available at: http://www.nature.nps.gov/air/Regs/redesig.cfm (accessed 31 January 2018).

National Park Service Air Resources Division (NPS ARD). 2010. Air quality in national parks: 2009 annual performance and progress report. Natural Resource Report NPS/NRPC/ARD/NRR—2010/266. National Park Service, Denver, Colorado. Available at: https://www.nature.nps.gov/air/pubs/pdf/gpra/AQ_Trends_In_Parks_2009_Final_Web.pdf (accessed 2 February 2018).

National Park Service Air Resources Division (NPS ARD). 2018a. Clean Air Act and regulations. Available at: http://www.nature.nps.gov/air/Regs/cleanAir.cfm (accessed 16 August 2018).

National Park Service Air Resources Division (NPS ARD). 2018b. Ozone effects on human health. Available at: https://www.nps.gov/subjects/air/humanhealth-ozone.htm (accessed 16 August 2018).

National Park Service Air Resources Division (NPS ARD). 2018c. Ozone effects on plants. Available at: https://www.nps.gov/subjects/air/nature-ozone.htm (accessed 16 August 2018).

National Park Service Air Resources Division (NPS ARD). 2018d. Mercury and toxics in nature. Available at: https://www.nps.gov/subjects/air/nature-toxics.htm (accessed 16 August 2018).

National Park Service Air Resources Division (NPS-ARD). 2018e. Guidance for evaluating air quality in Natural Resource Condition Assessments. National Park Service, Denver, Colorado.

National Park Service Air Resources Division (NPS ARD). 2018f. Air quality conditions and trends by NPS units: Tonto NM. National Park Service. Denver, CO. Available at: https://www.nps.gov/subjects/air/park-conditions-trends.htm (accessed 31 January 2018). AQ, Uplands

National Park Service Air Resources Division (NPS ARD). 2018g. Mercury/toxics data and information for Tonto NM, provided by Jim Cheatham, NPS Air Resources Division, to Lisa Baril, Utah State University, via email on 2 February 2018.

National Park Service Air Resources Division (NPS ARD). 2019. Nitrogen critical loads and estimated exceedences in NPS areas (2016-2016). Available at: https://irma.nps.gov/DataStore/Reference/Profile/2258993 (accessed 27 February 2018).

National Park Service (NPS). 2018. Natural Resource Stewardship and Science (NRSS) Directorate. Available at: https://nature.nps.gov/aboutus.cfm (12 December 2018).

National Park Service Water Resources Division (NPS WRD). 2013. Parks with Clean Water Act 303(d)-listed impairments. Available at: https://www.nature.nps.gov/water/HIS/related.cfm (accessed 19 November 2018).

National Park Service (NPS) Public Use Statistics Office. 2019. NPS visitor use statistics. Annual park visitation (all years). Available at: https://irma.nps.gov/Stats/Reports/ReportList (accessed 16 May 2018).

National Park Service Sonoran Desert Inventory and Monitoring Network (NPS SODN). 2017. In Order to Care, You Need to Know What's There. Available at: https://www.nps.gov/im/sodn/index.htm (accessed 22 January 2019).

National Park Service (NPS) Sonoran Desert Inventory and Monitoring Network (SODN). 2018. Sonoran Desert Plateau Network. Available at: http://science.nature.nps.gov/im/units/sodn/index.cfm. (accessed 2 January 2019).

Nauman, T. 2011. Soil inventory results and relationships to vegetation monitoring data at Gila Cliff Dwellings National Monument. Natural Resource Technical Report NPS/SODN/NRTR—2011/479. National Park Service, Fort Collins, Colorado. Available at: https://irma.nps.gov/DataStore/DownloadFile/433128 (accessed 6 March 2019).

Nowak, E.M., and T. Arundel. 2009. Co-occurrence of syntopic venomous reptiles at Tonto National Monument, Arizona, U.S.A. Final report to National Park Service (Tonto National Monument). USGS Southwest Biological Science Center, Colorado Plateau Research Station, Flagstaff, AZ.

Nowak, E. M. 2009. Ecology and management of venomous reptilian predators. Ph.D. Dissertation. Northern Arizona University, Flagstaff, Arizona.

O'Connor, Z. 2008. Facade colour and aesthetic response: examining patterns of response within the context of urban design and planning in Sydney, University of Sydney: Sydney, Austraila. Available at: https://core.ac.uk/download/pdf/41232383.pdf (accessed 3 September 2018).

O'Connor, Z. 2009. Facade colour and judgements about building size. In D. Smith, P. Green-Armytage, M. A. Pope, and N. Harkness (Eds.) AIC 2009: Proceedings of the 11th Congress of the International Colour Association, Sydney. Available at: https://aic-color.org/page-18077 (accessed 5 July 2018).

Ogle, H. 2016. Intermountain region cultural resource baseline documentation gap assessment. National Park Service, Denver, Colorado. Available at: https://irma.nps.gov/DataStore/DownloadFile/569648 (accessed 9 March 2019).

Pellant, M., P. Shaver, D. A. Pyke, and J. E. Herrick. 2005. Interpreting indicators of rangeland health, version 4. Technical Reference 1734-6. U.S. Department of the Interior, Bureau of Land Management, National Science and Technology Center, Denver, CO. BLM/WO/ST-00/001+1734/REV05. 122 pp. Available at: https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1043944.pdf (accessed 10 March 2019).

Porter, E., and A. Wondrak-Biel. 2011. Air quality monitoring protocol and standard operating procedures for the Sonoran Desert, Southern Plains, and Chihuahuan Desert networks. Version 2.00. Natural Resource Report NPS/SODN/NRTR—2011/390. National Park Service, Fort Collins, Colorado. Available at: https://science.nature.nps.gov/im/units/chdn/publications.cfm?tab=1&ProtocolAirQuality=open#ProtocolAirQuality (accessed 24 August 2018).

Potyondy, J. P. and T. W. Geier. 2011. Watershed condition classification technical guide. U.S. Department of Agriculture, U.S. Forest Service, Washington, D.C. Available at: https://www.fs.fed.us/biology/resources/pubs/watershed/maps/watershed_classification_guide2011FS978.pdf (accessed 20 November 2018).

Prein, A. F., G. J. Holland, R. M. Rasmussen, M. P. Clark, and M. R. Tye. 2016. Running dry: the U.S. Southwest's drift into a drier climate. Geophysical Research Letters 43: 1-8. Available at: https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1002/2015GL066727 (accessed 29 April 2018).

Rao, L.E., E.B. Allen, and T. Meixner. 2010. Risk-based determination of critical nitrogen deposition loads for fire spread in southern California deserts. Ecological Applications 20:1320–1335.

Ratcliff, F. 1972. Contour and contrast. Scientific American 226: 91-101.

Raup, Robert B. Jr. 1959. Some geologic features of the Tonto National Monument, Gila County, Arizona, unpublished report, 30 pp. as cited in Martin (2001).

Ribe, R. G. 2005. Aesthetic perceptions of green-tree retention harvests in vista views: The interaction of cut level, retention pattern, and harvest shape. Landscape and Urban Planning 73:277-293. Available at: https://ac.els-cdn.com/S0169204604000970/1-s2.0-S0169204604000970-main.pdf?_tid=8184b46c-593d-42b0-a6b3-efaf22e9115c&acdnat=1530830056_f6188eeeade305c480269efa47551ed7 (accessed 5 July 2018).

Richard, S.M., T.C. Shipman, L.C. Greene, and R.C. Harris. 2007. Estimated depth to bedrock in Arizona. Arizona Geological Survey Digital Geologic Map Series DGM-52, Version 1.0.

Romagosa, C. M.. 2012. Eurasian collared-dove (*Streptopelia decaocto*), version 2.0. The Birds of North America (P. G. Rodewald, editor). Cornell Lab of Ornithology, Ithaca, New York, USA. Available at: https://doi.org/10.2173/bna.630 (accessed 19 October 2018).

Royal Commission on Environmental Pollution. 2009. Artificial light in the environment. The Stationery Office Limited, London. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/228832/9780108508547.pdf.pdf (accessed 15 May 2018).

Rutenbeck, T. 1985. Structural monitoring of cliff and ruins - 1985. Tonto National Monument. Western Archeological and Conservation Center, Tucson, Arizona.

Rutenbeck, T. 1993. Structural movement monitoring, National Park Service, Southern Arizona Group. Bureau of Reclamation.

Ryan, R. L. 2006. Comparing the attitudes of local residents, planners, and developers about preserving rural character in New England. Landscape and Urban Planning 75: 5-22.

Santucci, V. L., J. P. Kenworth, and A. L. Mims. 2009. Monitoring in situ paleontological resources. The Geological Society of America. Available at: https://www.nps.gov/subjects/fossils/upload/geomon-08.pdf (accessed 10 March 2019).

Schauman, S. 1979. The countryside visual resource. In Proceedings of our national landscape: a conference on applied techniques for analysis and management of the visual resource, General Technical Report PSW-35, Pacific Southwest Forest and Range Experiment Station, Forest Service, USDA, Berkeley, California. Available at: https://www.fs.fed.us/psw/publications/documents/psw_gtr035/psw_gtr035_fm.pdf (accessed 5 July 2018).

Schwinning, S., B.I. Starr, N.J. Wojcik, M.E. Miller, J.E. Ehleringer, and R.L. Sanford. 2005. Effects of nitrogen deposition on an arid grassland in the Colorado plateau cold desert. Rangeland Ecology and Management. 58: 565–574.

Sekercioglu, C. H. 2002. Impacts of birdwatching on human and avian communities. Environmental Conservation 29:282–289. Available at: https://web.stanford.edu/~cagan/SekerciogluOrniTourismEnvCons2002.pdf (accessed 19 October 2018).

Selin, N.E. 2009. Global biogeochemical cycling of mercury: a review. Annual Review of Environment and Resources 34:43.

Sheibley, R.W., M. Enache, P.W. Swarzenski, P.W. Moran, and J.R. Foreman, 2014. Nitrogen deposition effects on diatom communities in lakes from three national parks in Washington State. Water, Air, & Soil Pollution 225:1857. Available at: https://link.springer.com/article/10.1007/s11270-013-1857-x (accessed 24 August 2018).

Sheppard, S. R. J. 2001. Beyond visual resource management: Emerging theories of an ecological aesthetic and visible stewardship. In Sheppard, S. R. J. and H. W. Harshaw, Eds., Forests and Landscapes: Linking Ecology, Sustainability and Aesthetics. CABI Publishing, New York.

Schuurman, G. and J. Wu. 2018. Birds and climate change: Tonto National Monument. Available at: https://www.nps.gov/subjects/climatechange/upload/TONT_2018_Birds_-_CC_508Compliant.pdf (accessed 19 October 2018).

Skagen, S. K., C. P. Melcher, W. H. Howe, and F. L. Knopf. 1998. Comparative use of riparian corridors and oases by migrating birds in southeastern Arizona. Conservation Biology 12:896–909. Available at: https://www.fort.usgs.gov/sites/default/files/products/publications/3160/3160.pdf (accessed 19 October 2018).

Society for the Study of Amphibians and Reptiles (SSAR). 2019. SSAR North American standard English and scientific names database. Available at: https://ssarherps.org/cndb/ (accessed 15 April 2019).

Stortz, S. D., C. E. Aslan, T. D. Sisk, T. A. Chaudhry, J. M. Rundall, J. Palumbo, L. Zachmann, and B. Dickson. 2018. Natural resource condition assessment: Greater Grand Canyon landscape assessment. Natural Resource Report. NPS/GRCA/NRR—2018/1645. National Park Service. Fort Collins, Colorado. Available at: https://irma.nps.gov/DataStore/DownloadFile/601805 (accessed 19 June 2019).

Strong, J. S. and S. J. Leroux. 2014. Impact of non-native terrestrial mammals on the structure of the terrestrial mammal food web of Newfoundland, Canada. PLoS ONE 9: e106264. doi:10.1371/journal.pone.0106264. Available at: https://journals.plos.org/plosone/article/file?id=10.1371/journal.pone.0106264&type=printable (accessed 6 February 2019).

Studd, S. E., J. A. Hubbard, B. Fallon, S. Drake, and M. Villarreal. 2017. Vegetation inventory, mapping, and characterization report, Tonto National Monument. Natural Resource Report NPS/SODN/NRR-2017/1498. National Park Service, Fort Collins, Colorado. Available at: https://irma.nps.gov/DataStore/Reference/Profile/2243620 (accessed 5 July 2018).

Sullivan, T. J. 2016. Air quality related values (AQRVs) for Sonoran Desert Network (SODN) parks: Effects from ozone; visibility reducing particles; and atmospheric deposition of acids, nutrients and toxics. Natural Resource Report NPS/SODN/NRR—2016/1193. National Park Service, Fort Collins, Colorado. Available at: https://irma.nps.gov/DataStore/Reference/Profile/2229119 (accessed 16 August 2018).

Swann, D. E., C. R. Schwalbe, R. C. Murray, and W. W. Shaw. 1996. An inventory of the terrestrial vertebrates at Tonto National Monument, Arizona. Cooperative Park Studies Unit, University of Arizona, Tucson, Arizona.

Taylor, K. A. 2017. National Park Service air quality analysis methods: August 2017. Natural Resource Report NPS/NRSS/ARD/NRR—2017/1490. National Park Service, Fort Collins, Colorado. Available at: https://www.nature.nps.gov/air/data/products/methods.cfm (accessed 24 August 2018).

Theobald, D.M. 2005. Landscape patterns of exurban growth in the USA from 1980 to 2020. Ecology and Society 10:32. Available at: https://www.ecologyandsociety.org/vol10/iss1/art32/ (accessed 5 July 2018).

Tweet, J. S., V. L. Santucci, and J. P. Kenworthy. 2008. Paleontological resource inventory and monitoring—Sonoran Desert Network. Natural Resource Technical Report NPS/NRPC/NRTR—2008/130. National Park Service, Fort Collins, Colorado.

U.S. Census Bureau. 2017. 2017 TIGER/Line Shapefiles: Roads. Available at: https://www.census.gov/cgi-bin/geo/shapefiles/index.php?year=2016&layergroup=Roads (accessed 5 July 2018).

U.S. Census Bureau. 2018. Quick facts. Available at: https://www.census.gov/quickfacts/fact/table/globecityarizona/PST045218 (accessed 27 January 2019).

U.S. Department of Agriculture (USDA). 2018. Resolution Copper project and land exchange environmental impact statement. Available at: http://www.resolutionmineeis.us/ (accessed 24 August 2018).

U.S. Environmental Protection Agency (USEPA). 2014. Policy assessment for the review of the ozone national ambient air quality standards. EPA-452/R-14-006. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Available at: http://www.epa.gov/ttn/naaqs/standards/ozone/data/20140829pa.pdf (accessed 24 August 2018).

U.S. Environmental Protection Agency (USEPA). 2016. National ambient air quality standards (NAAQS). Available at: https://www.epa.gov/criteria-air-pollutants/naaqs-table (accessed 24 August 2018).

U.S. Environmental Protection Agency (USEPA). 2017. Acid rain. Available at: https://www.epa.gov/acidrain/what-acid-rain (accessed 31 January 2018).

U.S. Fish and Wildlife Service (USFWS). 2012. Mexican spotted owl recovery plan, first revision (*Strix occidentalis lucida*). Southwest Region, USFWS, Albuquerque, New Mexico. Available at: https://www.fws.gov/southwest/es/arizona/Documents/SpeciesDocs/MSO/2012MSO_Recovery_Plan_First_Revision_Final.pdf(accessed 19 October 2018).

U.S. Fish and Wildlife Service (USFWS). 2018a. Species profile for Mexican spotted owl (*Strix occidentalis lucida*). Available at: https://ecos.fws.gov/ecp0/profile/speciesProfile?spcode=B074 (accessed 19 October 2018).

U.S. Fish and Wildlife Service (USFWS). 2018b. Species profile for yellow-billed cuckoo (*Coccyzus americanus*). Available at: https://ecos.fws.gov/ecp0/profile/speciesProfile?spcode=B06R (accessed 19 October 2018).

U.S. Fish and Wildlife Service (USFWS). 2018c. Threats to birds, migratory birds mortality- questions and answers. Available at: https://www.fws.gov/birds/bird-enthusiasts/threats-to-birds.php (accessed 19 October 2018).

U.S. Fish and Wildlife Service (USFWS). 2019a. Listed species believed or known to occur in Arizona. Available at: https://ecos.fws.gov/ecp0/reports/species-listed-by-state-report?state=AZ&status=listed (accessed 19 March 2019).

U.S. Fish and Wildlife Service (USFWS). 2019b. White-nose syndrome response team. Available at: https://www.whitenosesyndrome.org/ (accessed 20 March 2019).

U.S. Fish and Wildlife Service (USFWS). 2019c. Mexican wolf monthly updates. Available at: https://fws.maps.arcgis.com/apps/webappviewer/index.html?id=e87092240501466abd4606dcdb50ce98 (accessed 20 March 2019).

U.S. Fish and Wildlife Service (USFWS). 2019d. Ocelot (*Leopardus* (=*Felis*) *pardalis*). Available at: https://ecos.fws.gov/ecp0/profile/speciesProfile?spcode=A084 (accessed 20 March 2019).

U.S. Fish and Wildlife Service (USFWS). 2019e. Jaguar (*Panthera onca*). Available at: https://ecos.fws.gov/ecp0/profile/speciesProfile?spcode=A040 (accessed 20 March 2019).

U.S. Forest Service (USFS). no date. Mammals of the Tonto National Forest. Available at: https://www.fs.usda.gov/detail/tonto/learning/nature-science/?cid=fsbdev3_018781 (accessed 20 March 2019).

U.S. Forest Service (USFS). 1992a. Potential impacts of aircraft overflights of National Forest System wildernesses. Report to Congress. Available at: https://www.fs.fed.us/eng/pubs/pdfimage/92231208.pdf (accessed 10 March 2019). Geology

U.S. Forest Service (USFS). 1992b. Birds of the Tonto National Forest: a checklist. Available at: https://www.fs.usda.gov/detail/tonto/learning/nature-science/?cid=fsbdev3_018779 (accessed 19 October 2018).

U.S. Forest Service (USFS). 1995. Landscape aesthetics: a handbook for scenery management. Agricultural Handbook 710. Available at: https://www.fs.fed.us/cdt/carrying_capacity/landscape_aesthetics_handbook_701_no_append.pdf (accessed 5 July 2018).

U.S. Forest Service (USFS). 2011. Watershed condition and prioritization interactive map. U.S. Forest Service, Washington, D.C. Available at: https://www.fs.fed.us/biology/watershed/condition_framework.html (accessed 20 November 2018).

U.S. Forest Service (USFS). 2018. Scoping letter-Bighorn sheep population management. Tonto National Forest, Phoenix, Arizona. Available at: https://www.fs.usda.gov/nfs/11558/www/nepa/98402_FSPLT3_1632553.pdf (accessed 20 March 2019).

U.S. Forest Service (USFS). 2019. InciWeb, Woodbury fire. Available at: https://inciweb.nwcg.gov/incident/6382/ (accessed 30 June 2019).

U.S. Geological Survey (USGS). 2012. A summary of the relationship between GAP Status Codes and IUCN Definitions. Available at: http:// gapanalysis.usgs.gov/blog/iucn-definitions/(accessed 5 July 2018).

U.S. Geological Survey (USGS). 2015. Predicted surface water methylmercury concentrations in National Park Service Inventory and Monitoring Program Parks. Last modified February 20, 2015. U.S. Geological Survey. Wisconsin Water Science Center, Middleton, WI. Available at: http://wi.water.usgs.gov/mercury/NPSHgMap.html (accessed 24 August 2018).

U.S. Geological Survey (USGS), Gap Analysis Program (GAP). 2016. Protected Areas Database of the United States (PAD-US), version 1.4 Combined Feature Class. Available at: http://gapanalysis.usgs.gov/padus/data/download/ (accessed 5 July 2018).

U.S. Geological Survey (USGS). 2018a. The National Map Viewer. Available at: http://viewer.nationalmap.gov/basic/?basemap=b1&category=ned,nedsrc&title=3DEP%20View#productGroupSearch (accessed 4 July 2018).

U.S. Geological Survey (USGS). 2018b. Earthquake hazards map. Available at: https://earthquake.usgs.gov/hazards/hazmaps/conterminous/2014/images/HazardMap2014_lg.jpg (accessed 10 March 2019).

U.S. Geological Survey (USGS). 2018c. The USGS water science school. Available at: https://water.usgs.gov/edu/mwater.html (accessed 19 November 2018).

U.S. Geological Survey (USGS). 2018d. Hydrologic unit maps. Available at: https://water.usgs.gov/GIS/huc.html (accessed 20 November 2018).

van Riper, C., III., Hatten, J.R., Giermakowski, J.T., Mattson, D., Holmes, J.A., Johnson, M.J., Nowak, E.M., Ironside, K., Peters, M., Heinrich, P., Cole, K.L., Truettner, C., and Schwalbe, C.R. 2014. Projecting climate effects on birds and reptiles of the Southwestern United States: U.S. Geological Survey Open-File Report 2014-1050. Available at: http://dx.doi.org/10.3133/ofr20141050 (accessed 5 June 2019).

Virden, R. J. and G. J. Walker. 1999. Ethnic/racial and gender variations among meanings given to, and preferences for, the natural environment. Leisure Sciences 21:219-239. Available at: https://www.tandfonline.com/doi/abs/10.1080/014904099273110 (accessed 5 July 2018).

Wild Sheep Working Group. 2015. Records of wild sheep translocations-United States and Canada, 1922-present. Western Association of Fish and Wildlife Agencies, USA. Available at: https://www.wildsheepfoundation.org/cache/DOC25_RecordsofWildSheepTranslocations-UnitedStatesandCanada,1922-Present-Reduced.pdf?20160620034332 (accessed 13 April 2019).

Wildlife Society. 2011. Ecological impacts of feral cats. Two-page fact sheet. Available at: http://www.wildlife.org/policy/fact-sheets (accessed 19 October 2018).

Wittmer, G. W. and W. C. Pitt. 2012. Invasive rodents in the United States: ecology, impacts, and management. Pages 15-20 in J. Blanco. and A. Fernandes, editors. Invasive Species: Threats, Ecological Impacts and Control Methods.Nova Science Publishers, Inc., NY. Available at: https://www.aphis.usda.gov/wildlife_damage/nwrc/publications/14pubs/14-132%20witmer.pdf (accessed 6 February 2019).

Wondrak-Biel, A. 2005. Aesthetic conservation and the National Park Service. Yellowstone Science 13(3):1. Available at: https://www.nps.gov/yell/learn/upload/YS_13_3_sm.pdf (accessed 12 July 2018).

Worden, C. B. and D. J. Wald. 2016. ShakeMap manual online: technical manual, user's guide, and software guide, U. S. Geological Survey. Available at: http://usgs.github.io/shakemap/manual3_5/index.html (accessed 6 March 2019).

Wu, J. X., C. B. Wilsey, L. Taylor, and G. W. Schuurman. 2018. Projected avifaunal responses to climate change across the U.S. National Park System. PLoS ONE 13: e0190557. Available at: https://doi.org/10.1371/journal.pone.0190557 (accessed 19 October 2018).

Zaimes, G. N., M. A. Crimmins, D. M. Green, M. Nichols. 2007. Understanding Arizona's riparian areas. The University of Arizona, Arizona Cooperative Extension, College of Agriculture and Life Sciences. Tucson, Arizona. Available at: https://extension.arizona.edu/sites/extension.arizona.edu/files/pubs/az1432.pdf (accessed 20 November 2018).

Zube, E. H., J. L. Sell, and J. G. Taylor. 1982. Landscape perception: Research, application, and theory. Landscape Planning 9:1-33. Available at: https://ac.els-cdn.com/0304392482900090/1-s2.0-0304392482900090-main.pdf?_tid=6d3195f1-5542-4b2e-8128-52203e2f7c78&acdnat=1530827676_9d20168d80c9154aac78faaa1e5d698e (accessed 5 July 2018).

Appendix A. Scoping Meeting Participants and Report Reviewers

Table A-1. Scoping meeting participants.

Name	Affiliation and Position Title
Lisa Baril	Utah State University, Wildlife Biologist and Writer/Editor
Phyllis Pineda Bovin	National Park Service WASO Denver Service Center Planning Division, Natural Resource Specialist
Mark Brunson	Utah State University, Professor and Principal Investigator
Brett Cockrell	Tonto National Monument, Chief of Resources
Andy Hubbard	National Park Service Sonoran Desert Inventory and Monitoring Network, Program Manager
Duane Hubbard	Tonto National Monument, Superintendent
Stephanie Mack	Tonto National Monument, Archaeological Technician
Bianca Sicich	Tonto National Monument, Student Conservation Association Intern
Kim Struthers	Utah State University, NRCA Project Coordinator and Writer/Editor

Table A-2. Report reviewers.

Name	Affiliation and Position Title	Sections Reviewed or Other Role
Jeff Albright	National Park Service Water Resources Division, Natural Resource Condition Assessment Series Coordinator	Washington-level Program Manager
Phyllis Pineda Bovin	National Park Service WASO Denver Service Center Planning Division, Natural Resource Specialist	Regional Program Level Coordinator and Peer Review Manager
Kelly Adams and Todd Wilson	National Park Service, Grants and Contracting Officers	Executed Agreements
Fagan Johnson	National Park Service Inventory & Monitoring Division, Web and Report Specialist	Washington-level Publishing and 508 Compliance Review
Alyssa S. McGinnity	Contractor to National Park Service, Managed Business Solutions, a Sealaska Company	Washington-level Publishing and 508 Compliance Review
Brett Cockrell	National Park Service Tonto National Monument, Chief of Resources	Park Expert Reviewer
Stephanie Mack	National Park Service Tonto National Monument, Archaeological Technician	Park Expert Reviewer
Kara Raymond	National Park Service Southern Arizona Office, Hydrologist	Air Quality, Birds, Cave Canyon, Upland Vegetation, Herpetofauna, Mammals, Geology Assessments
Ksienya Taylor	National Park Service Air Resources Division, Natural Resource Specialist	Air Quality, Viewshed Assessments
Sallie Hejl	National Park Service Desert Southwest Cooperative Ecosystem Studies Unit, Research Coordinator	Birds Assessment
Li-Wei Hung	National Park Service Natural Sounds and Night Skies Division, Night Sky Research Scientist	Night Sky Assessment and Data
Danny Martin	National Park Service Organ Pipe Cactus National Monument, Wildlife Program Manager	Herpetofauna
Elaine Leslie	National Park Service Natural Resource Stewardship and Science	Mammals Assessment
Tim Connors	National Park Service Geologic Resources Division, Geologist	Geology Assessment
Sarah Studd	National Park Service Sonoran Desert Inventory and Monitoring Network, Vegetation Ecologist	Cave Canyon Assessment
Donna Shorrock	U.S. Forest Service, Rocky Mountain Regional Office, Regional Vegetation Ecologist, Research Natural Areas Coordinator	Upland Vegetation Assessment

Appendix B. Viewshed Analysis Steps

The process used to complete Tonto National Monument's viewshed analyses is listed below.

Downloaded eight of the 1/3 arc second national elevation dataset (NED) grid (roughly equivalent to a 30 m digital elevation model [DEM]) from U.S. Geological Survey's National Map Viewer (http://viewer.nationalmap.gov/basic/?basemap=b1&category=ned,nedsrc&title=3DEP%20View#productGroupSearch) (USGS 2018a) and created a mosaic dataset. The x and y values for the NED are in arc seconds while the z data are in meters. The DEMs were reprojected into NAD83 Albers Meter to get all data in meters and into a geographic extent that covered the entire area.

Prepared observation point layers for viewshed analyses by importing GPSd points for all vantage point locations selected for viewshed analysis. Exported data to a shapefile. Added field named "OFFSETA" (type = double) to shapefile and set value to an observer height of 1.68 m (~5'6"). ESRI (2016) provides a useful overview of the visibility analysis.

Ran Viewshed Analysis using the Viewshed Tool in ESRI's ArcGIS 10.2, Spatial Analyst Toolbox, ran viewsheds using the following inputs.

- Input raster = 1/3 arc second NED
- Input point observer feature = obs_point.shp.

The rasters were reclassified into visible areas only to create the maps. The area of analysis (AOA) was a 98 km (61 mi) buffer surrounding the monument, reprojected into the Albers Equal Area Conic USGS projection, then overlaid with the NPS NPScape's road, housing, and conservation status tools as described in NPS (2014a,b,c). A text attribute field was added to the AOA for the area of analysis identifier.

Housing (CONUS, Density, SERGoM, 1970 - 2100, Metric Data 9.3 File Geodatabase (Theobald 2005), U.S. Census Bureau 2017 TIGER/Line Shapefiles: Roads) (U.S. Census Bureau 2017), and conservation status (NPS 2014c, USGS GAP 2016) GIS datasets were downloaded from NPScape (NPS 2016) and the USGS GAP (USGS GAP 2016) websites. Standard Operating Procedures for all three tools were followed based on NPScape instructions (NPS 2014a,b,c).

Appendix C. Tonto National Monument Bird List

Listed in the table below are the bird species reported for Tonto National Monument (NM) according to NPSpecies (NPS 2018a), Albrecht et al. (2007), SODN survey data, and W. Moore (NPS intern). Scientific names were updated with the current taxonomy used by the American Ornithological Society (AOS 2018). A total of 193 species are contained within the table, but only the NPSpecies list (190) is certified (i.e., vetted for accuracy). Of the 190 species, 150 are considered "present", two species are considered "probably present", and 38 species are "unconfirmed". The additional three species were species observed during SODN's surveys, one of which was also observed by W. Moore.

Table C–1. Bird species list for Tonto NM.

Common Name	Scientific Name	NPSpecies Occurrence	NPSpecies Abundance	NPSpecies Status	BioInventory (2001–2002)[3]	SODN Surveys (2008–2015)[4]	W. Moore (Nov–April 2012–2018)[5]
Abert's towhee	*Melzone aberti*	Present	Uncommon	Breeder	X	X	X
Acorn woodpecker	*Melanerpes formicivorus*	Unconfirmed	–	–	–	–	–
American goldfinch	*Spinus tristis*	Unconfirmed	–	–	–	–	–
American kestrel	*Falco sparverius*	Present	Uncommon	Breeder	X	X	X
American robin	*Turdus migratorius*	Present	Uncommon	Migratory	–	–	–
American tree sparrow	*Spizella arborea*	Unconfirmed	–	–	–	–	–
American white pelican	*Pelecanus erythrorhynchos*	Present	Occasional	Migratory	–	–	–
Anna's hummingbird	*Calypte anna*	Present	Uncommon	Migratory	–	X	X
Ash–throated flycatcher	*Myiarchus cinerascens*	Present	Common	Breeder	X	X	X
Bald eagle	*Haliaeetus leucocephalus*	Present	Rare	Migratory	X	–	X
Band–tailed pigeon[1]	*Patagioenas fasciata*	Unconfirmed	–	–	–	–	–
Bank swallow	*Riparia riparia*	Present	Uncommon	Migratory	–	–	–
Barn owl	*Tyto alba*	Present	Uncommon	Breeder	X	–	–
Barn swallow	*Hirundo rustica*	Present	Common	Breeder	–	–	–
Bell's vireo	*Vireo bellii*	Present	Common	Breeder	X	X	X
Bewick's wren	*Thryomanes bewickii*	Present	Common	Breeder	X	X	X
Black phoebe	*Sayornis nigricans*	Present	Rare	Migratory	–	–	–
Black–and–white warbler	*Mniotilta varia*	Unconfirmed	–	–	–	–	–
Black–chinned hummingbird	*Archilochus alexandri*	Present	Common	Breeder	X	X	X
Black–chinned sparrow	*Spizella atrogularis*	Present	Uncommon	Breeder	X	X	X
Black–headed grosbeak	*Pheucticus melanocephalus*	Present	Uncommon	Migratory	X	X	X

[1] Species of concern (Latta et al. 1999).

[2] Non-native species.

[3] Albrecht et al. (2007).

[4] Data provided by K. Bonebrake, SODN data manager.

[5] Data provided by W. Moore.

Table C-1 continued. Bird species list for Tonto NM.

Common Name	Scientific Name	NPSpecies Occurrence	NPSpecies Abundance	NPSpecies Status	BioInventory (2001–2002)[3]	SODN Surveys (2008–2015)[4]	W. Moore (Nov–April 2012–2018)[5]
Black–tailed gnatcatcher	*Polioptila melanura*	Present	Common	Breeder	X	X	X
Black–throated gray warbler[1]	*Setophaga nigrescens*	Present	Uncommon	Migratory	X	X	X
Black–throated sparrow	*Amphispiza bilineata*	Present	Common	Breeder	X	X	X
Blue grosbeak	*Passerina caerulea*	Present	Uncommon	Breeder	X	X	–
Blue–gray gnatcatcher	*Polioptila caerulea*	Present	Uncommon	Breeder	X	X	X
Bohemian waxwing	*Bombycilla garrulus*	Unconfirmed	–	–	–	–	–
Brewer's blackbird	*Euphagus cyanocephalus*	Present	Rare	Migratory	–	–	–
Brewer's sparrow[1]	*Spizella breweri*	Present	Common	Resident	X	X	X
Bridled titmouse	*Baeolophus wollweberi*	Present	Occasional	Vagrant	–	–	–
Broad–tailed hummingbird	*Selasphorus platycercus*	Present	Uncommon	Migratory	X	X	–
Bronzed cowbird	*Molothrus aeneus*	Present	Uncommon	Breeder	–	–	–
Brown creeper	*Certhia americana*	Unconfirmed	–	–	–	–	–
Brown–crested flycatcher	*Myiarchus tyrannulus*	Present	Common	Breeder	X	X	–
Brown–headed cowbird	*Molothrus ater*	Present	Common	Breeder	X	X	X
Bullock's oriole	*Icterus bullockii*	Present	Common	Breeder	X	X	–
Bushtit	*Psaltriparus minimus*	Present	Rare	Resident	X	–	X
Cactus wren	*Campylorhynchus brunneicapillus*	Present	Common	Breeder	X	X	X
Canada goose	*Branta canadensis*	Unconfirmed	–	–	–	–	X
Canyon towhee	*Melozone fuscus*	Present	Common	Breeder	X	X	X
Canyon wren	*Catherpes mexicanus*	Present	Common	Breeder	X	X	X
Cassin's finch	*Haemorhous cassinii*	Present	Occasional	Migratory	–	–	–
Cassin's kingbird	*Tyrannus vociferans*	Present	Uncommon	Breeder	–	X	–
Cassin's vireo	*Vireo cassinii*	Present	Uncommon	Migratory	X	–	–
Cedar waxwing	*Bombycilla cedrorum*	Present	Rare	Migratory	–	–	–
Chipping sparrow	*Spizella passerina*	Present	Uncommon	Resident	X	X	X
Clark's nutcracker	*Nucifraga columbiana*	Unconfirmed	–	–	–	–	–

[1] Species of concern (Latta et al. 1999).

[2] Non-native species.

[3] Albrecht et al. (2007).

[4] Data provided by K. Bonebrake, SODN data manager.

[5] Data provided by W. Moore.

Table C-1 continued. Bird species list for Tonto NM.

Common Name	Scientific Name	NPSpecies Occurrence	NPSpecies Abundance	NPSpecies Status	BioInventory (2001–2002)[3]	SODN Surveys (2008–2015)[4]	W. Moore (Nov–April 2012–2018)[5]
Cliff swallow	*Petrochelidon pyrrhonota*	Present	Uncommon	Resident	X	–	–
Common black–hawk[1]	*Buteogallus anthracinus*	Not Listed	–	–	–	X	X
Common ground–dove	*Columbina passerina*	Present	Rare	Migratory	–	–	–
Common nighthawk	*Chordeiles minor*	Probably Present	–	–	–	–	–
Common poorwill	*Phalaenoptilus nuttallii*	Present	Common	Breeder	X	X	–
Common raven	*Corvus corax*	Present	Common	Breeder	X	X	X
Cooper's hawk	*Accipiter cooperii*	Present	Uncommon	Breeder	X	X	X
Cordilleran flycatcher[1]	*Empidonax occidentalis*	Unconfirmed	–	–	–	–	–
Costa's hummingbird[1]	*Calypte costae*	Present	Common	Breeder	X	X	X
Crissal thrasher	*Toxostoma crissale*	Present	Uncommon	Breeder	X	X	–
Curve–billed thrasher	*Toxostoma curvirostre*	Present	Common	Breeder	X	X	X
Dark–eyed junco	*Junco hyemalis*	Present	Uncommon	Resident	–	–	–
Double–crested cormorant	*Phalacrocorax auritus*	Present	Uncommon	Resident	–	X	–
Dusky flycatcher	*Empidonax oberholseri*	Present	Rare	Migratory	–	–	–
Elf owl	*Micrathene whitneyi*	Present	Common	Breeder	X	–	–
Eurasian collared–dove[2]	*Streptopelia decaocto*	Present	Occasional	–	–	X	X
European starling[2]	*Sturnus vulgaris*	Present	Uncommon	Breeder	–	–	–
Evening grosbeak	*Coccothraustes vespertinus*	Unconfirmed	–	–	–	–	–
Ferruginous hawk[1]	*Buteo regalis*	Unconfirmed	–	–	–	–	–
Ferruginous pygmy–owl	*Glaucidium brasilianum*	Unconfirmed	–	–	–	–	–
Franklin's gull	*Leucophaeus pipixcan*	Not Listed	–	–	–	X	–
Gambel's quail	*Callipepla gambelii*	Present	Common	Breeder	X	X	X
Gila woodpecker	*Melanerpes uropygialis*	Present	Common	Breeder	X	X	X
Gilded flicker[1]	*Colaptes chrysoides*	Present	Uncommon	Breeder	X	X	X
Golden eagle	*Aquila chrysaetos*	Present	Rare	Breeder	–	–	–

[1] Species of concern (Latta et al. 1999).

[2] Non-native species.

[3] Albrecht et al. (2007).

[4] Data provided by K. Bonebrake, SODN data manager.

[5] Data provided by W. Moore.

Table C-1 continued. ***Bird species list for Tonto NM.***

Common Name	Scientific Name	NPSpecies Occurrence	NPSpecies Abundance	NPSpecies Status	BioInventory (2001–2002)[3]	SODN Surveys (2008–2015)[4]	W. Moore (Nov–April 2012–2018)[5]
Golden–crowned sparrow	*Zonotrichia atricapilla*	Unconfirmed	–	–	–	–	–
Grace's warbler	*Setophaga graciae*	Unconfirmed	–	–	–	–	–
Gray flycatcher[1]	*Empidonax wrightii*	Present	Uncommon	Migratory	X	X	–
Gray hawk	*Buteo nitidus*	Present	Occasional	Vagrant	–	–	–
Gray vireo[1]	*Vireo vicinior*	Present	Uncommon	Breeder	X	X	X
Great blue heron	*Ardea herodias*	Present	Uncommon	Migratory	–	X	–
Great horned owl	*Bubo virginianus*	Present	Uncommon	Breeder	X	X	–
Greater pewee	*Contopus pertinax*	Not Listed	–	–	–	X	–
Greater roadrunner	*Geococcyx californianus*	Present	Uncommon	Breeder	X	X	X
Great–tailed grackle	*Quiscalus mexicanus*	Present	Uncommon	Resident	–	–	–
Green–tailed towhee	*Pipilo chlorurus*	Present	Uncommon	Resident	X	X	X
Hammond's flycatcher	*Empidonax hammondii*	Present	Rare	Migratory	–	X	–
Harris's hawk	*Parabuteo unicinctus*	Present	Rare	Resident	–	X	–
Hermit thrush	*Catharus guttatus*	Present	Uncommon	Resident	X	X	–
Hooded oriole	*Icterus cucullatus*	Present	Common	Breeder	X	X	X
House finch	*Haemorhous mexicanus*	Present	Common	Breeder	X	X	X
House sparrow[2]	*Passer domesticus*	Present	Uncommon	Breeder	–	X	–
House wren	*Troglodytes aedon*	Present	Uncommon	Resident	X	X	–
Hutton's vireo	*Vireo huttoni*	Present	Rare	Migratory	–	–	X
Indigo bunting	*Passerina cyanea*	Present	Occasional	Migratory	X	X	–
Ladder–backed woodpecker	*Picoides scalaris*	Present	Common	Breeder	X	X	X
Lark sparrow	*Chondestes grammacus*	Present	Uncommon	Migratory	–	X	–
Lawrence's goldfinch	*Carduelis lawrencei*	Unconfirmed	–	–	–	–	–
Lazuli bunting	*Passerina amoena*	Present	Uncommon	Migratory	X	X	X
Le Conte's thrasher[1]	*Toxostoma lecontei*	Unconfirmed	–	–	–	–	–
Lesser goldfinch	*Spinus psaltria*	Present	Common	Breeder	X	X	X
Lesser nighthawk	*Chordeiles acutipennis*	Present	Common	Breeder	–	X	–
Lincoln's sparrow	*Melospiza lincolnii*	Present	Uncommon	Resident	–	–	X

[1] Species of concern (Latta et al. 1999).

[2] Non-native species.

[3] Albrecht et al. (2007).

[4] Data provided by K. Bonebrake, SODN data manager.

[5] Data provided by W. Moore.

Table C-1 continued. Bird species list for Tonto NM.

Common Name	Scientific Name	NPSpecies Occurrence	NPSpecies Abundance	NPSpecies Status	BioInventory (2001–2002)[3]	SODN Surveys (2008–2015)[4]	W. Moore (Nov–April 2012–2018)[5]
Loggerhead shrike	*Lanius ludovicianus*	Present	Uncommon	Breeder	–	X	X
Lucy's warbler[1]	*Oreothlypis luciae*	Present	Common	Breeder	X	X	X
Macgillivray's warbler[1]	*Geothlypis tolmiei*	Present	Uncommon	Migratory	X	X	–
Mallard	*Anas platyrhynchos*	Present	Rare	Migratory	–	–	–
Merlin	*Falco columbarius*	Present	Occasional	Migratory	X	–	–
Mexican spotted owl[1]	*Strix occidentalis lucida*	Unconfirmed	–	–	–	–	–
Mountain bluebird	*Sialia currucoides*	Unconfirmed	–	–	–	–	–
Mountain chickadee	*Poecile gambeli*	Present	Occasional	Vagrant	–	–	–
Mourning dove	*Zenaida macroura*	Present	Abundant	Breeder	X	X	–
Nashville warbler	*Oreothlypis ruficapilla*	Present	Uncommon	Migratory	–	–	–
Northern beardless tyrannulet	*Camptostoma imberbe*	Present	Rare	Migratory	–	–	–
Northern cardinal	*Cardinalis cardinalis*	Present	Common	Breeder	X	X	X
Northern flicker	*Colaptes auratus*	Present	Uncommon	Resident	–	X	–
Northern goshawk[1]	*Accipiter gentilis*	Unconfirmed	–	–	–	–	–
Northern harrier	*Circus hudsonius*	Present	Rare	Migratory	–	–	X
Northern mockingbird	*Mimus polyglottos*	Present	Common	Breeder	X	X	X
Northern pygmy–owl	*Glaucidium gnoma*	Unconfirmed	–	–	–	–	–
Northern rough–winged swallow	*Stelgidopteryx serripennis*	Present	Uncommon	Resident	X	X	–
Oak titmouse	*Baeolophus inornatus*	Unconfirmed	–	–	–	–	–
Olive–sided flycatcher[1]	*Contopus cooperi*	Present	Rare	Migratory	X	–	–
Orange–crowned warbler	*Oreothlypis celata*	Present	Uncommon	Migratory	X	X	–
Osprey	*Pandion haliaetus*	Present	Uncommon	Migratory	–	–	–
Pacific–slope flycatcher	*Empidonax difficilis*	Present	Uncommon	Migratory	X	X	–
Painted bunting	*Passerina ciris*	Unconfirmed	–	–	–	–	–
Painted redstart	*Myioborus pictus*	Present	Occasional	Vagrant	–	X	X
Peregrine falcon	*Falco peregrinus*	Present	Rare	Breeder	X	–	–
Phainopepla	*Phainopepla nitens*	Present	Common	Breeder	X	X	X

[1] Species of concern (Latta et al. 1999).

[2] Non-native species.

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[4] Data provided by K. Bonebrake, SODN data manager.

[5] Data provided by W. Moore.

Table C-1 continued. Bird species list for Tonto NM.

Common Name	Scientific Name	NPSpecies Occurrence	NPSpecies Abundance	NPSpecies Status	BioInventory (2001–2002)[3]	SODN Surveys (2008–2015)[4]	W. Moore (Nov–April 2012–2018)[5]
Pine siskin	*Spinus pinus*	Present	Rare	Migratory	–	X	–
Pinyon jay[1]	*Gymnorhinus cyanocephalus*	Unconfirmed	–	–	–	–	–
Plumbeous vireo	*Vireo plumbeus*	Present	Uncommon	Migratory	X	X	–
Prairie falcon	*Falco mexicanus*	Present	Occasional	Migratory	–	–	–
Purple finch	*Haemorhous purpureus*	Unconfirmed	–	–	–	–	–
Purple martin[1]	*Progne subis*	Present	Uncommon	Breeder	–	–	–
Pyrrhuloxia	*Cardinalis sinuatus*	Present	Uncommon	Breeder	–	X	–
Red–breasted nuthatch	*Sitta canadensis*	Unconfirmed	–	–	–	–	–
Red–eyed vireo	*Vireo olivaceus*	Unconfirmed	–	–	–	–	–
Red–faced warbler[1]	*Cardellina rubrifrons*	Unconfirmed	–	–	–	–	–
Red–naped sapsucker[1]	*Sphyrapicus nuchalis*	Present	Occasional	Migratory	–	–	–
Red–tailed Hawk	*Buteo jamaicensis*	Present	Common	Breeder	X	X	X
Red–winged blackbird	*Agelaius phoeniceus*	Present	Rare	Migratory	–	–	–
Rock wren	*Salpinctes obsoletus*	Present	Common	Breeder	X	X	X
Ruby–crowned kinglet	*Regulus calendula*	Present	Uncommon	Resident	X	X	X
Rufous hummingbird	*Selasphorus rufus*	Present	Rare	Migratory	–	–	–
Rufous–backed robin	*Turdus rufopalliatus*	Unconfirmed	–	–	–	–	–
Rufous–crowned sparrow	*Aimophila ruficeps*	Present	Common	Breeder	X	X	X
Rufous–winged sparrow[1]	*Peucaea carpalis*	Present	Uncommon	–	X	X	–
Sage thrasher[1]	*Oreoscoptes montanus*	Unconfirmed	–	–	–	–	–
Say's phoebe	*Sayornis saya*	Present	Common	Breeder	X	X	X
Scaled quail	*Callipepla squamata*	Unconfirmed	–	–	–	–	–
Scarlet tanager	*Piranga olivacea*	Unconfirmed	–	–	X	–	–
Scott's oriole	*Icterus parisorum*	Present	Common	Breeder	X	X	X
Sharp–shinned hawk	*Accipiter striatus*	Present	Rare	Migratory	X	–	–
Song sparrow	*Melospiza melodia*	Unconfirmed	–	–	–	–	–
Spotted towhee	*Pipilo maculatus*	Present	Occasional	Vagrant	X	–	X
Steller's jay	*Cyanocitta stelleri*	Present	Occasional	Vagrant	–	–	–

[1] Species of concern (Latta et al. 1999).

[2] Non-native species.

[3] Albrecht et al. (2007).

[4] Data provided by K. Bonebrake, SODN data manager.

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Table C-1 continued. Bird species list for Tonto NM.

Common Name	Scientific Name	NPSpecies Occurrence	NPSpecies Abundance	NPSpecies Status	BioInventory (2001–2002)[3]	SODN Surveys (2008–2015)[4]	W. Moore (Nov–April 2012–2018)[5]
Summer tanager	*Piranga rubra*	Present	Uncommon	Breeder	X	X	X
Swainson's hawk	*Buteo swainsoni*	Present	Rare	Migratory	–	–	–
Swainson's thrush[1]	*Catharus ustulatus*	Present	Rare	Migratory	–	X	–
Thick–billed kingbird	*Tyrannus crassirostris*	Present	Occasional	Vagrant	–	–	–
Townsend's solitaire	*Myadestes townsendi*	Present	Occasional	Migratory	X	–	–
Townsend's warbler	*Setophaga townsendi*	Present	Rare	Migratory	X	X	X
Turkey vulture	*Cathartes aura*	Present	Common	Breeder	X	X	X
Vaux's swift	*Chaetura vauxi*	Present	Uncommon	Migratory	–	X	–
Verdin	*Auriparus flaviceps*	Present	Common	Breeder	X	X	X
Vermilion flycatcher	*Pyrocephalus rubinus*	Present	Rare	Breeder	–	–	–
Violet–green swallow	*Tachycineta thalassina*	Present	Uncommon	Migratory	X	X	–
Virginia's warbler	*Oreothlypis virginiae*	Present	Uncommon	Migratory	X	X	X
Warbling vireo	*Vireo gilvus*	Present	Uncommon	Migratory	X	X	–
Western bluebird	*Sialia mexicana*	Present	Occasional	Migratory	–	–	–
Western kingbird	*Tyrannus verticalis*	Present	Common	Breeder	X	X	X
Western meadowlark	*Sturnella neglecta*	Present	Rare	Migratory	–	–	–
Western screech–owl	*Megascops kennicottii*	Present	Uncommon	Breeder	X	X	–
Western tanager	*Piranga ludoviciana*	Present	Uncommon	Migratory	X	X	–
Western wood–pewee	*Contopus sordidulus*	Present	Uncommon	Migratory	X	X	–
Whiskered screech–owl	*Megascops trichopsis*	Unconfirmed	–	–	–	–	–
White–breasted nuthatch	*Sitta carolinensis*	Probably Present	–	–	–	–	–
White–crowned sparrow	*Zonotrichia leucophrys*	Present	Common	Resident	X	X	X
White–throated sparrow	*Zonotrichia albicollis*	Unconfirmed	–	–	–	–	–
White–throated swift	*Aeronautes saxatalis*	Present	Common	Breeder	X	X	X
White–winged dove	*Zenaida asiatica*	Present	Abundant	Breeder	X	X	X
Wild turkey	*Meleagris gallopavo*	Unconfirmed	–	–	–	–	–
Wilson's warbler	*Cardellina pusilla*	Present	Uncommon	Migratory	X	X	X

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Table C-1 continued. ***Bird species list for Tonto NM.***

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Wood stork	*Mycteria americana*	Unconfirmed	–	–	–	–	–
Woodhouse's scrub jay	*Aphelocoma woodhouseii*	Present	Rare	Migratory	X	X	X
Yellow warbler	*Setophaga petechia*	Present	Uncommon	Migratory	X	X	–
Yellow–bellied sapsucker	*Sphyrapicus varius*	Present	Occasional	Vagrant	–	–	–
Yellow–billed cuckoo[1]	*Coccyzus americanus*	Present	Occasional	Migratory	–	–	–
Yellow–breasted chat	*Icteria virens*	Present	Uncommon	Migratory	X	X	–
Yellow–eyed junco	*Junco phaeonotus*	Unconfirmed	–	–	X	–	–
Yellow–headed blackbird	*Xanthocephalus xanthocephalus*	Present	Uncommon	Migratory	X	–	–
Yellow–rumped warbler	*Setophaga coronata*	Present	Common	Resident	X	X	–
Yellow–throated vireo	*Vireo flavifrons*	Present	Occasional	Vagrant	X	–	–
Zone–tailed hawk	*Buteo albonotatus*	Present	Uncommon	Breeder	X	X	–

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