National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Montezuma Castle and Tuzigoot National Monuments

Natural Resource Condition Assessment

Natural Resource Report NPS/SODN/NRR—2019/1966

ON THE COVER

View from Tuzigoot pueblo (top). Montezuma Castle (left). Montezuma Well (right). Photo Credits: NPS.

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Natural Resource Report NPS/SODN/NRR—2019/1966

Prepared by
Lisa Baril[1], Kimberly Struthers[1], Andy Hubbard[2], Anna Mateljak[2], Deborah Angell[2], Cheryl McIntyre[2], and Mark Brunson[1]

[1]Department of Environment & Society
Utah State University
5215 Old Main Hill
Logan, UT 84322-5215

[2] Sonoran Desert Network
National Park Service
12661 E. Broadway Blvd.
Tucson, AZ 85748

Edited by
Kimberly Struthers and Lisa Baril

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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 the co-administered Tuzigoot and Montezuma Castle National Monuments (NMs) was initiated in 2010 as a collaborative effort between monument staff, the National Park Service Sonoran Desert Inventory and Monitoring Network (SODN) staff, NPS Intermountain Region, and the Sonoran Institute. Ten focal natural resources were selected for condition assessment reporting, and in 2017, Utah State University was added as a partner to complete the monuments' combined NRCA report.

Montezuma Castle was established as a national monument in 1906 because of "... the prehistoric structure known as Montezuma's Castle... is of the greatest ethnological value and scientific interest." In 1939, Tuzigoot NM was established to preserve "... historic and prehistoric structures and other objects of historic or scientific interest ..." and is one of the largest known pueblos of Sinaguan origin built during the period A.D. 1100-1450 and serves as a benchmark of the Tuzigoot Phase of the archeological record. Another unit, Montezuma Well, was added in 1943 and is a large spring in an otherwise arid region in Arizona.

In addition to the monuments' significant cultural resources, the natural resources are also significant. Tuzigoot NM includes a stretch of the Verde River, the only Wild and Scenic River in Arizona, and Montezuma Castle includes two of the river's tributaries, Beaver Creek and Wet Beaver Creek. Diverse assemblages of vegetation, mammals, birds, amphibians, and reptiles offer amazing opportunities for scientific inquiry and interpreting the relationship between the long history of human habitation throughout the Verde Valley and the area's environment.

The national monuments' 10 natural resources evaluated for current conditions were grouped into three broad categories: landscapes (i.e., landscape dynamics and air quality), supporting environment (i.e., hydrology and water quality), and biological integrity (i.e., vegetation and wildlife topics). The majority of resources were found to be in good condition or of moderate concern. Exceptions include fish due to the low diversity of species, which is considered to be of significant concern, and aspects of riparian vegetation due to the presence of invasive, non-native plants.

Maintaining or improving the monuments' resource conditions in light of rapidly changing environmental conditions, such as invasive plants and animals, increasing temperatures, decreasing precipitation, and land use change is challenging. The monuments' proximity to the Coconino National Forest provides outstanding opportunities for developing partnerships to achieve shared conservation goals. With the number of landscape-scale changes that are occurring, landscape-scale coordination of resource protection is paramount to resource preservation.

Acknowledgements

We thank Tina Greenawalt, Chief of Natural Resources at Montezuma Castle and Tuzigoot National Monuments. We also thank the National Park Service's (NPS) Sonoran Desert Inventory and Monitoring Network (SODN) staff, Andy Hubbard, Sarah Studd, Evan Gwilliam, and Alice Wondrak Biel, and former staff, Kristen Bonebrake, Debbie Angell and Anna Mateljak, for their assistance in gathering data; establishing indicators, measures, and reference conditions; and for reviewing drafts of the assessments and chapters, and in some cases, providing an initial condition assessment draft. SODN's inventory and/or monitoring data informed current conditions for several of the monument's water, wildlife, and vegetation topics.

Kara Raymond, hydrologist with the NPS Southern Arizona Office, provided timely expert reviews and information for assessment topics. Phyllis Pineda Bovin, NPS Intermountain Region Office (former) Natural Resource Condition Assessment Coordinator (NRCA), 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 Montezuma Castle and Tuzigoot NMs' NRCA report.

Montezuma Well. Photo Credit: NPS/Joseph Reynolds.

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.

However, it is important to note that NRCAs do not establish management targets for study indicators. That process must occur through park planning

Sunflowers. Photo Credit: NPS.

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.

Tuzigoot pueblo. Photo Credit: NPS.

Introduction and Resource Setting

Introduction

Enabling Legislation/Executive Orders

Between A.D. 600 and A.D. 1450, the Hohokam and Sinagua peoples settled in the Verde Valley of central Arizona where the rich riparian areas and adjacent uplands provided resources for daily life. Making extensive use of the freshwater in the area, they developed primitive irrigation systems to farm the adjacent floodplains of Beaver Creek. They also built imposing cliff dwellings and pueblos for shelter, which were abandoned around A.D. 1450. In order to preserve these prehistoric ruins, three sites were set aside as national monuments.

On December 8, 1906, Presidential Proclamation No. 696 (34 Stat. 3265) established Montezuma Castle National Monument (NM) because "... the prehistoric structure known as Montezuma's Castle . . . is of the greatest ethnological value and scientific interest" and also reserved "as much land as may be necessary for the proper protection thereof." Despite the fact that the cliff dwellings were not associated with the Aztec emperor Montezuma, early settlers to the area assumed that they were. In fact, the castle was abandoned almost a century before Montezuma was born.

Subsequent to the original designation, additional lands were added to the monument. In 1937, 182 ha (450 ac) "required for the proper care, management, and protection of said prehistoric ruins and ancient cliff dwellings" were added by Presidential Proclamation No. 2226 (50 Stat. 1817). "In order to facilitate the administration and protection" of the monument, Congress added 17 ha (42 ac) of land near Beaver Creek in 1959 (73 Stat. 108). In 1978, Public Law 95-625 (92 Stat. 3473) added approximately 5.3 ha (13 ac) to incorporate fossil mammal tracks and excluded approximately 2 ha (5 ac) for use as right-of-way for the Interstate 17 (I-17) freeway. In December, 2003, the boundary was again adjusted to include an additional 63.5 ha (157 ac) to further protect the Beaver Creek riparian areas (Public Law 108-190).

On October 19, 1943, the acquisition of property (approximately 72.8 ha; 180 ac) containing Montezuma Well, along with another 32.4 ha (80 ac) of government-owned land, was authorized by an Act of Congress (57 Stat. 572) to become a detached unit of Montezuma Castle NM. In 1959, an Act of Congress (73 Stat. 108) authorized the addition of another 6.9 ha (17 ac) "to facilitate the administration and protection" of the monument. This land has not yet been acquired and remains in private ownership.

Montezuma Castle NM comprises two sites, the Montezuma Castle unit and the Montezuma Well unit. The Castle unit preserves a 20-room, 5-story Sinaguan cliff dwelling that is the largest, most accessible, and best preserved Sinaguan cliff dwelling in the Southwest, as well as one of the best preserved cliff dwellings in North America. The Montezuma Well unit preserves an unusual example of a large spring-fed limestone sink as well as prehistoric Hohokam and Sinagua-period ruins and sites and historic Apache sites.

On July 25, 1939, Presidential Proclamation No. 2344 (53 Stat. 2548) established Tuzigoot National Monument (NM) by setting aside approximately 17.4 ha (43 ac) to preserve "… historic and prehistoric structures and other objects of historic or scientific interest . . ." as "it would be in the public interest to reserve such lands as a national monument." In 1965, an Act of Congress added a 6-ha (15-ac) donation easement for the entrance road to the monument.

In 1978, Public Law 95-625 authorized the acquisition of approximately 320 ha (791 ac) of additional land to expand the boundary of the monument. In December, 2005, 131 ha (324 ac) within Tuzigoot's expanded boundary were acquired through a land exchange with Phelps Dodge Corporation (now Freeport McMoRan Copper and Gold, Inc.) as mitigation for a mining project. Proposed by Phelps Dodge in 1994, the exchange was finalized in 2005 when the Bureau of Land Management completed the National Environmental Policy Act process on the mining project. Tavasci Marsh was later incorporated into the boundaries of the monument.

Tuzigoot NM is one of the largest known pueblos of Sinaguan origin built during the period A.D. 1100-1450, and it serves as a benchmark of the Tuzigoot Phase of the archeological record. The pueblo originally consisted of 100 rooms including second and third story structures. The first buildings were built around A.D. 1000. In the 1930s, archeologists Louis Caywood and Edward Spicer excavated the site and named the pueblo "Tuzigoot," the Tonto Apache name for nearby Peck's Lake that means "crooked water."

These two monuments illustrate the importance of water and riparian habitat to the Sinaguan people for farming and wild foods. Because the geological forms and biotic components of the monuments are integral features of the cultural resources, the monuments are dedicated to maintaining the landscapes that attracted these early residents. Therefore, protecting and preserving the ecological processes that created the cultural setting is essential to interpretation of the relationship between the Sinaguas and their natural environment.

Geographic Setting

Tuzigoot and Montezuma Castle NMs are administered jointly and are approximately 40 km (25 mi) apart (Figure 1), with administrative offices located in the town of Camp Verde, Arizona. The two units of Montezuma Castle NM are located about 17.7 km (11 mi) apart along Beaver Creek and Wet Beaver Creek, respectively, near the town of Camp Verde in central Arizona's Yavapai County at an altitude of approximately 975 m (3,200 ft). The total area of the two units is approximately 406 ha (1,004 ac) (NPS 2016a). Lands surrounding the two units include private lands and the U.S. Forest Service Coconino National Forest. Portions of the Yavapai Apache Indian Reservation are near and between the two Montezuma Castle NM units. State Trust Land, managed by the Arizona State Land Board, is also near the units (NPS 2016a).

Tuzigoot NM is located approximately 161 km (100 mi) northeast of Phoenix, Arizona, on the Verde River just east of the town of Clarkdale, Arizona, at an approximate altitude of 1,016 m (3,332 ft). The monument is situated on a limestone ridge rising 328 m (100 ft) above the Verde River floodplain lying within the Verde Valley. Most of the 305 ha (754 ac) within Tuzigoot NM's boundary is in private ownership. The private parcels include Verde River frontage owned by the State of Arizona and managed by Arizona State Parks as a part of the Verde River Greenway and land owned by the Phelps Dodge Corporation. In September 2005, Tuzigoot acquired 131 ha (323.75 ac) acres that included Tavasci Marsh. (NPS 2016b).

Tuzigoot NM is bordered by U.S. Forest Service Prescott and Coconino National Forests to the north and east, respectively. The southern end of the monument is defined by the Verde River, Dead Horse State Park, and the town of Clarkdale, Arizona (Mau-Crimmins et al. 2005, Schmidt et al. 2005).

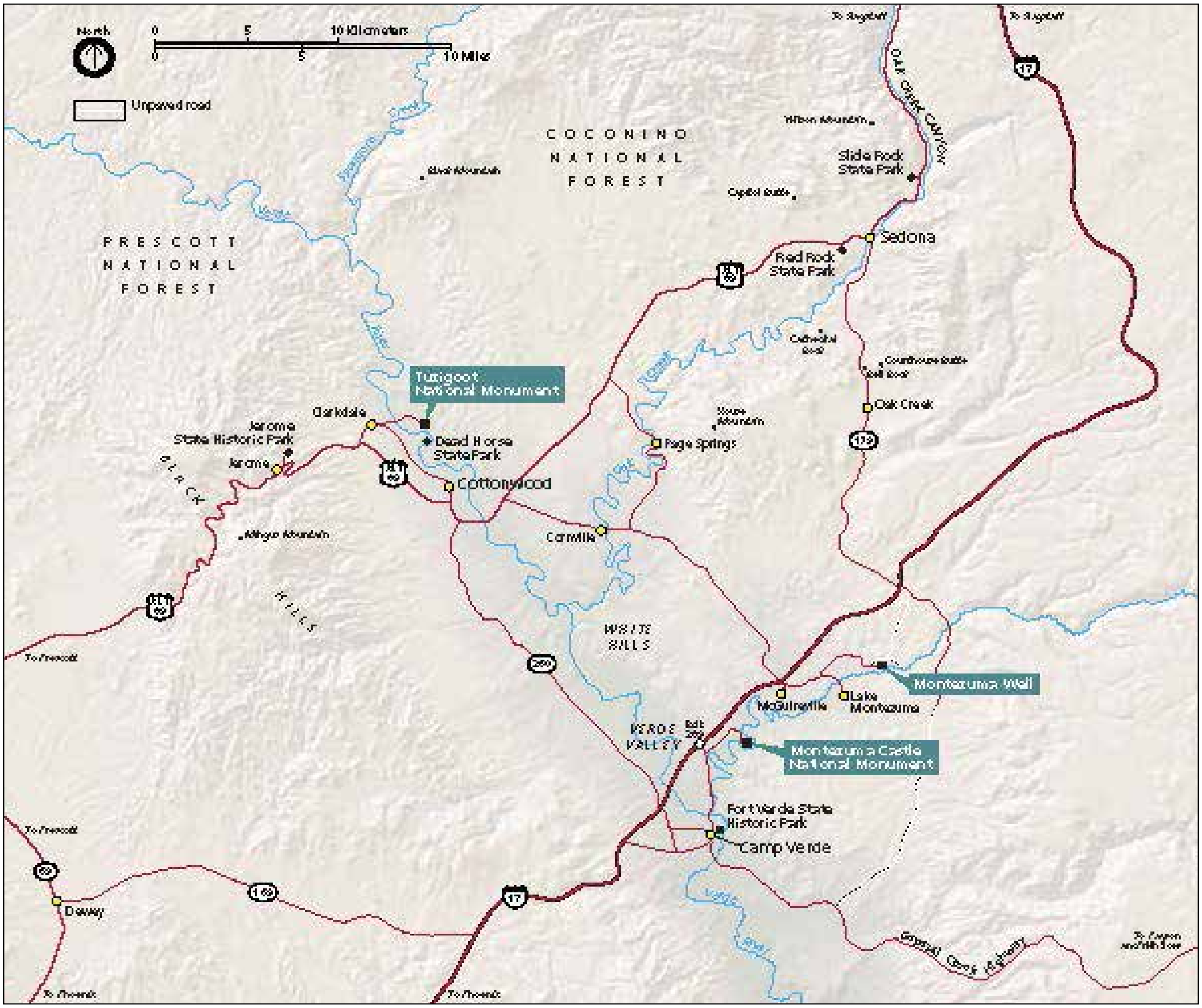


Figure 1. **Tuzigoot and both units of Montezuma Castle NMs are jointly administered and located 40 km (25 mi) apart, north of Phoenix, Arizona. Figure Credit: NPS.**

The Southwest is one of the fastest growing regions in the United States. Population in the Verde watershed (Upper and portion of the Middle watershed upstream of Camp Verde) has increased from approximately 82,000 in 1990 to an average population of over 148,000 from 2005-2009 (ESRI 2011). The number of housing units and households also increased from 1990 to 2005-2009 with over 63,000 households and over 75,000 housing units estimated in 2005-2009. According to the U.S. Census Bureau's July 1, 2017 population estimate of 228,168 for Yavapai County, Arizona, the population increased by 8.1% between 2010 and 2017 (U.S. Census Bureau 2018). Also, as of July 1, 2017, housing units were estimated at 116,541 (U.S. Census Bureau 2018).

Tuzigoot and Montezuma Castle NMs experience the Southwestern or Arizona climate pattern, which is a distinct bimodal regime characterized by violent summer thunderstorms from the North American monsoon and frequent, low-intensity Pacific frontal precipitation in the winter months (Mau-Crimmins et al. 2005). The National Park Service (NPS) Sonoran Desert Inventory and Monitoring Network's (SODN) recent findings for monitoring climate and water at both monuments is as follows (NPS SODN 2018a):

> In WY2017, overall annual precipitation was 117% of normal for Montezuma Castle National Monument (16.8" vs. 14.4") and 129% of normal for Tuzigoot NM (16.36" vs. 12.71"). Precipitation at both parks was

above normal both for fall and winter and for spring and summer. Maximum and minimum temperatures were generally warmer than normal, except in January, when the mean maximum temperature was at least 5.0°F below normal in both parks. The reconnaissance drought index for both parks reflected the extended regional drought that began in 2000, although conditions in WY2017 indicated a limited recovery. Extremely cold days occurred less often than normal at both parks (6 vs. 22.3 ±1.4 days for Montezuma Castle, 10 days vs. 14.6 ± 1.1 days for Tuzigoot). A storm on August 12 dropped 2.9" of rain at Montezuma Castle—an event expected to occur once every 10 years, based on the historic record.

Visitation Statistics

Both Montezuma Castle and Tuzigoot national monuments have become increasingly well-known and popular park units. This notoriety, along with the state's efforts to promote tourism in Arizona, resulted in increases in visitation. The close proximity to I-17 and the popularity of the Phoenix and Flagstaff metropolitan areas as year-round and winter retirement residences also contributed to the upward trend. In addition, commercial tours frequently stop at the Castle unit as tourists travel from the major nearby destination/departure points of Phoenix and the Grand Canyon (NPS 1994a,b).

Based on monthly visitation for the six years from 2002-2007, March is the month with the most visitation at all three monument units, with a second, smaller peak in October. Visitation drops off during the hottest summer months, to levels similar to those occurring in February and November. The lowest visitation occurs in December and January. Regional use is more evident on weekends and holidays. Heaviest use occurs from mid-morning to early afternoon, coinciding with tour bus schedules and the travel time from Phoenix and the Grand Canyon (NPS 2010a).

Despite remaining relatively stable, all three units have experienced a decline in visitation numbers since the early 1990s. However, based on the surrounding region's growing population and the increased development of tourism services, visitation is expected to increase over the next 15-20 years (NPS 2010a).

Statistics show that visitation at Montezuma Castle NM was fewer than 20,000 visitors annually between 1920 and 1946, ranging from a low of 2,500 in 1920 to a high of 19,298 in 1930 (Figure 2). Following World War II, visitation climbed steadily, reaching a peak of 1,029,336 visitors in 1996. Visitation gradually declined over the next five years, and annual visitation remained relatively stable at around 600,000 visitors until 2009. It has since declined and was at 390,151 visitors in 2018 (NPS Public Use Statistics 2019). It is interesting to note that despite its small size, the Castle unit is among the most heavily visited national park units in the southwest, one of the most visited prehistoric ruins in the southwest, and the best-known Sinaguan site (NPS 2010a). Visitation to the Montezuma Well unit is typically about 25% to 30% of the Castle visitation (NPS 2010a).

Because Tuzigoot NM is not adjacent to major travel routes in the area, visitation is lower than that at Montezuma Castle (NPS 2010a). Statistics show that visitation peaked at about 117,000 in 1970 and again in 1991 and 1992 when almost 140,000 people visited the monument each year (Figure 3). Yearly visitation then averaged approximately 117,000 per year through 2006, when it began to decline to an average of about 105,000 visitors each year between 2007 and 2010. In 2018, 98,090 people visited the monument (NPS Public Use Statistics 2019).

Natural Resources

Ecological Units and Watersheds

Montezuma and Tuzigoot NMs are within the Apache Highlands Ecoregion (as defined by The Nature Conservancy), which spans 12 million ha (30 million ac) in the states of Arizona and New Mexico in the U.S. and the states of Sonora and Chihuahua in Mexico. It is bounded by the Mogollon Rim to the north, the Sonoran and Mohave Desert Ecoregions to the west, the Sierra Madre Occidental to the south, and the Chihuahuan Desert Ecoregion to the east. The region covers 25% of Arizona and contains 32% of the state's perennial stream systems, which are crucial to the sustainability of Arizona's biodiversity and human habitation. The Apache Highlands Ecoregion is best known for its mountainous "sky islands" alternating with desert basins (Marshall et al. 2004).

During the development of Arizona's comprehensive wildlife conservation strategy, the Arizona Game and Fish Department divided the Apache Highlands

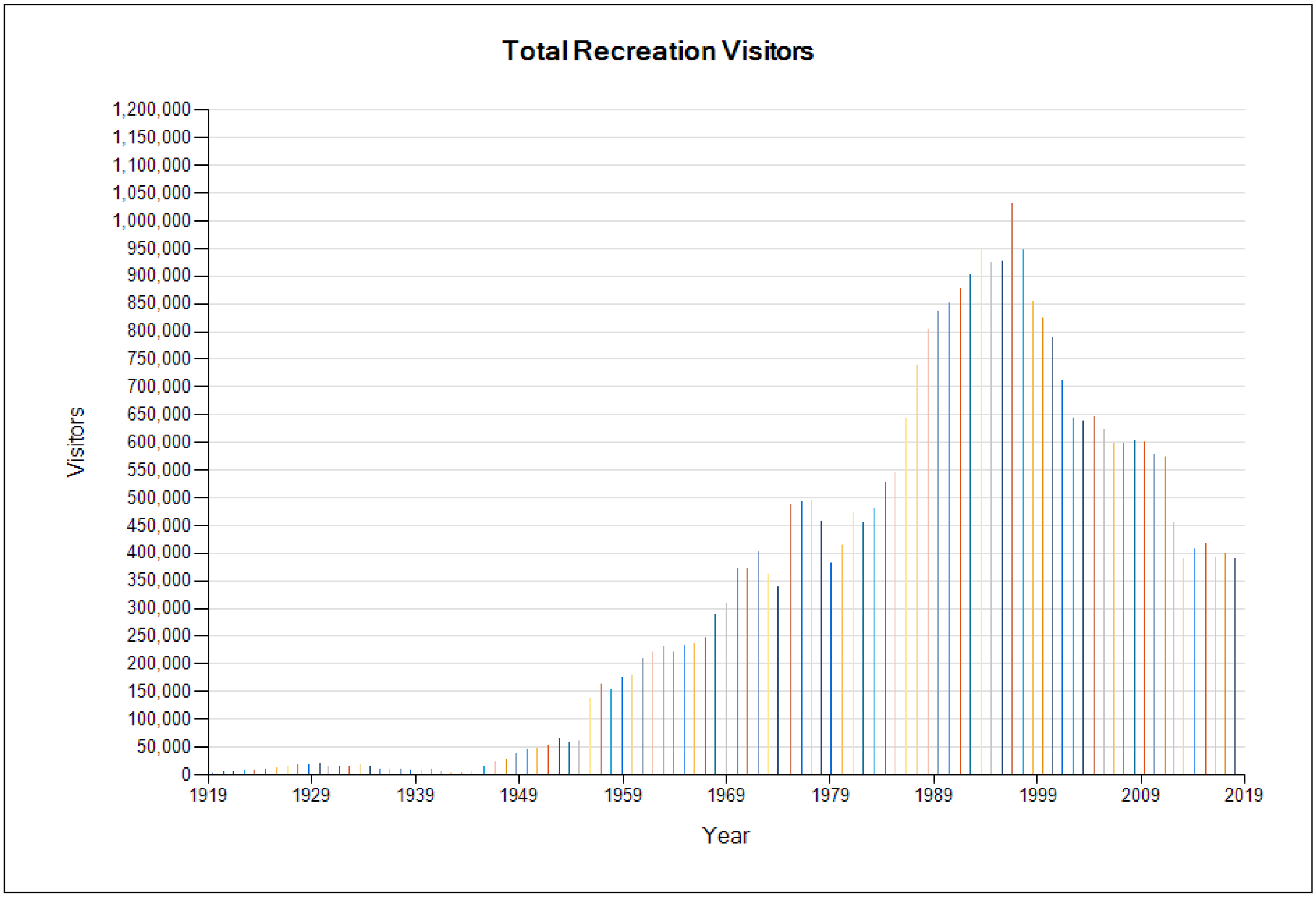


Figure 2. Total number of annual visitors to Montezuma Castle NM from 1920-2018. Figure Credit: NPS Public Use Statistics Office 2019.

Ecoregion into north and south ecoregions. The monuments are located in the north region, which covers 3.8 million ha (9.4 million ac) in Arizona. Elevations range from approximately 640 to 2,682 m (2,100 to 8,800 ft), averaging approximately 1,509 m (4,950 ft). Precipitation ranges from 25.4 to 45.7 cm (10 to 18 in) in this ecoregion and is distributed bimodally, with approximately equal portions falling in winter and summer (AGFD 2005).

The highly dissected nature of the landform is the dominant characteristic of the Apache Highlands North Ecoregion. The northern extent of the eastern part of this ecoregion is defined by the Mogollon Rim, where the primary landforms are canyons, broad flat valleys, and the intervening small mountain ranges, ridges, and plateaus. One such mountain range is the Hualapai, a "sky island" similar to those found in the Apache Highlands South Ecoregion. The higher elevations in the northwestern part of this ecoregion are dominated by more extensive and relatively flatter plateaus. Toward the south, the plateau country breaks into similarly highly dissected drainages and small mountain ranges (AGFD 2005).

Throughout its extent, the Apache Highlands North is transitional in nature. Striking variety in habitat types and wildlife are associated with dramatic local differences in elevation, slope, and aspect. Vegetation at the lower elevations is dominated by grasslands, chaparral, and pinyon/juniper woodlands; considerable mixed stands of Madrean evergreen oak woodlands and ponderosa pine/mixed conifer forests are also found at higher elevations (Marshall et al. 2004). The part of the state in which the Apache Highlands North is located is relatively well-watered (AGFD 2005). The Verde, the only Wild and Scenic River in Arizona, bisects this ecoregion; other significant drainages include Beaver Creek and the East Verde River, both tributaries of the Verde (Smith and Ledbetter 2011).

Montezuma Castle and Tuzigoot NMs lie within the Middle portion of the Verde River watershed, which

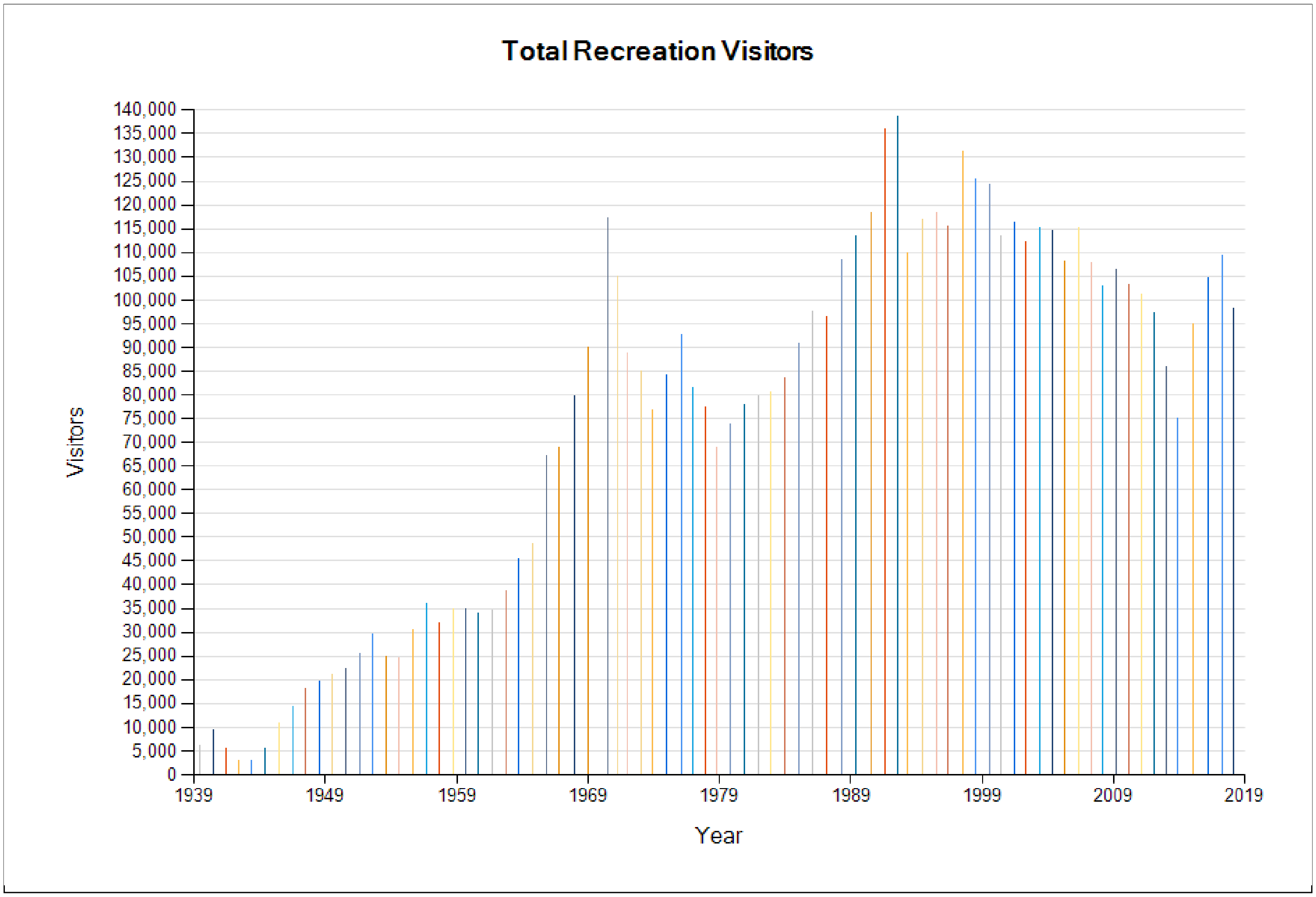


Figure 3. Total number of annual visitors to Tuzigoot NM from 1940-2018. Figure Credit: NPS Public Use Statistics Office 2019.

coincides with the 6,475-km^2 (2,500-mi^2) Verde Valley subbasin of the Verde River groundwater basin (Figure 4). The Verde Valley subbasin extends along the Verde River between Paulden and Camp Verde and includes Sycamore Creek, Oak Creek, Wet and Dry Beaver Creeks, and West Clear Creek (Blasch et al. 2006). The 225-km (140-mi) Verde River drains 17,133-km^2 (6,615 mi^2) of Arizona (total watershed area), and the riparian zone was over a mile wide in some areas until the 1890s. This created a series of marshes and sloughs that furnish suitable habitat for a variety of plants and animals. In 1983, a severe flood incised the river channel. Near Cottonwood, Peck's Lake and Tavasci Marsh are abandoned meanders of the ancestral Verde River (Smith and Ledbetter 2011).

Seasonal precipitation patterns cause extremely variable flows on the Verde River. Intense summer storms result in the highest discharge; the lowest flows occur in late spring. Diversions for economic and recreational uses also substantially influence downstream flows, with the lowest flows following diversions for irrigation in the late spring and early summer (VRCP 1991). The highest flow ever recorded for the Verde was 112,000 cubic feet per second (cfs) on February 15, 1980, at the Tangle Creek gauge (downstream of Camp Verde; VRCP 1991).

Resource Descriptions

The Verde Valley, in which all three parks units are located, is a down-faulted Cenozoic sedimentary basin dominated by Verde Formation sediment, a young lacustrine sediment with classic, evaporitic, and limestone facies (Lindsay 2000a,b). Deposits of lacustrine and fluvial origin dominate the area surrounding the monuments. Fluvial deposits from the Verde River are further separated into terraced (moderately sorted and lightly cemented) and alluvial (unsorted and uncemented) deposits (Mau-Crimmins et al. 2005).

Two broad types of soils predominate at Montezuma Castle NM: riverine bottomland soils composed of alluvium and upland, rocky calcareous soils. The

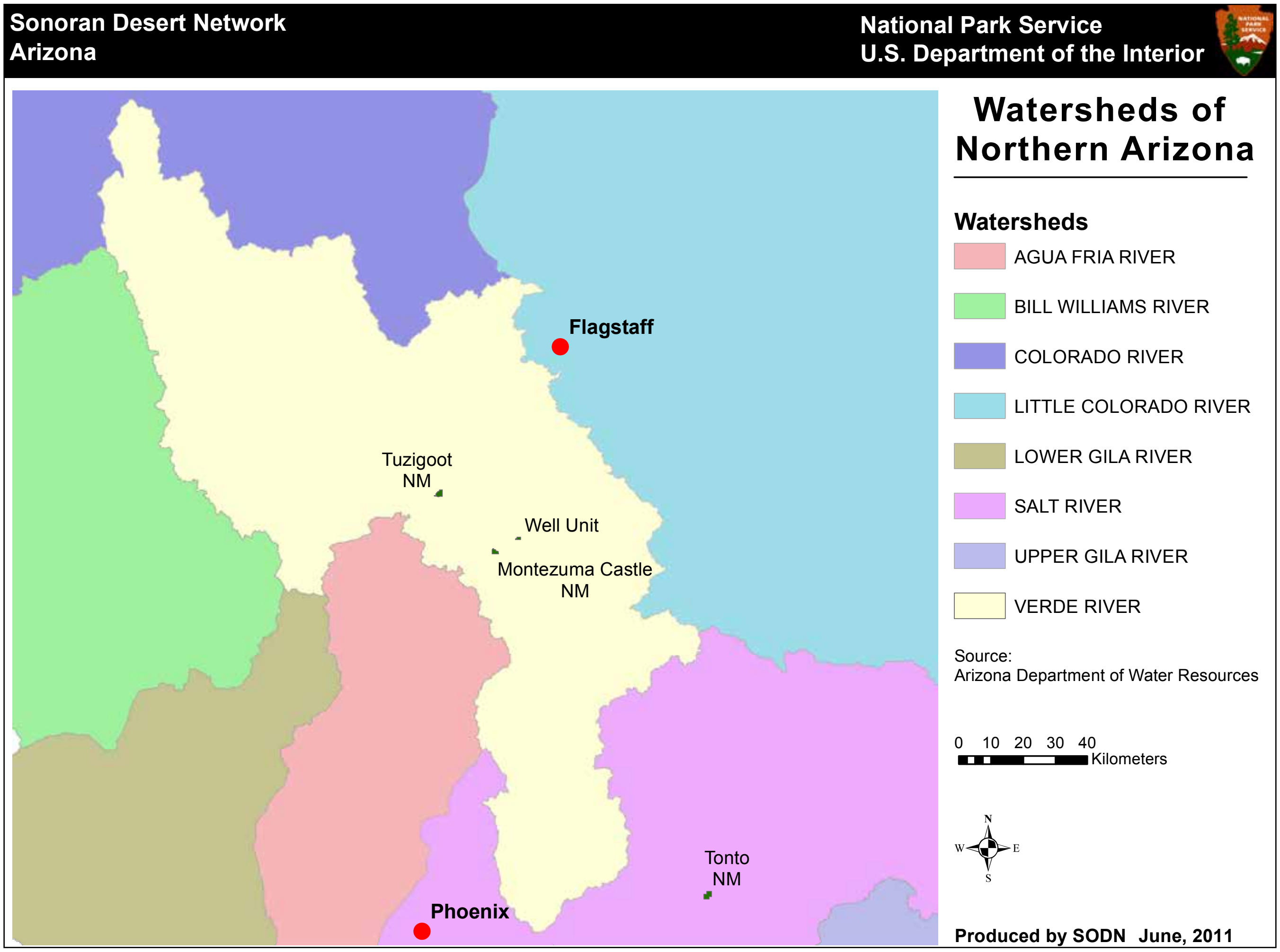


Figure 4. Tuzigoot and Montezuma Castle NMs are within the Verde River watershed. Figure Credit: NPS SODN.

Retriever soil series, which consists of limestone outcrops and soils derived from limestone, is dominant at the Castle unit and is found on upland mesas, ridges, and side-slopes. Riverwash soils along Beaver Creek consist of stratified sand, silt, and clay with scattered deposits of gravel, cobbles, stones, and boulders. The remainder of the Castle unit is characterized by several series of finer calcareous soils consisting of fine sandy loams, gravelly, sandy loams, and clays (Rowlands 1999). The dominant soil at Montezuma Well is the Guest series, a clayey bottomland soil derived from flood-borne fine sediment deposits. Riverwash and Retriever soils are also found at the Well (Rowlands 1999). At Tuzigoot NM, Retriever soils are dominant with the exception of Tavasci Marsh (NPS 2010a).

Both Montezuma Castle and Tuzigoot NMs are designated as Class II airsheds. Historically, smelting activities in Clarkdale for the Verde Mine produced air pollution that might have posed a problem for surface water quality in Tuzigoot NM. However, the mine and smelting operations were stopped in the 1960s, and since then, air quality has improved considerably.

Beaver Creek, one of the Verde River's tributaries, runs through the Montezuma Castle unit, and its tributary, Wet Beaver Creek, runs through the Well unit. Both creeks are characterized by intermittent water flow (Schmidt et al. 2006) with perennial stretches through portions of the units. Montezuma Well is a limestone sink created long ago when an underground cavern collapsed around a travertine spring. Groundwater occurring in the Supai and Verde Formations, alluvium found in stream channels and along the Beaver Creek floodplain, and volcanic rocks along the margins of the Verde Formation feed the well. The well is 112 m (368 ft) in diameter, the water reaches a depth of 17 m (55 ft), and it produces a constant flow of water at 4,164 liters per minute (Sprouse et al. 2002).

The Verde River passes just to the south of Tuzigoot NM's boundary as it flows from the northwest to the southeast through the Verde Valley. Upstream of the monument, a channel dug by Phelps Dodge Corporation diverts water from the Verde into Peck's Lake (Sprouse et al. 2002), an old oxbow of the Verde River transformed into a man-made lake once used for recreation (Schmidt et al. 2005). That water is then channeled into Tavasci Marsh (Sprouse et al. 2002), which was previously fed only by Shea Spring on the marsh's northeast corner, then eventually back into the Verde River near the southeast corner of the monument (Schmidt et al. 2005). According to Doug Von Gausig (pers. comm. as cited in Schmidt et al. 2005), increased water flow from Peck's Lake into Tavasci Marsh, along with a recently built beaver dam, has resulted in much higher than (recent) historic water levels and large areas of open water.

Groundwater is extremely important in this area. Discharge of groundwater into the river and its tributaries accounts for approximately half of the flow of the Verde River as it leaves the valley, most occurring as non-point discharge into streams along their courses. Springs, such as Montezuma Well that discharges approximately 1000 gpm and Shea Spring in Tavasci Marsh that discharges an unknown quantity, furnish another portion (NPS 1994a,b).

The combination of upland and lowland habitats dissected by floodplains produces unique and diverse biological communities, making this area where the monuments are located one of the most significant bioregions of Arizona (NPS 1994a). The major vegetation formations at Montezuma Castle NM include Sonoran Desertscrub and Interior Perennial Riparian Forest, and the major formations in Tuzigoot NM are Lowland Perennial Riparian Forest, Southwestern Marsh Wetlands, and Sonoran Desertscrub (Mau-Crimmins et al. 2005). At Tuzigoot NM, Upper Sonoran life zone vegetation predominates with species such as *Yucca* spp., velvet mesquite (*Prosopis velutina*), and fourwing saltbush (*Atriplex canescens*). Large stands of Fremont cottonwood (*Populus fremontii*), and Goodding's willow (*Salix gooddingii*) line the banks of the Verde River and Tavasci Marsh. In general, the Castle unit of the monument is characterized by mesquite, *Acacia* spp., and creosote bush (*Larrea tridentata*) at lower elevations and scattered juniper at higher elevations, with a rich cottonwood riparian association established along Beaver Creek.

The remarkable diversity of aquatic and terrestrial habitats in Montezuma Castle and Tuzigoot NMs supports a wide variety of wildlife (NPS 1994a,b). Terrestrial species include birds, large and small mammals, reptiles, and insects. Aquatic species include fish, amphibians, and insects (NPS 2010a).

The most commonly observed wildlife in both upland and riparian habitats are birds (NPS 1994a,b). Many species use the riparian areas for breeding, but the uplands also provide breeding, post breeding, migrating, and wintering habitat. The black-throated sparrow (*Amphispiza bilineata*), Bewick's wren (*Thryomanes bewickii*), and brown-headed cowbird (*Molothrus ater*) are commonly found during the breeding season (NPS 2010a). Breeding densities in undisturbed riparian habitat (e.g., Tavasci Marsh) are reported as being among the highest recorded from North America (NPS 1994a,b). Even the most predominant species in a given year account for no more than 12% of observed species due to the diversity of habitats that occur in the monuments. The high number of avian breeding species in the monuments reflects the topographic and habitat variability, including the riparian areas. Half of all species recorded in the monuments are migratory or resident. The southern location in the U.S. and relatively low elevation of the monuments (Beaupré et al. 2013) suggest that they may also provide important wintering habitat for many species.

The desert cottontail (*Sylvilagus audubonii*), ground squirrels (*Sciuridae* family), elk (*Cervus canadensis*), mule deer (*Odocoileus hemionus*), gray fox (*Urocyon cinereoargenteus*), bobcat (*Felis rufus*), coyote (*Canis latrans*), and mountain lion (*Felis concolor*) are examples of the mammals known to live or use the habitats in Montezuma Castle and Tuzigoot NMs. The hot climate and lack of water in the uplands favors smaller mammals that require less food and water and have an easier time finding shelter (NPS 2010a). In addition, the bat richness at both monuments is very high, with 20 species recorded at Montezuma Castle NM and 17 of the same species recorded at Tuzigoot NM. A variety of amphibians and reptiles are also found at the monuments, including frogs, toads, turtles, lizards, and snakes. In addition, several species of conservation concern have been recorded at both monuments throughout the various inventories and studies that have occurred.

Beaver Creek and the Verde River support a number of native species of trout and suckers, but both are dominated by non-native introduced fish species such as carp, catfish, and bass (Montgomery et al. 1995, NPS 2010a). Montezuma Well does not support any fish populations because of the water's high carbon dioxide level (NPS 2010a). The Well does, however, provide habitat for unique invertebrates known only from that location – an amphipod, a diatom, a leech, a springtail, and a water scorpion – the most endemic species found in any spring in the southwestern United States (NPS 1994a).

Resource Issues Overview

Primary threats to the natural resources at Montezuma Castle and Tuzigoot NM are impending climate change, the increased pressures in the Verde Valley due to adjacent land use, development, and water use patterns, encroachment of non-native species, and impacts from visitor use. Additional details pertaining to these and other resource threats, concerns, and data gaps can be found in each Chapter 4 condition assessment and in Chapter 5 of this report.

Resource Stewardship

Management Directives and Planning Guidance

In addition to NPS staff input based on both parks' 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 SODN, I&M NPScape Program for landscape-scale measures, and Air Resources Division for the air quality 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. Both monuments are part of the SODN, which includes nine 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. SODN

Black-tailed rattlesnake. Photo Credit: NPS.

monitors air quality, climate, invasive exotic plants, springs, seeps, and tinajas, streams, and landbirds at both monuments, and groundwater and vegetation and soils at Montezuma Castle NM only (NPS SODN 2018b).

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 State of the Park (SotP) and Resource Stewardship Strategy (RSS) 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 for both monuments was completed in 2016 (NPS 2016a,b).

A SotP report is intended for non-technical audiences and summarizes key findings of park conditions and management issues, highlighting recent park accomplishments and activities. NRCA condition findings are used in SotP reports, and each NRCA Chapter 4 assessment includes a SotP condition summary.

A Resource Stewardship Strategy (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 the park. After each indicator is chosen, a target value is determined and the current condition is compared to the desired condition. An RSS has not yet been started for the monuments.

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 and listed in the Literature Cited section of this report. Important sources of information included the library, central files, and resource management staff files at Tuzigoot and Montezuma Castle NMs, the archived collections at the Western Archeological and Conservation Center, the Sonoran Desert I&M Network reference library, and numerous online databases and collections.


View of Montezuma Well with snow. Photo Credit: NPS.

Study Scoping and Design

Montezuma Castle and Tuzigoot National Monuments' (NMs) Natural Resource Condition Assessment (NRCA) was initiated in 2010 as a collaborative effort between the national monument staff, the National Park Service (NPS) Sonoran Desert Inventory and Monitoring Network (SODN), the NPS Intermountain Region Office, and the Sonoran Institute. A scoping meeting was held at the monuments and focal resources were selected for condition assessment reporting. Various stages of drafts were completed for these selected resources but no final report was produced. In 2017, Utah State University (USU) was added as a partner to complete the monuments' NRCA through a Colorado Plateau Cooperative Ecosystem Studies Unit task agreement, P17AC00941. Original resource topics were retained for condition assessment reporting but new data sets and reference conditions were incorporated, and in some instances, new templates and guidance were added.

Preliminary Scoping

The NRCA scoping meeting for Montezuma Castle and Tuzigoot national monuments was held at park headquarters in Camp Verde, Arizona, on June 18, 2010. Attendees included staff members from SODN and Southern Plains (SOPN) networks, the monuments, and regional office.

An overview of the NRCA project was presented by the SODN and SOPN program managers, followed by a discussion of the management reporting areas for each monument. Monument staff outlined management reporting areas on base maps and identified the primary management and interpretive themes, character-defining features, and resources for each area.

Study Design

Indicator Framework, Focal Study Resources and Indicators

The usefulness, consistency, and interpretation of NRCAs are facilitated by a framework that:

- employs indicators and reference conditions/ values.
- analyzes indicator findings to report conditions by ecosystem characteristics,
- analyzes indicator findings to report conditions by park areas.

There are several frameworks that meet these criteria, most of which overlap considerably but differ slightly in how they group and split categories. For this NRCA report, 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.

Scoping meeting participants identified fundamental and important resources at both monuments, and when applicable, resource topics were incorporated from monument planning documents. However, topic inclusion was not limited to resources only identified in those documents. Resources identified were taken from broad categories, such as animals, plants, geology, soils, hydrology, water quality, water quantity, and invasive species. In addition, resources with high ecological significance were discussed, even if they were not considered a priority at either monument. In total, 10 focal natural resources were selected for natural resource condition assessment reporting.

Within each of the 10 resource categories, indicators and measures were identified and are listed in Tables 1-3. For each indicator/measure, literature and data sets were identified for condition reporting purposes. Reference conditions were discussed to determine if sufficient context for comparison of the current resource condition existed. Reference conditions provided the point(s) of reference against which current conditions were measured, interpreted, and reported. These were either benchmarks, standards, norms, or thresholds but were not desired conditions or management targets.

Ecological reference conditions (values developed via historic data, modeling site comparisons, best professional judgment, etc.), based on natural resource management priorities and context, were primarily used. In some cases, reference conditions were legal or regulatory standards, such as Arizona water quality standards. For resources that lacked sufficient data or

Table 1. Montezuma Castle and Tuzigoot NMs' natural resource condition assessment framework based on the NPS Inventory & Monitoring Program's Ecological Monitoring Framework for air and climate (landscape).

Resource	Indicators	Measures
Landscape Dynamics	Land Cover	Natural Land Cover
	Land Cover	Impervious Surfaces
	Housing	Density
	Roads	Density
	Conservation Status	Land Stewardship
Air Quality	Visibility	Haze Index
	Level of Ozone	Human Health
	Level of Ozone	Vegetation Health
	Wet Deposition	Nitrogen
	Wet Deposition	Sulfur
	Wet Deposition	Mercury and Predicted Methylmercury Concentration

Table 2. Montezuma Castle and Tuzigoot NMs' natural resource condition assessment framework based on the NPS Inventory & Monitoring Program's Ecological Monitoring Framework for water.

Resource	Indicator	Measure
Hydrology	Groundwater	Depth to Groundwater
	Surface Water Quantity	Number of No-Flow Events
	Surface Water Quantity	Number of 50-year or Greater Flow Events
	Surface Water Quantity	Number of Bankfull Events
	Surface Water Quantity	Change in Mean Annual Discharge
	Stream Channel Geomorphology	Sinuosity
	Stream Channel Geomorphology	Cross-sectional Area
	Stream Channel Geomorphology	Dominant Particle Size
	Stream Channel Geomorphology	Particle Size Assessment
Water Quality	Core Water Quality	pH (SU)
	Core Water Quality	Dissolved Oxygen (mg/L)
	Metals and Metalloids	Several Measures
	Nutrients	Four Measures
	Inorganics	Several Measures
	Microbiological Organisms	*E. coli* (cfu/100 ml)
	Benthic Macroinvertebrates	Arizona Index of Biological Integrity
	Benthic Macroinvertebrates	USEPA Multi-metric Index

Table 3. Montezuma Castle and Tuzigoot NMs' natural resource condition assessment framework based on the NPS Inventory & Monitoring Program's Ecological Monitoring Framework for biological integrity.

Resource	Indicators	Measures
Upland Vegetation and Soils	Erosion Hazard	Bare Ground Cover
	Erosion Hazard	Soil Aggregate Stability
	Erosion Hazard	Biological Soil Crusts
	Erosion Features	Estimated Soil Loss by Feature Type
	Erosion Features	Extent of Affected Area by Feature Type
	Site Resilience	Foliar Cover of Dead Perennial Plants
	Site Resilience	Foliar Cover of Dead Perennial Plants
	Fire Hazard	Grass and Forb Cover
	Fire Hazard	Ratio of Annual Plant Cover to Total Plant Cover
	Native Perennial Plant Community Composition and Structure	Cover of Common Species
	Native Perennial Plant Community Composition and Structure	Frequency of Uncommon Species
	Non-native Plants	Extent
	Non-native Plants	Total Cover
	Non-native Plants	Ratio of Non-native Plants to Total Plant Cover
Riparian Vegetation	Loss of Obligate Wetland Plants	Richness and Distribution
	Non-native Plant Dispersal and Invasion	Percent Frequency
	Non-native Plant Dispersal and Invasion	Percent Cover
Birds	Species Occurrence	Richness and Composition
	Species Occurrence	Species of Conservation Concern
Mammals	Species Occurrence (by group)	Species Presence / Absence
	Species Occurrence	Species Nativity
	Species Occurrence	Species of Conservation Concern
Fish	Species Occurrence	Presence/Absence

Table 3 continued. Montezuma Castle and Tuzigoot NMs' natural resource condition assessment framework based on the NPS Inventory & Monitoring Program's Ecological Monitoring Framework for biological integrity.

Resource	Indicators	Measures
Herpetofauna	Species Occurrence (by group)	Species Presence / Absence
	Species Occurrence	Species Nativity
	Species Occurrence	Species of Conservation Concern

context to report on current condition, we provided a descriptive narrative and/or identified important data gaps for that resource within each condition assessment in Chapter 4.

Reporting Areas

The broad habitat types (upland vegetation vs. aquatic/riparian vegetation) were used as the ecological foundation for monument-scale indicators. In many cases, the broad habitat types were similar to the management reporting areas identified by monument staff. For the purpose of this NRCA, management reporting areas were defined as specific areas in each monument that differed in resources and primary management or interpretive themes. It is important to note, however, that these thematic overlays have no official designation for park planning other than as reporting areas for studies referenced in the NRCA.

Four management areas were identified for Montezuma's Castle unit (Figure 5, Table 4), five areas were identified for Montezuma's Well unit (Figure 6, Table 5), and five management areas were identified for Tuzigoot NM (Figure 7, Table 6). For each management area within both monuments, the primary management themes and character-defining features are presented in the tables.

General Approach and Methods

Each natural resource condition assessment relied on existing data and literature to evaluate the selected indicators and measures. Additional data analyses were performed as needed. Where possible, data for each measure were compared to a reference condition, making it possible to report a condition, trend, and confidence level status.

The NRCA information manager for Southern Intermountain Region parks led the literature search

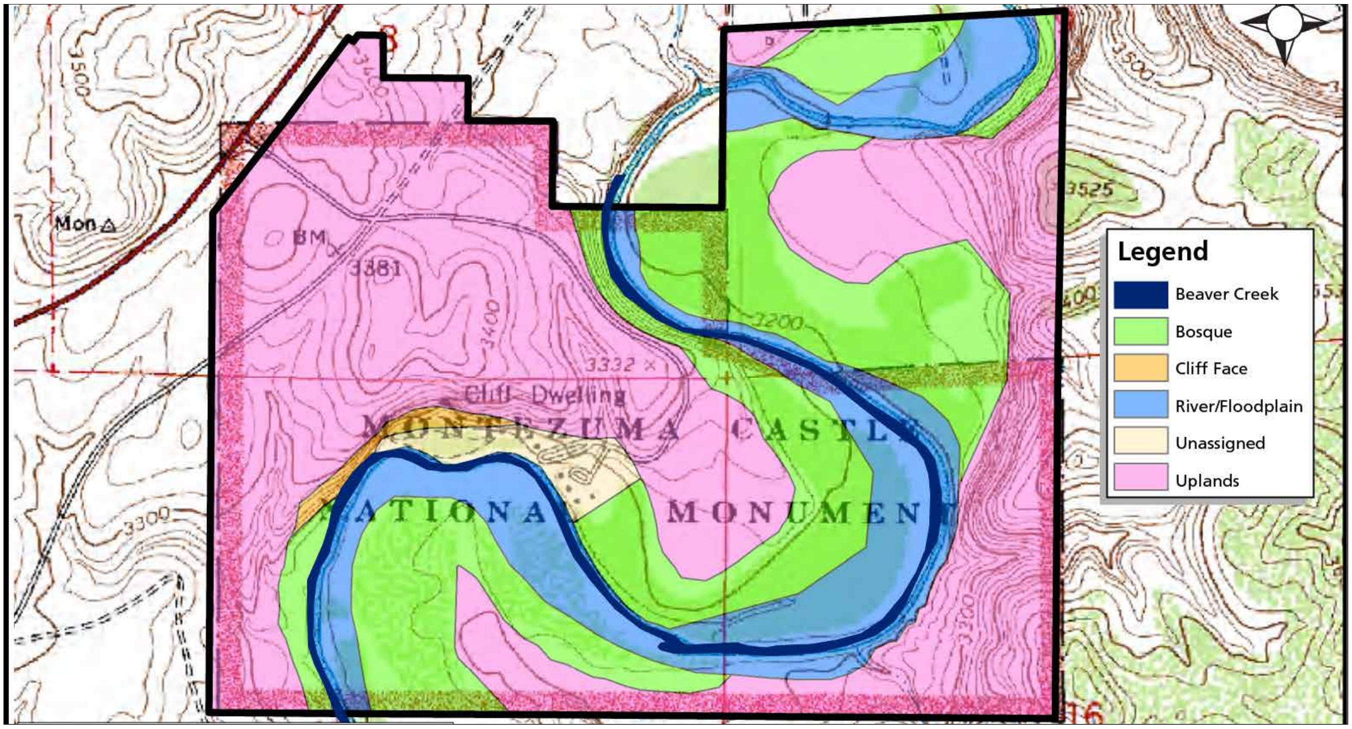


Figure 5. Management reporting areas for the Castle unit of Montezuma Castle NM. Figure Credit: NPS/SODN.

Table 4. Natural resources identified for each management reporting area in the Castle unit of Montezuma Castle NM.

Resource	Management Reporting Area			
	Bosque	Cliff Face	River/Floodplain	Uplands
Character-defining features	Unique stands of mature mesquite trees found along Beaver Creek, with scattered archeological sites, and the floodplain hydrology	Natural and culturally modified niches, geology, archeological features, and the viewshed. It includes the Montezuma Castle ruin and the surrounding geologic features	Beaver Creek and its hydrologic function, cottonwood forest, springs, groundwater interface, geology, and alluvium deposits	Native plant communities with scattered archeological sites. The viewshed is also an important feature
Management focus	Preservation of ecological resources, with a secondary focus on cultural resources	Preservation of the integrity of the cultural resources and cavettes of the cliff face	Preservation of the ecological integrity and dynamic nature of the river and floodplain ecosystems	Preservation of ecological resources, with a secondary focus on cultural resources
Animals	X	X	X	X
Plants	X	–	X	X
Geology	–	X	–	–
Soils	X	–	–	X
Geomorphology	–	–	X	–
Invasives	X	–	X	–
Water quality	–	–	X	–
Water quantity	–	–	X	–
Paleontological	–	–	–	X

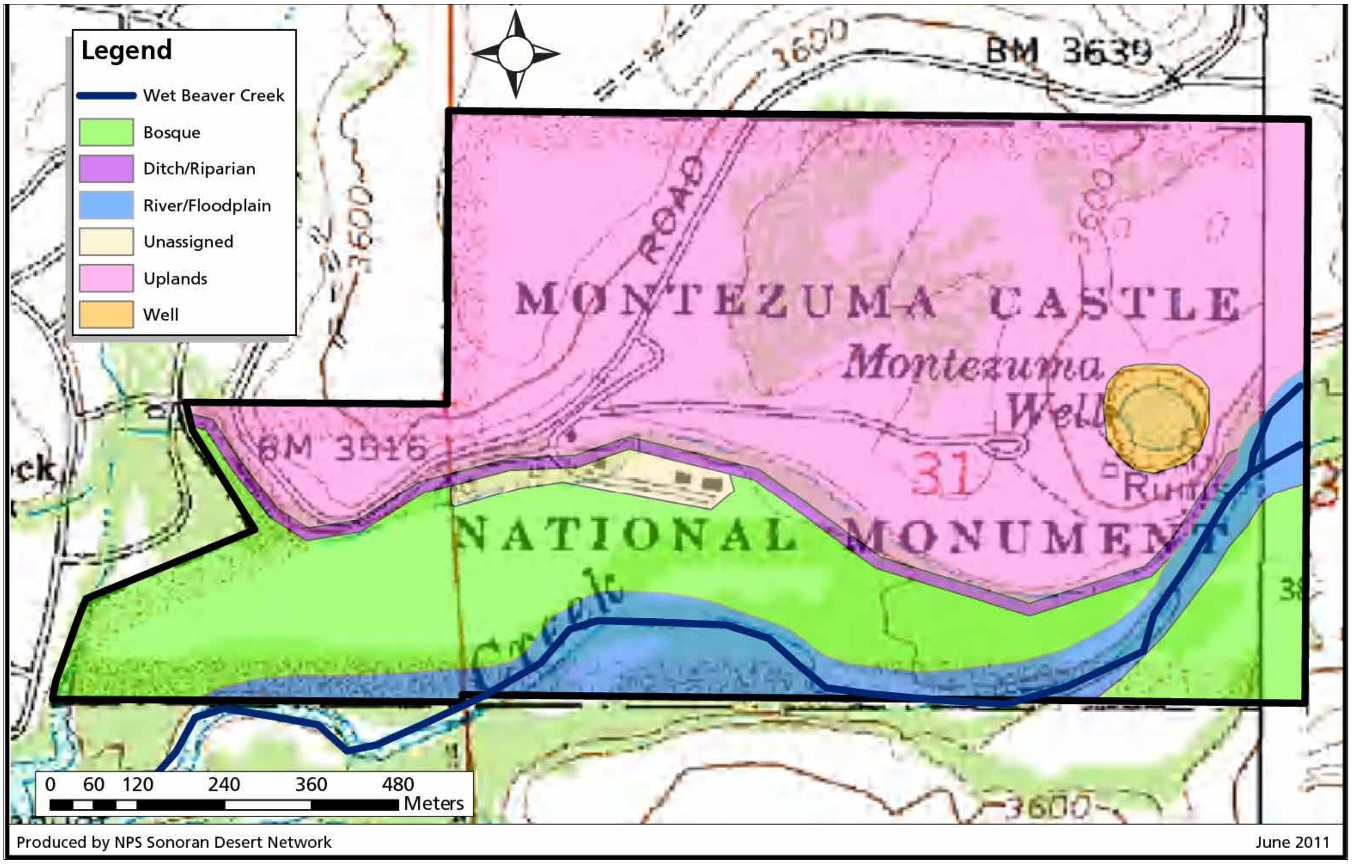


Figure 6. **Management reporting areas for the Well unit of Montezuma Castle NM. Figure Credit: NPS/SODN.**

Table 5. **Natural resources identified for each management reporting area in the Well unit of Montezuma Castle NM.**

Resource	Management Reporting Area				
	Bosque	Ditch/Riparian	Montezuma Well	River/Floodplain	Uplands
Character-defining features	Unique stands of mature mesquite trees found along Beaver Creek, with scattered archeological sites, and the floodplain hydrology	Riparian gallery forest, alcoves and archeological sites, and the irrigation ditch	Unique hydrology of the well, unique and endemic biota found in the waters, surrounding archeological sites, geology, and viewshed	Beaver Creek and its hydrologic function, riparian vegetation, and alluvium deposits	Scattered archeological sites in the native plant communities, limestone geology of the well, and viewshed
Management focus	Preservation of cultural resources, with a secondary focus on ecological resources	Preservation of the integrity of the cultural resources and maintenance of water rights	Preservation of the integrity of the ecological, cultural, and geological (specifically limestone) resources	Preservation of the ecological integrity and dynamic nature of the river and floodplain ecosystems	Preservation of ecological and cultural resources
Animals	X	X	X	X	X
Plants	X	X	X	X	X
Geology	–	X	X	–	X
Soils	–	X	–	–	X
Geomorphology	–	–	–	X	–
Travertine	–	X	–	–	–
Invasives	X	X	–	X	–
Water quality	–	–	X	X	–
Water quantity	–	–	X	X	–

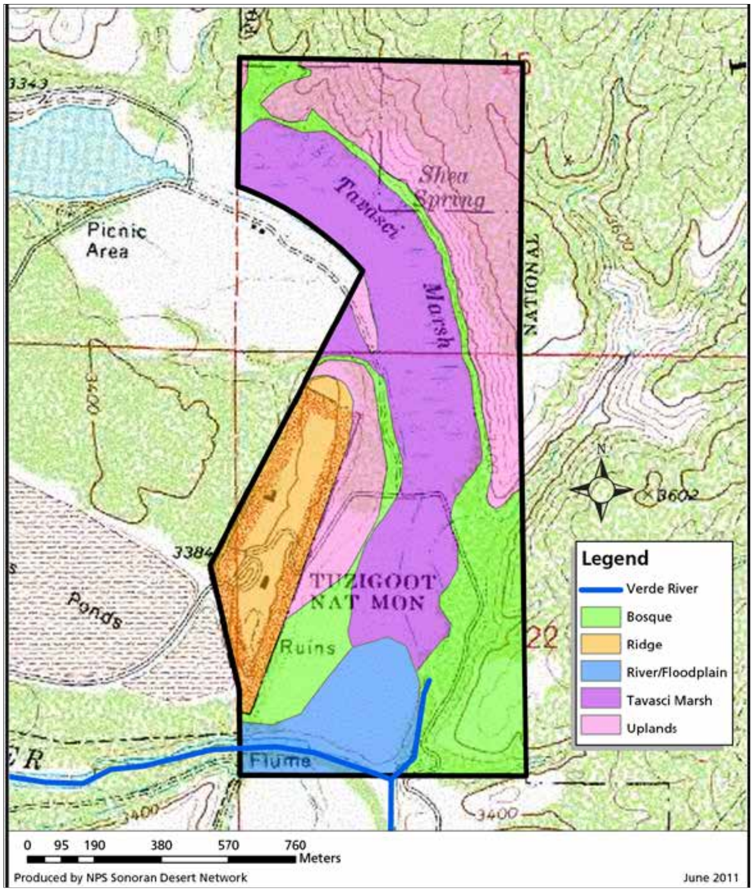


Figure 7. Management reporting areas for Tuzigoot NM.
Figure Credit: NPS/SODN.

and data-mining effort. A copy of the online NatureBib database containing 327 records for Montezuma Castle and Tuzigoot NMs was downloaded, and the desktop version of NatureBib was used to manage the literature. The information manager coordinated with monument staff to search park libraries and files for NPS reports, other governmental reports, and research documents. The information manager also searched online data and literature sources, the SODN library holdings, and the Western Archeological and Conservation Center. During the literature-search process, the information manager identified information that was important but outside the scope of the NRCA. The project team helped analyze the documents for quality and relevancy to the selected indicators. Hard copies of priority documents were scanned as Adobe pdf documents to facilitate sharing among the project team. After entering newly discovered references, the database contained approximately 800 records.

Table 6. Natural resources identified for each management reporting area of Tuzigoot NM.

Resource	Management Reporting Area				
	Bosque	Ridge	River/Floodplain	Tavasci Marsh	Uplands
Character-defining features	Unique stands of mature mesquite trees, with scattered archeological sites, and hydrology of the terraces	The cultural and historic sites (Tuzigoot pueblo) and the viewshed from the top of the ridge	Verde River and its hydrologic function, riparian vegetation (gallery cottonwood forest), and alluvium deposits	Structural and community diversity, hydrologic function (spring-fed and historic cultural features), and topographic variation	Native plant communities containing scattered archeological sites, and the viewshed
Management focus	Preservation of ecological resources	Preservation of the cultural resources	Preservation of the ecological integrity and dynamic nature of the river and floodplain ecosystems	Restoration/ preservation of a naturally functioning wetland system with interspersed cultural features	Preservation of ecological and cultural resources
Animals	X	–	X	X	X
Plants	X	X	X	X	X
Geology	–	–	–	–	X
Soils	X	X	–	–	X
Geomorphology	–	–	X	–	–
Invasives	X	X	X	X	X
Water quality	–	–	X	X	–
Water quantity	–	–	X	X	–

The data mining continued with the USU team obtaining current information to report on condition status for each selected measure.

Data were found in numerous formats, including spatial, tabular, and prose. Data analysis was specific to each indicator and is described in each assessment in Chapter 4. Tabular data were managed in the most appropriate format (e.g., Microsoft Excel or Access), as determined by the subject-matter expert within the project team. A geographic information system (GIS) was used to manage and display the spatial data, following SODN's standard protocols. The project team utilized ESRI's ArcMap to manage and visualize data. All relevant data were re-projected into the North American Datum 1983 (NAD83) datum and the Universal Transverse Mercator (UTM) zone 12 projection, and Federal Geographic Data Committee (FGDC)-compliant metadata were generated for data collected specifically for the NRCA. The final GIS products, collected specifically for this project, were shared with monument staff, otherwise web links for original data sources were shared.

Following the NPS NRCA guidelines (NPS 2010b), each natural resource condition assessment included five sections (note that the literature cited was compiled into one comprehensive list at the end of the report as a separate chapter).

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

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

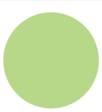
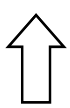
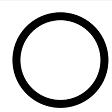
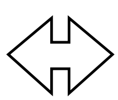
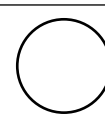
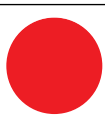
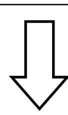
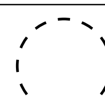
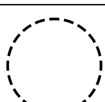
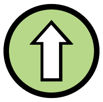
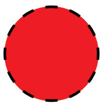
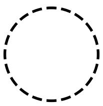
Condition Status		Trend in Condition		Confidence in Assessment	
	Resource is in good condition.		Condition is Improving.		High
	Resource warrants moderate concern.		Condition is unchanging.		Medium
	Resource warrants significant concern.		Condition is deteriorating.		Low
	An open (uncolored) circle indicates 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.

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. Key uncertainties and resource threats are treated as a separate section for each resource topic.

5. The sources of expertise list the individuals who were consulted. Assessment author(s) are also listed in this section for each condition assessment.

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 monument staff and the NPS IMRO NRCA Coordinator.

Desert marigold. Photo Credit: NPS/Laura Varon-Burkhart.

Natural Resource Conditions

Chapter 4 delivers current condition reporting for the 10 important natural resources and indicators selected for Montezuma Castle and Tuzigoot NMs' NRCA report. The resource topics are presented following the National Park Service's (NPS) Inventory & Monitoring Program's NPS Ecological Monitoring Framework (2005) that is presented in Chapter 3.

Landscape Dynamics

Background and Importance

Landscape dynamics consider various aspects of land cover and land use in addressing both the vulnerability and opportunity for conservation of natural resources in areas surrounding National Park Service (NPS) units (Monahan et al. 2012). The composition, configuration, and connectivity of land-cover types surrounding Montezuma Castle and Tuzigoot National Monuments (NM) (such as forest, woodland, and scrubland) influence the amount of habitat available for wildlife, how wildlife moves across the landscape, and the flow of material and energy (Monahan et al. 2012). Land-use activities surrounding these monuments can have major implications to these patterns and processes (Monahan et al. 2012). For example, increases in housing development, and associated roads, can fragment the landscape, decrease the size of the functional ecosystem, reduce connectivity among native habitat patches, isolate species in small patches, and increase the contrast in vegetation along management boundaries (Davis and Hansen 2011, Hansen et al. 2014).

Natural resources and ecosystem processes within NPS units are also influenced by the land management type in the area surrounding their borders. Adjacent lands often differ with respect to their conservation status. While some lands are fully protected from human disturbances (e.g., wilderness areas), others may be only partially protected from resource extraction, or not protected at all (Monahan et al. 2012). Understanding conservation status and land use surrounding the monuments provides an important context for understanding the status and trends of park resources and is key to coordinated conservation efforts (DeFries et al. 2007, Hansen et al. 2014).

Data and Methods

The National Park System Advisory Board (NPSAB) identified “conservation at the landscape scale” as an important model to help guide NPS planning and management activities (NPSAB 2012a). According to NPSAB, transitioning from a model of standalone national parks into one of innovative partnering with others to protect landscapes that transcend administrative boundaries will help parks meet their conservation goals (NPSAB 2012a,b). Managing resources along ecological rather than political boundaries promotes stewardship by comprehensively addressing resource needs in ways that can lead to sustainability and cost-effectiveness. Landscape-scale information provides a broader, ecological perspective for assessing and interpreting park resource conditions and for guiding potential ‘next steps’ for management considerations and actions.

Landscape view from Montezuma Well. Photo Credit: NPS SODN.

The spatial scale (e.g., 3 km [2 mi], 30 km [19 mi], viewshed, watershed, etc.) and type of dataset(s) chosen for analysis depend upon the questions that are being asked. NPScape data are excellent for larger areas that extend beyond a park's boundary, but may not be as suitable for finer-scale evaluations due to the resolutions of data sets. Through an extensive literature review of ecologically-relevant areas of analysis (AOAs), Monahan et al. (2012) identified a 30 km (19 mi) area as sufficient for meeting most parks' natural resource survival needs. As a result, a 30 km (19 mi) radius surrounding each monument's boundary served as the AOA for evaluating landscape dynamics for Montezuma Castle and Tuzigoot NMs. The area within 30 km (19 mi) of the Montezuma Castle NM boundary is 3,506 km^2 (1,354 mi^2). The area within 30 km of the Tuzigoot NM boundary is 3,067 km^2 (1,184 mi^2).

NPScape is a landscape dynamics monitoring program that produces and delivers geographic information system (GIS) data, maps, and statistics that are integral to understanding natural resource conservation and conditions within a landscape context (NPS 2016c, Monahan et al. 2012). NPScape data include seven major categories, each with several measures. In this assessment, three indicators (land cover, housing, roads, and conservation status) with a total of five measures were used to address landscape dynamics for both monument's AOAs. The NPScape datasets used in this analysis are described in the sections that follow.

The land cover indicator included two measures: natural land cover and cover of impervious surfaces. For these measures, we acquired data from the Multi-Resolution Land Characteristics Consortium (MRLC 2017). The Consortium is a coordinated effort between multiple federal agencies, including the NPS, providing land cover data for the U.S. and its territories (MRLC 2017). The available data can be used to address ecosystem status and health, spatial patterns in biodiversity, land use planning, and for deriving landscape pattern metrics such as those used in this assessment.

The 2011 National Land Cover database (NLCD) was used as the input for the NPScape Land Cover toolset to calculate the proportion of area in broad land cover categories within each monument's AOA (NPS 2013a). The land cover categories were as follows: converted (i.e., developed and agriculture) and natural (i.e., forest, scrub/shrub, herbaceous/grasslands, open water, wetlands, and barren areas). Using the natural versus converted area per category tool, we generated the proportion of land area within each AOA that had been either converted or had remained the same from 2001 to 2011 using the NLCD 2001 to 2011 Land Cover from to Change Index raster layer as the input. The change categories were as follows: unchanged (i.e., remained natural and remained converted) and changed (i.e., natural to agriculture, natural to urban, and converted to natural).

We acquired the NLCD 2011 Percent Developed Imperviousness raster layer for the conterminous U.S. and used the impervious surface tool provided by NPScape to determine the proportion of area within each AOA across nine impervious surface classes as follows: 0-2%, 2-4%, 4-6%, 6-8%, 8-10%, 10-15%, 15-25%, 25-50%, and 50-100% (MRLC 2017, NPS 2013a, Xian et al. 2011).

For the housing indicator, the NPScape 2010 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 from 1950 to 2100 using county specific population estimates and variable growth rates that were location-specific. We focused our analysis on 1970 to 2010. In the SERGoM data, each cell (100 × 100-m) on private land with no development restrictions (i.e., "developable land") was assigned to one of six density classes as shown in Table 9. For Arizona, SERGoM does not consider the potential for State Trust Lands, managed by the State Land Board, to eventually be sold to benefit Arizona schools. However, SERGoM does allow for development on Native American lands. NPScape's housing density standard operating procedure (NPS 2013b) and toolset were used to clip the raster to the monument's AOA then to recalculate the housing

Table 9. 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

densities. Using the output from this analysis, we also calculated the percent change in housing density from 1970 to 2010 using ArcGIS Spatial Analyst's Raster Calculator tool.

For the roads indicator, the U.S. Census Bureau's 2015 TIGER/Line geodatabase (U.S. Census Bureau 2016) was used to calculate road density within each monument's AOA (U.S. Census Bureau 2016). The TIGER/Line geodatabase was accessed through the NPScape website (NPS 2016c). Within each AOA, road density was calculated for all roads and two subset roads files: major roads and primary roads. Primary roads included interstates, highways, and state highways, while major roads included all primary roads as well as county highways, major highways, and other state roads (Groeth et al. 2016). New road density rasters, feature classes, and statistics were generated from these data using the NPScape Road Density tool (NPS 2013c).

Land stewardship was the single measure of the conservation status indicator. 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 was available for conversion and where it was located in relation to the park boundary), as well as opportunities (e.g., connectivity and networking of protected areas)." The land-stewardship measure was based on version 1.4 of the Protected Areas Database of the United States (PAD-US; USGS GAP 2016). The PAD-US, a collaborative effort between the Conservation Biology Institute and the USGS, compiles information on land ownership, stewardship, and management status from a variety of sources, including state and federal governments. Stewardship and management status were classified using GAP (Gap Analysis Project) status codes and International Union for the Conservation of Nature (IUCN) categories. NPScape defines areas with GAP status codes 1 or 2 as "protected areas." The GAP status codes were defined as follows (USGS GAP 2012):

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.

The IUCN categories were defined as follows (USGS GAP 2012):

Category Ia: *Strict Nature Reserves* are strictly protected areas set aside to protect biodiversity and also possibly geological/geomorphological features, where human visitation, use and impacts are strictly controlled and limited to ensure preservation of the conservation values. Such protected areas can serve as indispensable reference areas for scientific research and monitoring. This IUCN status corresponds with GAP Status 1.

Category Ib: *Wilderness Areas* are protected areas are usually large unmodified or slightly modified areas, retaining their natural character and influence, without permanent or significant human habitation, which are protected and managed so as to preserve their natural condition.

Category II: *National Park Protected Areas* are large natural or near natural areas set aside to protect large-scale ecological processes, along with the complement of species and ecosystems characteristic of the area, which also provide a foundation for environmentally and culturally compatible spiritual, scientific, educational, recreational and visitor opportunities.

Category III: *Natural Monument or Feature Protected Areas* are set aside to protect a specific natural monument, which can be a land form, sea mount, submarine caverns, geological feature such as caves or even a living feature such as an ancient grove. They are generally quite small protected areas and often have high visitor value. This IUCN status corresponds with GAP Status 2.

Category IV: *Habitat/Species Management Protected Areas* aim to protect particular species or habitats and management reflects this priority. Many category IV protected areas will need regular, active interventions to address the requirements of particular species or to maintain habitats, but this is not a requirement of this category.

Category V: *Protected Landscape/Seascape Protected Areas* occur where the interaction of people and nature over time has produced an area of distinct character with significant ecological, biological, cultural, and scenic value.

Category VI: *Protected Areas with Sustainable Use of Natural Resources* are generally large, with much of the area in a more-or-less natural condition and where a proportion is under sustainable natural resource management and where such exploitation is seen as one of the main aims of the area.

NPScape's Conservation Status toolset was used to clip the PAD-US version 1.4 (USGS GAP 2016) to each monument's AOA, and then to recalculate the GAP Status and IUCN categories within the AOAs (NPS 2013d).

Reference Conditions

Reference conditions used to assess landscape dynamics at Montezuma Castle and Tuzigoot NMs are shown in Table 10. The amount of natural land cover is a simple indicator of ecological integrity (O'Neill et al. 1997) and can be described using four broad categories: intact (>90% habitat remaining), variegated (60–90% remaining), fragmented (10–60% remaining), and relictual (<10% remaining) (McIntyre and Hobbs 1999). Although the amount of natural land cover required to maintain wildlife species varies from species to species, studies generally suggest that most species are affected when less than 60–70% of natural land cover remains within a landscape (Monahan et al. 2012). Therefore, we utilized 70% natural cover as the reference condition for natural land cover (Table 10).

Paul and Meyer (2001) reviewed several studies investigating the thresholds at which the proportion of impervious surfaces within a watershed affects stream characteristics. According to Paul and Meyer (2001), thresholds for impervious surfaces range from 2–10% for stream channel geomorphology, 10–15% for fish, and 1–33% for invertebrates. While thresholds vary geographically (Utz et al. 2009), we utilized a threshold of 10% impervious surfaces to capture potential effects on fish, invertebrates, and stream geomorphology (Table 10).

The effect of housing development on ecosystem structure and function depends on a variety of factors, including landscape, pet ownership, and geographic location. Because these variables make thresholds and/or reference conditions difficult to describe, we did not establish a reference condition for housing density (Table 10).The ecological impact of roads is influenced by their geographic density, traffic volume, and surface types (NRC 2005). While several thresholds for road density (kilometers of roads per square kilometer; km/km^2) relative to wildlife have been described in the scientific literature, the studies were not specific to the greater Sonoran Desert (Monahan et al. 2012). Reported thresholds range from <0.6 km/km^2 (1.0 mi/mi^2) for wolves and mountain lions (Mladenoff et al. 1999, Forman and Alexander 1998) to <1.5 km/km^2 (2.4 mi/mi^2) for turtles (Steen and Gibbs 2004, Gibbs and Shriver 2002). For this assessment, we utilized a reference condition for road density of <1 km/km^2 (1.6 mi/mi^2) in an attempt to capture the potential effects of roads on wildlife (Table 10).

In conservation planning, the amount of land that should be conserved or stewarded in a given manner is driven by policy and science. Svancara et al. (2005) investigated and compared policy-driven versus science-based conservation target amounts from nearly 160 references. In general, they found that science-based conservation targets (e.g., ~30%) were almost three times higher than policy-based targets (e.g., ~13%) but that the science-based targets were

Table 10. Reference conditions used to assess landscape dynamics.

Indicators	Measures	Good	Moderate/Significant Concern
Land Cover	Natural Land Cover	≥ 70% of the landscape is considered natural.	< 70% of the landscape is considered natural.
	Impervious Surfaces	< 10% of the landscape was mapped as impervious.	≥ 10 of the landscape was mapped as impervious.
Housing	Density	No reference conditions.	No reference conditions.
Roads	Density	< 1 km/km^2	≥ 1 km/km^2
Conservation Status	Land Stewardship	No reference conditions.	No reference conditions.

more variable. According to Svancara et al.'s (2005) review, there is no single, ideal target amount of conservation lands that will ensure the protection of biodiversity. Because setting conservation targets is more appropriate in a regional planning setting, with the input of both scientists and policymakers, we did not set a reference condition for land stewardship (Table 10).

Condition and Trend

In 2011, the majority of land in and around Montezuma Castle and Tuzigoot NMs was considered natural forest and shrub scrub (Figure 8), with less than 5% of each AOA in the converted category (Table 11). The majority of the converted lands were developed areas near the towns of Prescott, Jerome, Cottonwood, Camp Verde, and Sedona, and along the interstates and other highways (Figure 8). From 2001 to 2011, the majority of land remained natural and there was very little change in the broad landcover categories (< 1%) (Table 12). Of the less than 0.2% of each AOA that changed, the relatively largest change occurred with the conversion of natural areas to developed/urban areas.

Since more than 70% of the AOA for both monuments was considered natural as of 2011, and there has

Table 11. Percent cover of natural and converted land cover types within Montezuma Castle and Tuzigoot NMs' AOAs.

Cover Types	Class	Montezuma Castle NM	Tuzigoot NM
Primary	Converted	3.4	3.4
	Natural	96.6	96.6
Converted	Developed	3.1	3.3
	Agriculture	0.2	0.2
Natural	Forest	35.4	27.2
	Scrub/Shrub	59.8	66.1
	Grassland/Herbaceous	0.4	1.4
	Open Water	< 0.1	< 0.1
	Wetlands	0.7	0.6
	Barren	0.4	1.2

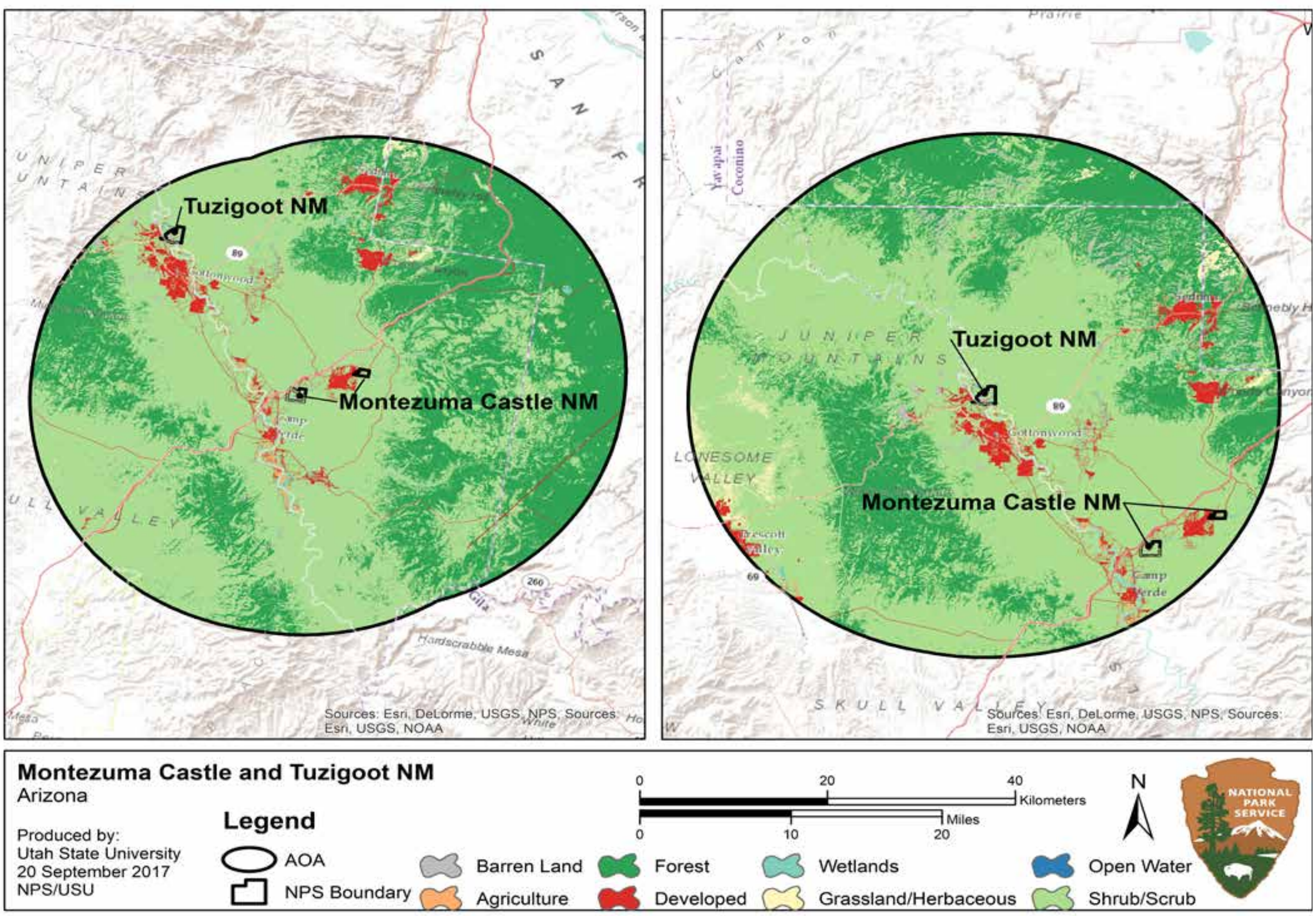


Figure 8. Map of land cover within Montezuma Castle and Tuzigoot NMs' AOAs.

Table 12. Percent change in land cover within Montezuma Castle and Tuzigoot NMs' AOAs.

Status	Class	Montezuma Castle NM	Tuzigoot NM
Unchanged from 2001 to 2011	Remained Converted	3.3	3.3
	Remained Natural	96.6	96.5
Changed from 2001 to 2011	Natural to Agriculture	< 0.1	< 0.1
	Natural to Urban	0.1	0.1
	Converted to Natural	< 0.1	< 0.1

been little change in landcover from 2001 to 2011, the condition for this measure is good and the trend is stable. However, confidence is medium since the results were based on modeled data and have not been ground-truthed.

The total amount of impervious surface within each AOA, as estimated by the 2011 NLCD, was less than 2% (Table 13). More than 95% of the AOA for each monument was mapped in the lowest impervious category, which indicates good condition. When comparing the proportion of the AOA within each category from 2006 to 2011, little has changed indicating a stable trend. As with land cover, confidence is medium because the results were obtained from modeled data and have not been ground-truthed.

For the housing density measure, we found that the amount of "developable land" considered by the SERGoM within the AOA totalled 327 km^2, or 9% of Montezuma Castle NM's AOA (Table 14). In Tuzigoot NM's AOA, the amount of developable land comprised 506 km^2, or 17% of the area. These numbers are likely skewed because SERGoM does not consider the potential for State Trust Lands, managed by the Arizona State Land Board, to eventually be sold to benefit Arizona schools but does consider Native American lands developable, such as the Hualapai Indian Reservation. Most of the developed lands were in the highest housing density category of >6 units/km^2 (Table 14). Trends from 1970 to 2010 revealed that 21% of the developable land within Montezuma Castle NM's AOA has increased in development, and 45% of Tuzigoot NM's AOA has increased in development. However, there were no reference conditions to which the housing density estimates could be compared. Therefore, the condition of housing density is unknown, but the trend has declined. Confidence is low as a result of the unknown condition.

Table 13. Percent cover of impervious surface categories for 2011 within Montezuma Castle and Tuzigoot NMs' AOAs.

Class (% Impervious)	Montezuma Castle NM		Tuzigoot NM	
	2001	2011	2001	2011
0-2%	96.0	95.9	95.8	99.6
2-4%	0.4	0.4	0.5	0.5
4-6%	0.4	0.3	0.4	0.4
6-8%	0.3	0.3	0.3	0.3
8-10%	0.3	0.3	0.3	0.3
10-15%	0.7	0.7	0.7	0.6
15-25%	0.8	0.8	0.8	0.8
25-50%	0.9	0.9	1.0	1.0
50-100%	0.3	0.4	0.3	0.5

Table 14. Housing densities for 2010 within Montezuma Castle and Tuzigoot NMs' AOAs.

Density Class (units/km^2)	Montezuma Castle NM		Tuzigoot NM	
	Area (km^2)	Percent of Total	Area (km^2)	Percent of Total
Private Undeveloped	15.85	4.9	73.47	14.5
< 1.5 units	26.68	8.2	80.83	16.0
1.5 - 6 units	47.27	14.5	108.54	21.4
> 6 units	227.56	69.6	233.20	46.1
Commercial/Industrial	7.69	2.4	8.19	1.6
Urban-Regional Park	1.97	0.6	1.97	0.4
Total Area	327.02	100	506.20	100

In Montezuma Castle NM's AOA total road density was 1.45 km/km^2 (2.3 mi/mi^2). Density of major roads was 0.12 km/km^2 (0.19 mi/mi^2) and primary road density was 0.03 km/km^2 (0.05 mi/mi^2). In Tuzigoot NM's AOA total road density also averaged 1.45 km/km^2 (2.3 mi/mi2), while major road density was 0.13 km/km^2 (0.21 mi/mi^2) and primary road density was 0.05 km/km^2 (0.8 mi/mi^2). Since total road density in both AOAs averaged greater than 1.0 km/km^2 (1.6 mi/mi^2), the condition warrants moderate/significant concern.

Figure 9 shows the amount of land by GAP status within each monument's AOA. Of Montezuma Castle NM's total AOA, 90% was categorized in one of the four GAP status classes. The majority (80%) 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 9% of land within the AOA was considered GAP Status 1 (permanently

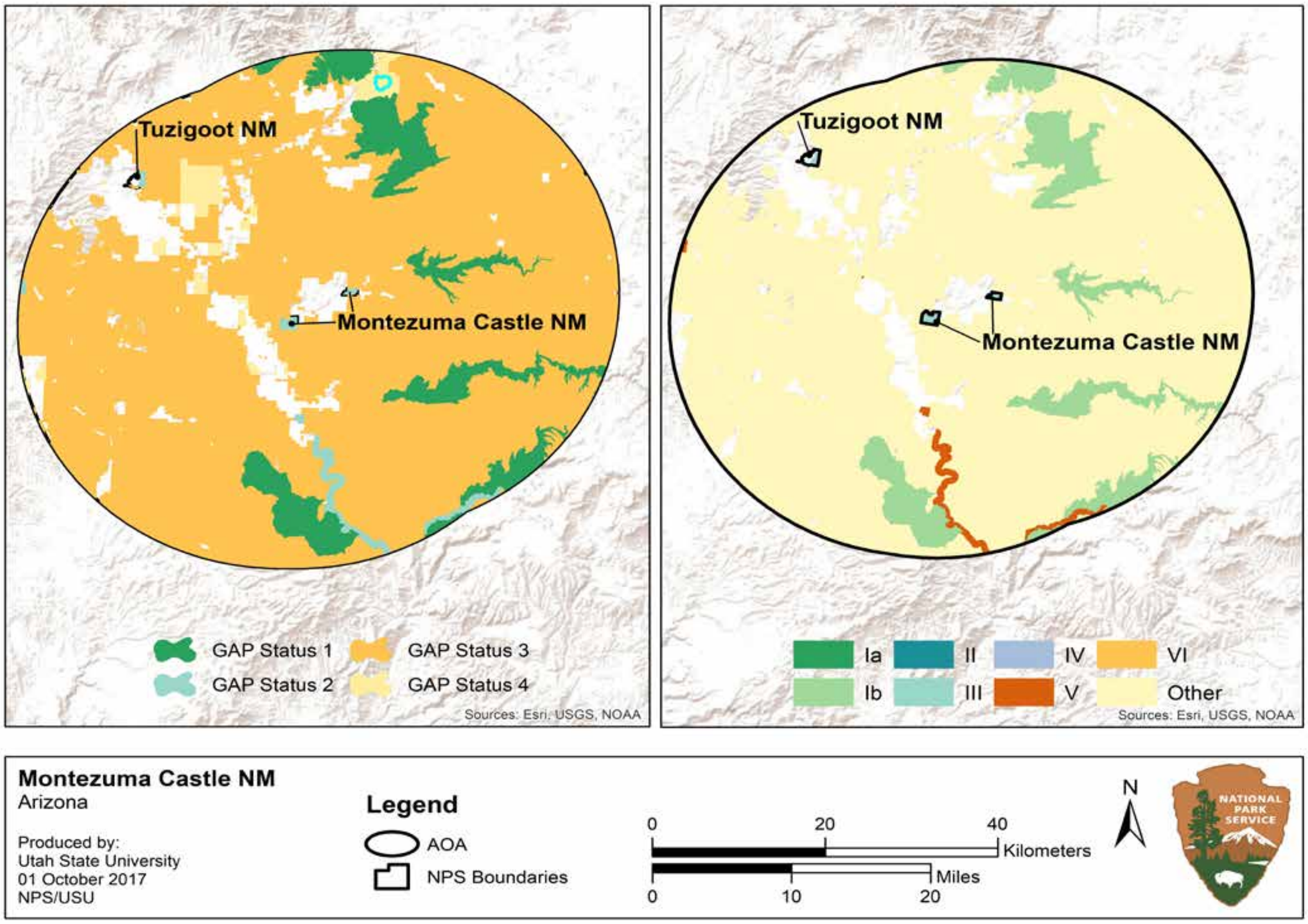


Figure 9. **Map of GAP Status and IUCN lands within Montezuma Castle NM's AOA.**

protected lands managed for biodiversity and natural processes) or GAP Status 2 (permanently protected lands managed for biodiversity but with suppression of disturbances). Finally, less than 2% of land was considered GAP status 4 (no known protections). The remaining 10% of land was not classified in any of the GAP status categories, which indicates private land. The majority of lands were not assigned to an IUCN category (Figure 9). When considering only those lands that were assigned an IUCN category, most (85%) were assigned as Ib: wilderness areas. The Forest Service administers the majority (~90%) of land within the AOA, with much of the remaining land in private ownership (Table 15).

Figure 10 shows the amount of land by GAP status within Tuzigoot NM's AOA. Of the total AOA, 97% was categorized in one of the four GAP status classes. The majority (77%) 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 14% 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, 6% 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. The majority of lands were not assigned to an IUCN category (Figure 10). When only considering lands that were assigned an IUCN category, most (85%) were assigned Ib: wilderness areas. As with Montezuma Castle NM, the Forest Service administers the majority (78%)of land Tuzigoot NM's AOA, with much of the remaining land in private ownership (Table 15).

Overall Condition, Threats, and Data Gaps

Based on this assessment, the landscape dynamics condition at both monuments is split between good and moderate concern condition (Table 16). Natural land cover and impervious surfaces data indicate good condition, while road density data warrant moderate to significant concern. The two measures

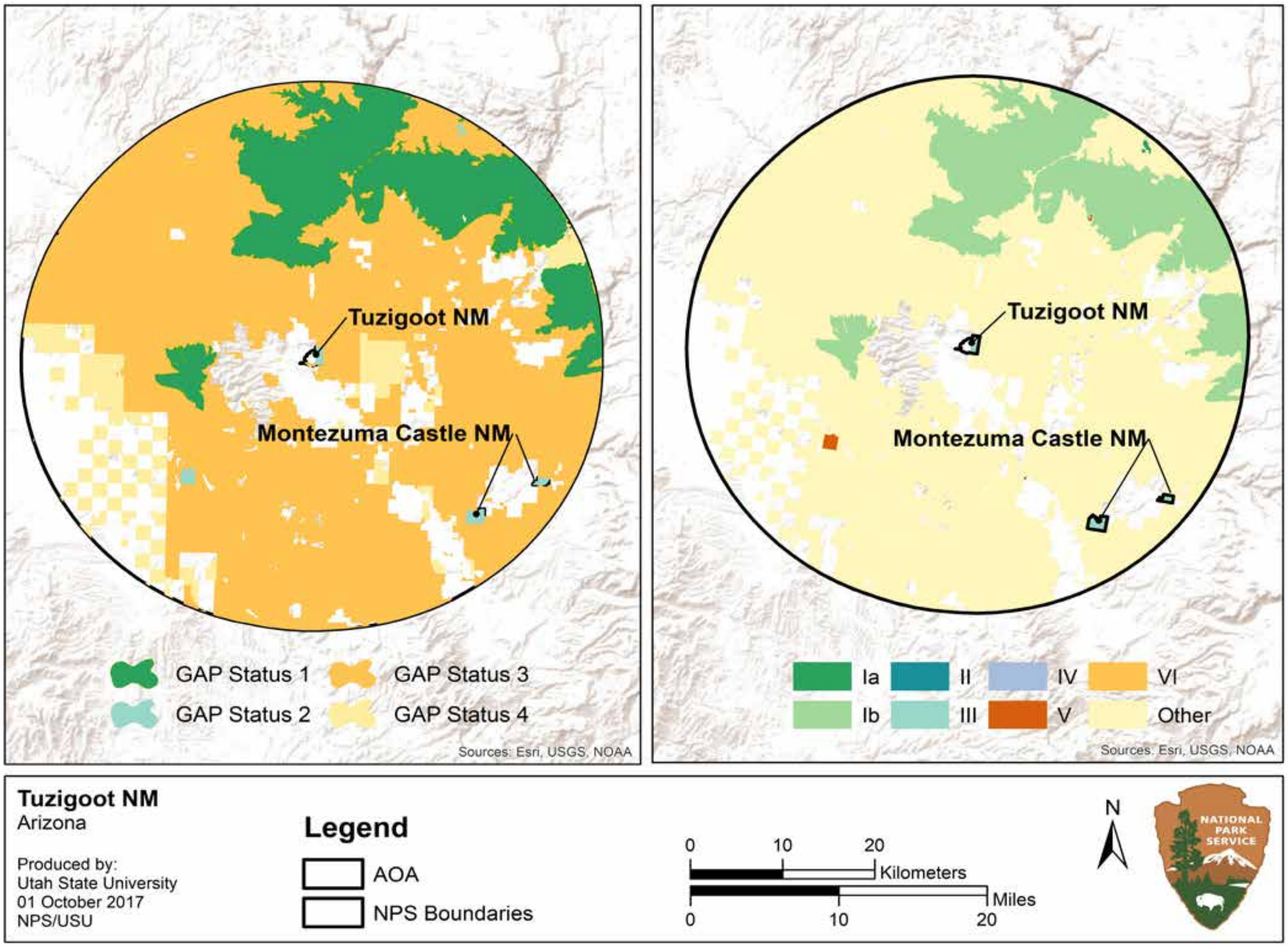


Figure 10. **Map of GAP Status and IUCN lands within Tuzigoot NM's AOA.**

Table 15. Proportion of land by manager within Montezuma Castle and Tuzigoot NMs' AOA.

Category	Manager	Montezuma Castle NM (%)	Tuzigoot NM (%)
Federal	Bureau of Land Management	0.02	0.26
	Forest Service	88.88	77.28
	National Park Service	0.16	0.18
Native American	Yavapai-Apache Nation of the Camp Verde Indian Reservation	0.07	0.08
State	State Park & Recreation	0.15	0.17
	State Trust Land	1.38	5.61
	State Fish and Game	0.01	0.02
Private	The Nature Conservancy	0.03	0.01
	Private - Open Development	9.35	16.40

with unknown condition (housing density and land stewardship) did not factor into the overall condition rating. The vast majority of the land area within each AOA was considered natural and has changed little over time. Although road densities exceeded reference thresholds for good condition, the amount of impervious surfaces was low. This is probably because most roads in the AOAs were considered secondary and are likely unpaved. It's important to note that the data used to assess all measures in this assessment were based on models that have not been ground-truthed. Therefore, confidence in the condition rating is medium. Overall trend was difficult to determine and depends on the measure under consideration. For this reason, no overall trend was assigned.

Key uncertainties are that the land cover and land use classes assume single homogeneous categories based on the dominant type and do not necessarily differentiate patch/stand characteristics such as stand age or

Table 16. **Summary of the landscape dynamics indicators, measures, and condition rationale.**

Indicators	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Land Cover	Natural Land Cover		More than 90% of the AOA for both monuments was considered natural as of 2011, and less than 1% of the AOA for both monuments has changed from 2001 to 2011. The high amount of natural land that has remained natural suggests that ecological processes such as animal movements remain intact.
	Impervious Surfaces		For both monument's AOA the majority (~96%) of the landscape fell within the 0-2% impervious category and has changed little from 2001 to 2011. This suggests that hydrologic function has not likely been affected by the amount of impervious surfaces within the AOA, but the models have not been ground-truthed.
Housing	Density		Approximately 70% of Montezuma Castle NM's AOA was within the >6 units/km². For Tuzigoot NM, 46% of the AOA was in this density class. Trends from 1970 to 2010 revealed that 21% of the developable land within Montezuma Castle NM's AOA has increased in development and 45% of Tuzigoot NM's AOA has increased in development. Because factors such as pet ownership and land cover make reference conditions difficult to describe, we did not establish a reference condition for this measure.
Roads	Density		Total road density within each monument's AOA was estimated at 1.45 km/km², which exceeded the 1.0 km/km² threshold for good condition. When considering primary roads or major roads only, road density was below this threshold. However, even secondary roads, which were included in total road density, may adversely affect wildlife movements. No trend data were available, but trends likely mirror housing density.
Conservation Status	Land Stewardship		The federal government manages the majority of the lands surrounding Montezuma Castle and Tuzigoot NMs, with only 9–14% of the AOAs classified as GAP Status 1 or 2. Most lands in each AOA allow for extractive uses, which could have adverse effects on ecosystem structure and function, but because there was not a reference condition to which the land stewardship estimates can be compared, condition could not be determined.
Overall Condition	Summary of All Measures		Natural land cover dominated both AOAs and impervious surfaces were low despite high road density. Many of these roads were secondary roads and are probably dirt or gravel. Although much of the landscape surrounding both monuments is natural, most lands were categorized as GAP Status 3, or those that allow for extractive uses. Extractive uses could alter ecosystem patterns and processes now or in the future. The condition rating partly depends on the AOA used, and in this assessment, the condition rating applies to the a 30 km (19 mi) area surrounding each monument.

understory composition. Furthermore, the boundaries between vegetation types along real environmental gradients are seldom as sharp as implied by land cover maps. Transition areas between classes represent gradients of condition that likely change positively and negatively with time. Similarly, aggregating thematic classes (e.g., "natural" versus "converted") implies simple relationships when realistically they are also gradients variable with temporal and spatial scale. The USGS' GAP Analysis Program's PAD contained many overlapping features (i.e., some land areas were counted more than once for multiple GAP Status categories and/or land management agencies). While most overlapping features were corrected prior to analysis, some features may have been missed due to the nature of the error (e.g., errors along boundaries or sliver errors). Finally, calculating the proportion of area in any manner is always a function of the sampling unit being measured (e.g., county, biome, grid cell size) and must be interpreted within that context (Homer and Fry 2012). The described metrics will not account for land units smaller than the minimum mapping unit of the input datasets and is valid only at the point in time that the data were acquired and, as with all spatial analyses, inaccuracies in the input data will be compounded in the output.

Protected natural landscapes surrounding NPS units are critical for maintaining ecosystem processes and habitats within NPS boundaries. NPS units are rarely large enough to maintain ecosystem function on their own, especially for small units such as Montezuma Castle NM and Tuzigoot NM (DeFries et al. 2007). Although NPS units generally afford high levels of protection for resources within their borders, broad-scale threats, such as changes in long-term climate, may alter the timing and severity of natural disturbances (e.g., floods, wildfires, disease outbreaks, and spread of non-native species) over wide geographic areas (NPS 2016a,b). In Tuzigoot NM and Montezuma Castle NM the climate has become warmer and drier over the last 30 years; however, the consequences of climate change for these monuments and the surrounding landscape are not fully understood (Monahan and Fisichelli 2014a,b).

On a more localized scale, water resources in both parks have been affected by activities (e.g., mining) outside of the monuments, namely with respect to water quality and soil chemistry (NPS 2016a,b; Beisner et al. 2014). There is also the potential for commercial well drilling outside of both monuments that could affect the hydrology of springs, seeps, and streams (NPS 2016a,b). Development along monument boundaries has also increased and is expected to continue to increase. Growth along Montezuma Castle NM's borders has led to an increase in light and sound pollution, particularly for the Well Unit (NPS 2016a).

In addition to light and sound pollution, development along monument boundaries creates issues with respect to trespass and habitat fragmentation. For example, at Tuzigoot NM the boundary between Dead Horse Ranch State Park and the monument creates visitor confusion regarding rules and regulations with respect to fishing (NPS 2016b). Cattle also occasionally wander across the border (NPS 2016b).

Additional information on land use adjacent to and near the monuments would be useful for interpreting trends in resources. However, compiling detailed land-use information is time-consuming and a national land-use mapping standard does not exist. To augment the NLCD land-cover information, high-resolution satellite imagery, such as Quickbird, will be obtained for the park units as part of the vegetation-mapping effort. Such imagery can provide a more detailed description of land cover and land use. After the current economy is better understood, it will be useful to re-project housing density for the next 30 years, to aid understanding of potential threats in the region. The historic condition and use of the landscape is only partially documented.

Sources of Expertise

Original assessment author was Cheryl McIntyre, former Ecologist at Sonoran Institute. Second draft author was Lisa Baril, wildlife biologist and science writer, Utah State University. Reviewers are listed in Appendix A.

Air Quality

Background and Importance

Under the direction of the National Park Service's (NPS) Organic Act, Air Quality Management Policy 4.7.1 (NPS 2006), and the Clean Air Act (CAA) of 1970 (U.S. Federal Register 1970), the NPS has a responsibility to protect air quality and any air quality related values (e.g., scenic, biological, cultural, and recreational resources) that may be impaired from air pollutants.

One of 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] 2006).

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).

Class I areas include parks that are larger than 2,428 ha (6,000 ac) or wilderness areas over 2,023 ha (5,000 ac) that were in existence when the CAA was amended in 1977 (NPS ARD 2010). Because of their small size, both Montezuma Castle and Tuzigoot National Monuments (NM) are designated as Class II airsheds. However, it is important to note that even though the CAA gives Class I areas the greatest protection against air quality deterioration, NPS management policies do not distinguish between the levels of protection afforded to any unit of the National Park System (NPS 2006).

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 2017a). The two types of NAAQS are primary and secondary, with the primary standards establishing limits to protect human health, and the secondary

Clear blue sky at Tavasci Marsh at Tuzigoot NM. Photo Credits: NPS.

standards establishing limits to protect public welfare from air pollution effects, including decreased visibility, and damage to animals, crops, vegetation, and buildings (USEPA 2017a).

The NPS' ARD (NPS ARD) air quality monitoring program 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 how far (visual range) one can see (NPS ARD 2002), but air pollution can degrade visibility. Both particulate matter (e.g. soot and dust) and certain gases and particles in the atmosphere, such as sulfate and nitrate particles, 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 (NPS ARD 2003), 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 2013a).

Ozone is also phytotoxic, causing foliar damage to plants (NPS ARD 2003). Ozone penetrates leaves through stomata (openings) and oxidizes plant tissue, which alters the physiological and biochemical processes (NPS ARD 2013b). Once the ozone is inside the plant's cellular system, the chemical reactions can cause cell injury or even death (NPS ARD 2013b), but more often reduce the plant's resistance to insects and diseases, reduce growth, and reduce reproductive capability (NPS ARD 2015).

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 exists when the species of plants are 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 2013b).

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, and accumulation of mercury or toxins (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 2013a). 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 (2017b), 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 2017b), including at Montezuma Castle and Tuzigoot NMs.

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 2013a).

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 Montezuma Castle and Tuzigoot NM's airshed was developed by the NPS ARD for use in Natural Resource Condition Assessments (NPS ARD 2018). 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 17). NPS ARD uses all available data from NPS, USEPA, state, and/or tribal monitoring stations to interpolate air quality values, with a specific value assigned to the maximum value within each park. Even though the data were derived from all available monitors, data from the closest stations "outweigh" the rest.

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 are averaged over a 5-year period 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 Montezuma Castle and Tuzigoot NM's boundaries is reported as the visibility condition from this national analysis. There were no on-site or nearby monitors with which to assess trend.

Table 17. 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. Ozone data were collected at a monitoring station located farther than 10 km (7 mi), which is beyond the distance at which NPS ARD considers representative for calculating trends (Taylor 2017).

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 based on human health effects. 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 monuments were the maximum estimated values within monument boundaries derived from this national analysis. There were no on-site or nearby monitors to assess trends.

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 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 monument boundaries derived from this national analysis. There were no on-site or nearby monitors to assess trends.

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 only nationally 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 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. Nitrogen and sulfur conditions were derived by interpolating measured values from multiple monitoring stations farther than 16 km (10 mi). NPS ARD considers stations located farther than this distance outside the range that is representative for calculating trends (Taylor 2017).

The third measure of the wet deposition indicator was evaluated using a mercury risk 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 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 these monuments.

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 it is biologically available and able to accumulate in food webs (NPS ARD 2013a). 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 18.

A haze index estimate of less than 2 dv above 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 (2017a) at a level to protect human health: 4th-highest daily maximum 8-hour ozone concentration of 70 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

Table 18. Reference conditions for air quality parameters.

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

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 vegetation health W126 condition thresholds are 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 is considered good; 7-13 ppm-hrs is considered to be of "moderate" concern; and >13 ppm-hrs is considered to be of "significant concern" (Taylor 2017).

For nitrogen and sulfur, 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."

Ratings for mercury wet deposition and predicted methylmercury concentrations can be evaluated using the mercury condition assessment matrix shown in Table 19 to identify one of three condition categories. 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).

Table 19. 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 and Trend

The values used to determine conditions for all air quality indicators and measures are listed in Table 20.

The estimated 5-year (2011-2015) haze index measure of visibility for Montezuma Castle NM (4.8 dv) and Tuzigoot NM (5.3 dv) fell within the moderate concern condition rating, which indicates visibility was degraded from the good reference condition of <2 dv above the natural condition (Taylor 2017). There were not sufficient on-site or nearby monitors with which to determine trends. Confidence in this measure is medium because estimates were based on interpolated data from more distant visibility monitors. Visibility impairment primarily results from small particles in the atmosphere that include natural particles from dust and wildfires and anthropogenic sources from organic compounds, NO_x and SO_2. The contributions made by different classes of particles to haze varies by region but often includes ammonium sulfate, coarse mass, and organic carbon. 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 road dust, agriculture dust, construction sites, mining operations, and other similar activities. Data on the contribution of visibility impairing particulates for the monuments were not available.

Data for the human health measure of ozone were derived from estimated five-year (2011-2015) values of 73.3 (Montezuma Castle NM) and 72.5 (Tuzigoot NM) parts per billion, which resulted in a condition rating warranting significant concern (NPS ARD 2016). Trend could not be determined because there were not sufficient on-site or nearby monitoring data. The level of confidence is medium because estimates were based on interpolated data from more distant ozone monitors.

Ozone data used for the W126 vegetation health measure of the condition assessment were derived from estimated five-year (2011-2015) values of 18.2 (Montezuma Castle NM) and 17.4 (Tuzigoot NM) parts per million-hours (ppm-hrs). Using these numbers, vegetation health risk from ground-level ozone warrants significant concern at both monuments (NPS ARD 2016). Trend could not be determined because there were not sufficient on-site or nearby monitoring data. Our level of confidence in this measure is medium because estimates were based on interpolated data from more distant ozone monitors.

There are 12 and eight species of ozone-sensitive plants in Montezuma Castle NM and Tuzigoot NM, respectively (Tables 21 and 22). In Montezuma Castle NM, seven species are considered bioindicators, while there were six bioindicator species in Tuzigoot NM. Bioindicators are species that can reveal ozone stress in ecosystems by producing distinct visible and identifiable injuries to plant leaves (Bell, In Review).

Wet N deposition data used for the condition assessment were derived from estimated five-year average values (2011-2015) of 1.6 (Montezuma Castle NM) and 1.3 (Tuzigoot NM) kg/ha/yr. This resulted in a condition rating of moderate concern for Tuzigoot NM (NPS ARD 2016). At Montezuma Castle NM, however, the condition rating was elevated to significant concern because ecosystems there may be more vulnerable to

Table 20. Condition and trend results for air quality indicators at Montezuma Castle and Tuzigoot National Monuments.

NPS Unit	Visibility (dv)	Ozone: Human Health (ppb)	Ozone: Vegetation Health (ppm-hrs)	N (kg/ha/yr)	S (kg/ha/yr)	Wet Mercury (µg/m^2/yr)	Predicted Methymercury (ng/L)
Montezuma Castle NM	Moderate Concern (4.8) 2011-2015	Significant Concern (73.3) 2011-2015	Significant Concern (18.2) 2011-2015	Significant Concern (1.6*) 2011-2015	Good (0.6) 2011-2015	Moderate Concern (5.7-6.4) 2013-2015	Good (0.04) 2013-2015
Tuzigoot NM	Moderate Concern (5.3) 2011-2015	Significant Concern (72.5) 2011-2015	Significant Concern (17.4) 2011-2015	Moderate Concern (1.3) 2011-2015	Good (0.5) 2011-2015	Good (5.2) 2013-2015	Good (0.04) 2013-2015

* Value is within the range considered moderate concern, but ecosystems at the monuments may be particularly sensitive to nitrogen-enrichment effects. Thus, the condition has was elevated to significant concern (NPS ARD 2016).

Sources: NPS ARD (2016).

Table 21. Ozone sensitive plants in Montezuma Castle NM.

Scientific Name	Common Name	Bioindicator
Acer negundo	Ashleaf maple, boxelder	Yes
Ailanthus altissima	Copal tree, tree of heaven	Yes
Apocynum cannabinum	Common dogbane	No
Artemisia ludoviciana	Cudweed sagewort, white sagebrush	Yes
Mentzelia albicaulis	Small-flowered blazing star	Yes
Oenothera elata	Hooker's evening primrose	Yes
Parthenocissus vitacea	Virginia creeper	No
Populus fremontii	Freemont's cottonwood	Yes
Rhus aromatica	Fragrant sumac	Yes
Salix exigua	Coyote willow, sandbar willow	No
Salix gooddingii	Goodding's willow	No
Solidago canadensis	Canada goldenrod	No

Table 22. Ozone sensitive plants in Tuzigoot NM.

Scientific Name	Common Name	Bioindicator
Acer negundo	Ashleaf maple, boxelder	Yes
Ailanthus altissima	Copal tree, tree of heaven	Yes
Artemisia ludoviciana	Cudweed sagewort, white sagebrush	Yes
Humulus lupulus	Common hops	Yes
Mentzelia albicaulis	Small-flowered blazing star	Yes
Populus fremontii	Freemont's cottonwood	Yes
Salix exigua	Coyote willow, sandbar willow	No
Salix gooddingii	Goodding's willow	No

the adverse effects of excess nitrogen deposition (NPS ARD 2016). 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 0.6 (Montezuma Castle NM) and 0.5 (Tuzigoot NM) kg/ha/yr, which resulted in a good condition rating for both monuments (NPS ARD 2016). 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 (2016) studied the risk from acidification from acid pollutant exposure and ecosystem sensitivity for Sonoran Desert Network (SODN) parks, which includes Montezuma Castle NM and Tuzigoot 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 were considered low for estimated acid pollutant exposure and ecosystem sensitivity to acidification at Montezuma Castle NM (Sullivan 2016). At Tuzigoot NM, the risk rankings were also low. The effects of acidification can include changes in water and soil chemistry that impact ecosystem health. Little has been done regarding the ecological effects of acidification on arid ecosystems in the SODN, but it is unlikely that significant effects have occurred in the network except near metropolitan areas such as Phoenix and Tucson (Sullivan 2016).

Sullivan (2016) also developed risk rankings for nutrient N pollutant exposure and ecosystem sensitivity to nutrient N enrichment. These risk rankings were considered low for nutrient N pollutant exposure and ecosystem sensitivity to nutrient N enrichment at both monuments. Potential effects of nitrogen deposition include the disruption of soil nutrient cycling and impacts to the biodiversity of some plant communities, including arid and semi-arid communities, grasslands, 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 monuments were identified (E&S Environmental Chemistry, Inc. 2009). In Tuzigoot NM, the NLCD dataset mapped 57 ha (141 ac) of grassland and meadow nitrogen-sensitive areas, while LANDFIRE mapped 1 ha (~3 ac) of this habitat type (Figure 11). An additional 210 ha (519 ac) of arid and semi-arid nitrogen-sensitive plant communities were mapped in the monument by LANDFIRE. In Montezuma Castle NM, 319 ha (788 ac) of arid and semi-arid nitrogen-sensitive plant communities were mapped by LANDFIRE (Figure 12).

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 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 Casa Grande Ruins 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.

Because rainfall in the arid southwest is low, there is relatively little wet S or N deposition (Sullivan 2016). Dry S and N deposition is more common in arid ecosystems but difficult to quantify because many factors influence deposition, including the mix of air

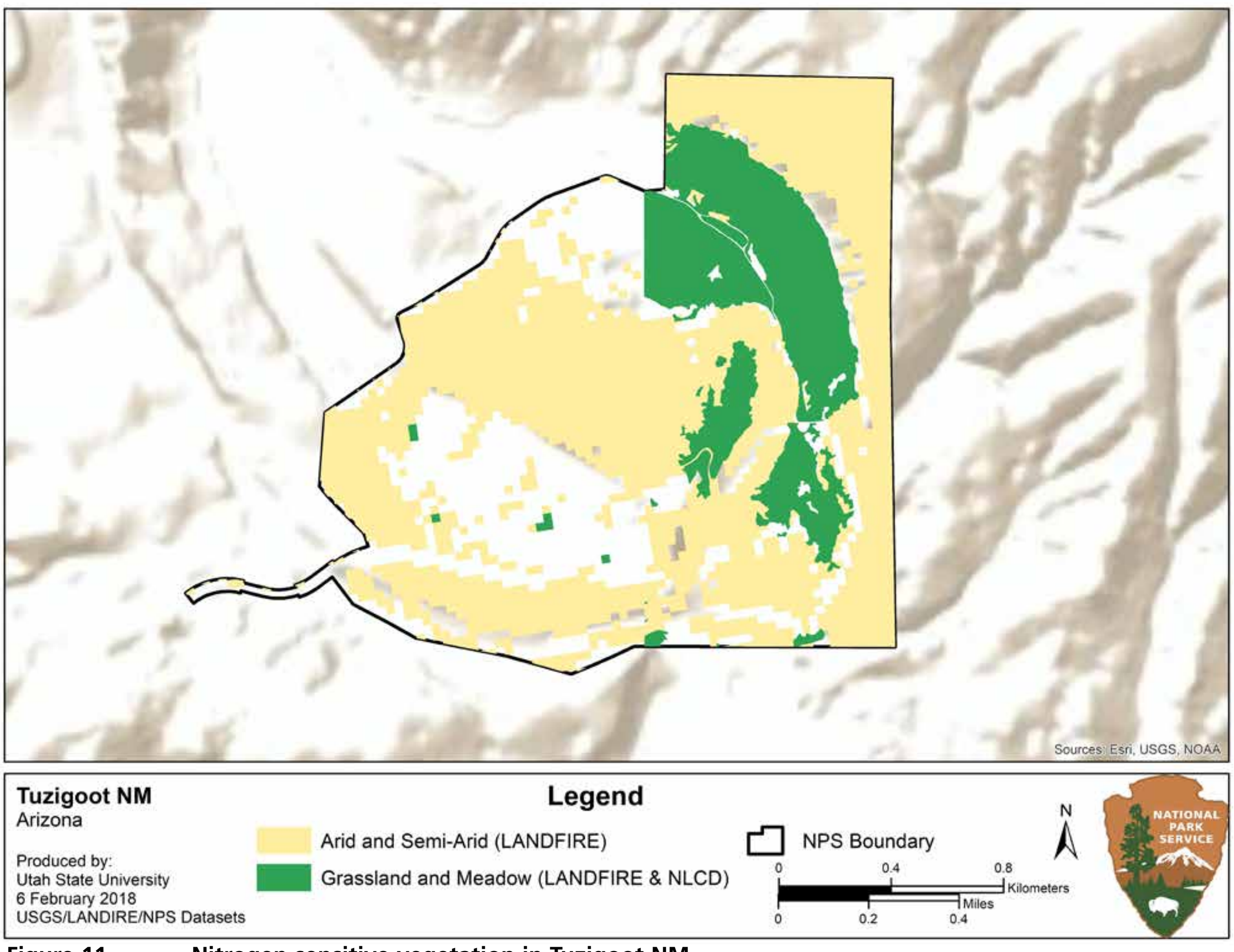


Figure 11. **Nitrogen sensitive vegetation in Tuzigoot NM.**

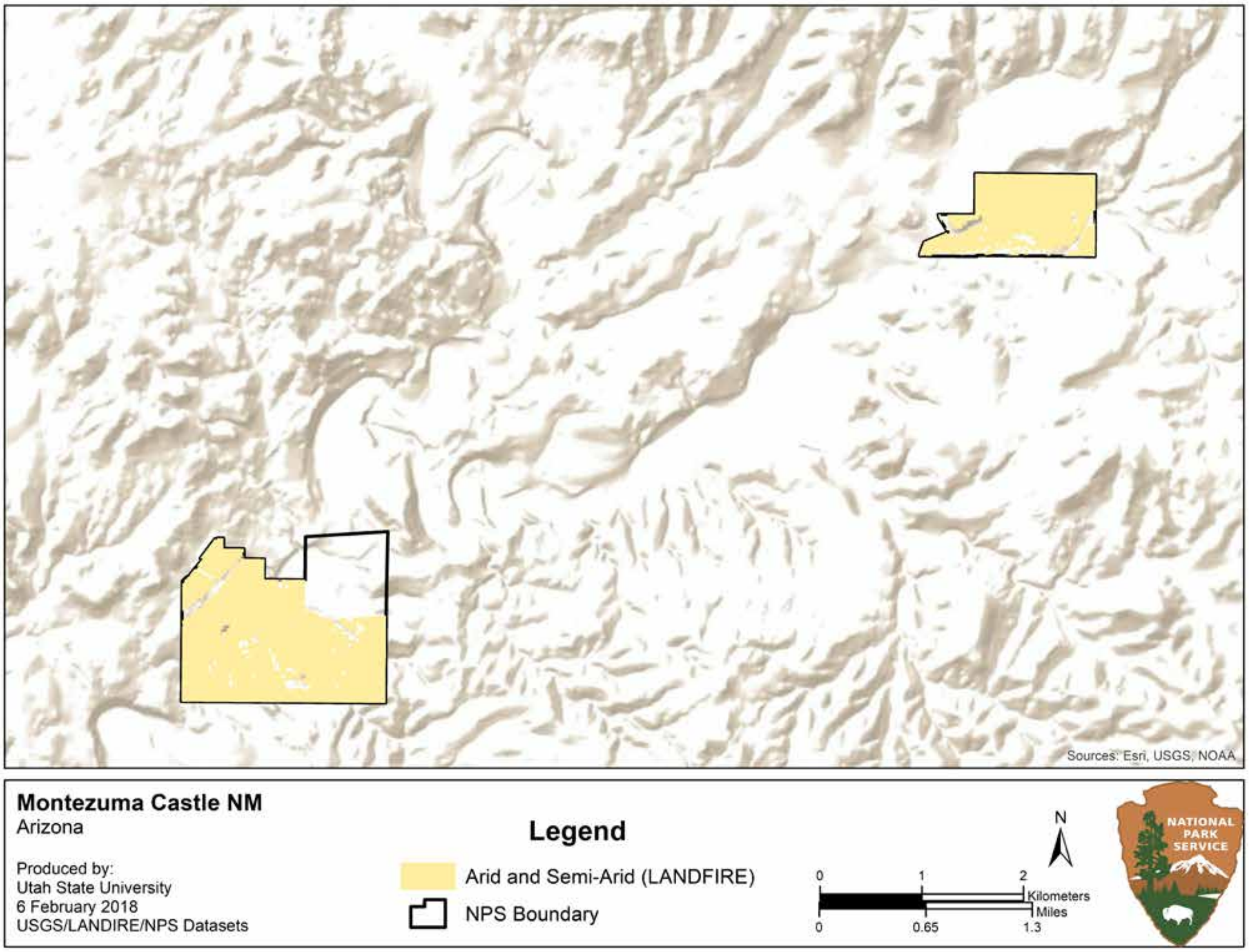


Figure 12. Nitrogen sensitive vegetation in Montezuma Castle NM.

pollutants present, surface characteristics of soil and vegetation, and meteorological conditions (Fenn et al. 2003, Weathers et al. 2006). Sparse vegetation may increase the exposure of sols to direct dry deposition of atmospheric pollutants (Sullivan 2016).

The 2013–2015 estimated wet mercury deposition was moderate at Montezuma Castle NM, ranging from 5.7 to 6.4 µ/m^2/yr (NPS ARD 2017a). The predicted methylmercury concentration in monument surface waters was low, estimated at 0.04 ng/L. Wet deposition and predicted methylmercury ratings were combined to determine a moderate concern condition status for the monument. The degree of confidence in the mercury/toxics deposition condition is low because there are no park-specific studies examining contaminant levels. Trend could not be determined.

At Tuzigoot NM, the 2013–2015 estimated wet mercury deposition was low at 5.2 µm^2/yr (NPS ARD 2017a). The predicted methylmercury concentration in monument surface waters was low, estimated at 0.04 ng/L, and was also in good condition. Wet deposition and predicted methylmercury ratings were combined for an overall good condition status. The degree of confidence in the mercury/toxics deposition condition was low because there are no park-specific studies examining contaminant levels. 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 seven measures, which are summarized in Table 23. Based on these indicators and measures, the overall condition of air quality at both monuments warrants moderate concern. The overall confidence is medium since the values for all measures were collected from more distant monitors, which also represents a key uncertainty since the values may not accurately reflect conditions

Table 23. Summary of air quality indicators, measures, and condition rationale.

Indicators	Measures	Condition/Trend/ Confidence	Rationale for Condition
Visibility	Haze Index		The haze index was within the range considered moderate concern at both monuments. Visibility may be impacted by local and regional cities such as Phoenix, Arizona; Las Vegas, Nevada; and Los Angeles, CA. Hazy days reduces a visitor's ability to distinguish color, form, and texture. Clear skies are important to visitor enjoyment, especially where the park includes scenic vistas. Dark night skies are also affected by haze.
Level of Ozone	Human Health: Annual 4th-Highest 8-hour Concentration		The five-year (2011-2015) average ozone level as it relates to human health warrants significant concern. At levels found in the monuments, ozone may irritate respiratory systems and increase a person's susceptibility to lung infections, allergens, and other air pollutants.
	Vegetation Health: 3-month maximum 12hr W126		The five-year (2011-2015) ozone level (11.2 ppm-hrs) as it relates to plant health also warrants significant concern. Some plants are particularly sensitive to high levels of ozone (e.g., lichens, mosses, and liverworts). Plant response to ozone can serve as an early warning sign of air pollution. Shrubs, trees, and herbaceous species may also be affected.
Wet Deposition	N in kg/ha/yr	Montezuma Castle Tuzigoot	Although nitrogen values for both monuments were within the moderate concern range, the condition was elevated to significant concern for Montezuma Castle NM since ecosystems there may be particularly sensitive to excessive nitrogen deposition. In excess, nitrogen can cause changes in water and soil chemistry that can have rippling effects throughout the ecosystem. Algal blooms, fish kills, and loss of biodiversity are some of the potential adverse consequences of excess nitrogen in the environment.
	S in kg/ha/yr		Unlike nitrogen, wet deposition of sulfur values indicated good condition for both monuments. As with nitrogen, excess sulfur deposition can also influence aquatic and terrestrial environments by altering soil and water chemistry with potential rippling effects through the ecosystem. However, this measure indicated wet sulfur deposition was within the range of normal variability.
	Wet Mercury Deposition (μg/m²/yr)	Montezuma Castle Tuzigoot	Mercury/toxics deposition warrants moderate concern at Montezuma Castle NM but was in good condition at Tuzigoot NM. Given landscape factors that influence the uptake of mercury in the ecosystem, the status is based on estimated wet mercury deposition and predicted levels of methylmercury in surface waters. The degree of confidence in the mercury/toxics deposition status is low because wet deposition and methylmercury concentration estimates are based on interpolated or modeled data rather than in-park studies.
Overall Condition	Summary of All Measures		Air quality data indicate that most measures are degraded from good condition at both monuments. A key data gap is that most measures were interpolated from distant monitors and may not accurately reflect conditions within the park. For this reason, confidence in the overall condition rating is medium and trend is unknown. While protecting air quality is fundamental to ecosystem health within the monuments, the majority of threats originate from outside their boundaries; however, both monuments are committed to reducing emissions from administrative and recreational use as well as participating in regional planning to improve air quality.

within the monuments. An additional key uncertainty of the air quality assessment is knowing the effect(s) of air pollution, especially of nitrogen deposition, on ecosystems within the national monuments. The lack of a wet deposition monitor in central Arizona is a notable gap in the national deposition-monitoring network, and the NPS ARD has recommended the placement of one at Tonto NM. Combining the data from a monitor at Tonto NM with data from the existing monitor at Grand Canyon National Park could provide more accurate wet deposition estimates for Montezuma Castle and Tuzigoot NMs.

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 2006). The majority of threats to air quality within the monuments originate from outside their boundaries and include the effects of climate change, forest fires (natural or prescribed), dust created from mineral and rock quarries, and carbon emissions.

Coal-burning power plants are a major source of mercury in remote ecosystems (Landers et al. 2010). Across the SODN region, there are numerous coal-burning power plants (Sullivan 2016). Mercury emissions may threaten ecosystems within the monument, including amphibians, invertebrates, and other wildlife that depend on rock pools, springs, and riparian areas. Mercury is not monitored across SODN parks, but data from the Mercury Deposition Network for other areas in the southwest suggest that mercury concentrations in rainfall are high. A study examining mercury concentrations in fish from 21 national parks in the western U.S., found that in Capitol Reef NP and Zion NP in Utah, speckled dace (*Rhinichthys osculus*) contained mercury levels that exceeded those associated with biochemical and reproductive effects in fish and reproductive impairment in birds (Eagles-Smith et al. 2014). This was particularly concerning since speckled dace forage on invertebrates, yet exhibited concentrations that were greater than larger, predatory fish species such as lake trout (*Salvelinus namaycush*) (Eagles-Smith et al. 2014).

Stressors to air quality include both naturally-occurring events and anthropogenic activities. Emissions from power and industrial plants, factories, mining operations, dry cleaning facilities, vehicles, and agriculture can negatively affect air quality (Mau-Crimmins et al. 2005, Porter and Wondrak-Biel 2011). Historically, air quality was adversely affected by mining and smelting activities in Jerome and Clarkdale, Arizona, but air quality has improved since the mine and smelter were closed in the 1950s (Mau-Crimmins et al. 2005) and the mine tailings area was capped with natural soil and seeded with native grasses and other plants in 2007 (Freeport-McMoRan n.d.). In order to help alleviate threats to air quality, Montezuma Castle and Tuzigoot NMs intend to "eliminate or reduce emissions associated with administrative and recreational use of the monuments" and "participate in regional air planning and research, and the implementation of air quality standards" (NPS 2010a).

The western U.S., and the Southwest in particular, has experienced increasing temperatures and 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). In both national monuments, the annual average temperature has significantly increased and precipitation has declined (Monahan and Fisichelli 2014a,b). One effect of climate change is a potential 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). In addition to prescribed burns by the U.S. Forest Service (USFS 2016), natural wildfires have increased across the western U.S., and the potential for the number of wildfires to grow is high as climate in the Southwest becomes warmer and drier (Abatzoglou and Williams 2016). Warmer conditions can 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 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 National Park Service's 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. The assessment was written by Lisa Baril, science writer at Utah State University. Reviewers are listed in Appendix A.

Hydrology

Background and Importance

In Tuzigoot and Montezuma Castle National Monuments (NM), streams, rivers, and wetlands are major components of the ecosystem, supporting a variety of wildlife and plants as well as humans, both past and present. Proximity to streams and rivers were the major draw for the Sinagua people who inhabited the Verde Valley for three centuries before abandoning the area sometime during the 1400s (NPS 2016a,b). During their occupation, the Sinagua constructed complex multi-room structures for which the monuments are known. They also made use of and expanded upon a series of canals constructed in 600 CE (common era) by the Hohokam who came before the Sinagua (NPS 2016a). These canals were constructed to divert water resources from the Verde River and its tributaries for agriculture (NPS 2016a). Today the Verde River and its tributaries continue to support humans, wildlife, and plants, but land use upstream and surrounding the monuments has the potential to affect the natural hydrology of the area.

In Tuzigoot NM 0.4 km (0.2 mi) of the Verde River flows through the monument, and in Montezuma Castle NM, a combined 6.9 km (4.3 mi) of stream flow through the monument's two units (Gwilliam et al. 2013). Beaver Creek, a major tributary of the Verde River, flows through the Castle Unit, and Wet Beaver Creek, a tributary of Beaver Creek, flows through the Well Unit (Gwilliam et al. 2013). Like many watersheds in Arizona and across the western U.S., the middle Verde River watershed has a long history of development and resource extraction, including ranching, agriculture, and mining (Black et al. 2005). These land uses have and continue to influence hydrology in the Verde River and its tributaries (Garner et al. 2013).

Since streams and rivers are generally sensitive to stressors, both locally and at the watershed-level, they are one of the most useful ecosystems to monitor to determine long-term conditions and trends (Mau-Crimmins et al. 2005). However, groundwater is inextricably linked to surface water. Considering both groundwater and surface water together is critical to understanding the condition of hydrologic resources. Groundwater may reappear at the surface months, years, or even centuries later (Filippone et al. 2014). At the right depth, groundwater sustains riparian plants and is the primary source of water for humans across the southwestern U.S. (Stromberg et al. 1996). The potential loss of ground- and surface water in Tuzigoot and Montezuma Castle NMs due to long-term concerns, such as climate change, groundwater withdrawals outside monument boundaries, and water diversions upstream of the monuments is of significant concern to park

Tavasci Marsh in Tuzigoot NM lies in an abandoned oxbow of the Verde River. Photo Credit: NPS.

managers (NPS 2016a,b). This hydrology assessment for Montezuma Castle and Tuzigoot NMs focuses on groundwater availability, surface water quantity, and the physical characteristics of the stream channel, which influences streamflow and rates of aquifer recharge.

Data and Methods

To assess the current condition of hydrology in Montezuma Castle and Tuzigoot NMs, we used three indicators with between one and four measures each for a total of nine measures. The indicators are groundwater, surface water quantity, and stream channel geomorphology. Indictors and measures are based on the National Park Service (NPS) Sonoran Desert Inventory and Monitoring Network (SODN) ground- and surface water monitoring program (Gwilliam et al. 2013, 2017). We relied primarily on data collected and provided by the State of Arizona's Department of Water Resources (ADWR) (ADWR 2018) and the U.S. Geological Survey's (USGS) National Water Information System (NWIS) database (USGS 2018a). Additional data and background information were available in SODN's two reports for the monuments (Gwilliam et al. 2013, 2017).

Depth to groundwater is a measure of how close the water table is to the Earth's surface, and the lower the depth to groundwater, the more available water is to riparian plants (USGS 2016). SODN monitors three wells in and around each monument (Table 24). In Montezuma Castle NM, the water supply well is the only well located within NPS boundaries (Filippone et al. 2014). The three wells monitored for Tuzigoot NM are located outside the monument's boundary (Filippone et al. 2014). The three wells monitored for Tuzigoot NM draw from the Verde Formation local aquifer, while the water supply well for Montezuma Castle NM draws from the Verde Formation limestone aquifer. The aquifers for the remaining two wells monitored for Montezuma Castle NM are unknown.

Wet Beaver Creek in Montezuma Well unit. Photo Credit: NPS.

Depth to groundwater data for five of the six wells listed in Table 24 were downloaded from ADWR (2018). Data for the USGS well were downloaded from the NWIS

Table 24. Wells monitored by SODN in Montezuma Castle and Tuzigoot NMs.

NPS Unit	Well Name	Aquifer/Groundwater Basin	Well Depth (m)	Dates of Data Availability (mm/dd/yy)	State and/or USGS Well ID
Montezuma Castle NM	Water Supply Well	Verde Formation Limestone/ Verde River Basin	160	11/25/58-04/12/18 (annually)	55-629124
	Arizona Department of Water Resources Index Well	Unknown/Verde River Basin	300	09/29/91-04/09/18 (intermittent)	55-514006
	U.S. Geological Survey Well	Unknown/Verde River Basin	89	07/26/15-03/09/2017 (daily)	343852111460301
Tuzigoot NM	Kauzlarik Arizona Department of Water Resources Index Well	Verde Formation local aquifer/ Verde River Basin	1,400	10/09/02-04/13/18 (annually)	A-16-03 22DCD (55-629211)
	City of Cottonwood Index Well #1	Verde Formation local aquifer/ Verde River Basin	300	10/09/02-4/13/18 (annually)	A-16-03 34AAD (55-609076)
	State Land Department	Verde Formation local aquifer/ Verde River Basin	1,200	06/22/05-06/23/17 (daily)	A-16-03 36CDC (55-614257)

Source: Filippone et al. (2014).

website (USGS 2018a). All data were accessed on 26 July 2018. The length of time during which each well has been monitored varies substantially. At Tuzigoot NM, the wells were monitored beginning in 2002 or 2005 through 2017 or 2018. In Montezuma Castle NM, well data range from 1958 to 2018 and as short as 2015 to 2017. Most wells were monitored annually or intermittently, but one well for each monument has been monitored daily.

Surface water quantity is an important indicator of the amount of water available for wildlife and plants and for maintaining ecosystem processes. Data for the four measures used to assess the condition of surface water quantity were obtained from the USGS NWIS website on 26 July 2018 (USGS 2018a). Data were reported by water year (WY), which begins October 1 and ends September 30. SODN monitors surface water quantity in Tuzigoot NM using USGS stream gage 09504000 located on the Verde River approximately 5 km (3 mi) upstream of the monument's index site (Gwilliam et al. 2017). The index site is the water quality sampling site surveyed by SODN (map available in Gwilliam et al. 2017). There is an agricultural diversion dam located between the USGS gage and the index site, which significantly impacts flow (Gwilliam et al. 2017). Flows through the monument can be reduced by as much as 86% (Gwilliam et al. 2017). Data for this gage were available for WYs 1966 through 2017 and a portion of WY 2018. Data for WYs 1916, 1918, and 1920 were also available for this stream gage.

In Montezuma Castle NM, data for the USGS gage 09505200 on Wet Beaver Creek 4.6 km (2.9 mi) upstream of SODN's index site were available for WYs 1962 through 2017 in addition to a portion of WY 2018. USGS data for the Beaver Creek stream gage 09505400 were limited and only available for WYs 2004-2009. Therefore, we did not include those data in this assessment.

The first surface water quantity measure is the number of no-flow events. We accessed the number of no-flow events through the USGS' water-year summary tables for the two stream gages. A no-flow event was defined as the period during which daily mean flow averaged 0.0 cubic feet per second (cfs), regardless of the number of days in the event. For example, an event could last a single day or more than 30 days. Since the length of the event is also important, we summarized data by the number of events per WY and the dates, or length, of each event.

The number of 50-year or greater flood events is the second measure of surface water quantity. The probability of a 50-year flood event is 1 in 50, or a 2% chance of occurrence in any given year (USGS 2018b). According to the USGS StreamStats Data-Collection Station Report for the Verde River stream gage, the flow for a 50-year peak flood is 51,700 cfs (USGS 2018c). The estimate for Wet Beaver Creek is 12,700 cfs (USGS 2018d). To determine when or if a 50-year flood event occurred at either stream gage, we downloaded instantaneous peak flow data from the USGS NWIS stream gage website (USGS 2018a).

The third measure of surface water quantity is the number of bankfull events. A bankfull event is considered a 2-year flood event, which has a 1 in 2 chance of occurring in any given year, or a 50% chance of occurrence (Gwilliam et al. 2013, USGS 2018b). Bankfull events scour channels of fine materials, form bars, and maintain channel structure (Gwilliam et al. 2013). The 2-year flood event flow data provided in the StreamStats Data-Collection Station Report for the Verde River at Clarkdale, Arizona is 5,210 cfs (USGS 2018c). At Wet Beaver Creek the estimate is 3,040 cfs (USGS 2018d). We determined the years for which the instantaneous peak flow exceeded the 2-year flood estimate for each stream gage and then examined the summary data for those years to determine the total number of bankfull events for each of those water years (USGS 2018a).

The last measure of surface water quantity is the change in mean annual discharge. We examined long-term trends in mean annual discharge and discharge by season for both stream gages. For this analysis we downloaded mean annual discharge data and daily discharge data. Daily discharge data were summed by hydrologic season as defined in the baseline water quality reports (NPS 1995, 1999) and in Gwilliam et al. (2013) for each monument (Table 25).

Stream channel geomorphology is an important indicator of watershed condition, integrating both biological and geomorphological processes (e.g., soil erosion, nutrient cycling, discharge characteristics, disturbance events, and surface and groundwater quality and quantity) (Gwilliam et al. 2013). Geomorphology data were collected at Beaver Creek

Table 25. Hydrologic seasons in Montezuma Castle and Tuzigoot NMs.

Season	Months
Winter	November - March
Spring	March - April
Summer	May - July
Monsoon	July - November

Sources: NPS (1995,1996) and Gwilliam et al. (2013).

during WYs 2009-2011 and were reported in Gwilliam et al. (2013). Below we provide a brief description of each of the four measures of stream channel geomorphology and its significance. For details on data collection methods see Gwilliam et al. (2013).

Sinuosity is a measure of the length of the channel thalweg (lowest point in the stream channel) to the length of the stream valley as measured between the same two points (Rosgen 1996). Sinuosity determines how well a stream dissipates energy. Water in a stream with low sinuosity flows at a higher rate than a stream with high sinuosity (Rosgen 1996). High water flows accelerate erosion, which further alters sinuosity. Sinuosity depends on the landscape setting and is different for each stream (Rosgen 1996).

Cross-sectional area refers to the channel capacity, or size of the river channel cross-section to bankfull stage (Rosgen 1996). This measure varies with position in the stream and discharge. Changes in discharge will alter the shape of the channel. Higher discharge rates will result in a deeper and wider stream, while lower discharge rates will result in a narrower, more shallow channel (Rosgen 1996).

The dominant particle size can inform stream flow characteristics with larger particles present in higher-gradient streams than streams with smaller particles (Rosgen 1996). Bedrock, boulder, cobble, gravel, sand, and silt/clay are sediment/particle composition types. The relative composition of these particle sizes provides clues to stream flow velocity and gradient (Rosgen 1996).

The purpose of the particle size assessment is to determine changes in particle size, particularly from coarse to fine particles (Gwilliam et al. 2013). Fine particles are an indicator of erosion, and fine particles can have detrimental effects on benthic macroinvertebrates (Gwilliam et al. 2013).

Reference Conditions

Reference conditions are described for resources in good or moderate/significant concern conditions (Table 26). Except for depth to groundwater and change in mean annual discharge, reference conditions were based on Management Assessment Points (MAPS) developed by SODN for Montezuma Castle and Tuzigoot NMs (Gwilliam 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

Table 26. Reference conditions used to assess hydrology.

Indicators	Measures	Good	Moderate/Significant Concern
Groundwater	Depth to Groundwater	≤2.0 m	>2.0 m
Surface Water Quantity	Number of No-Flow Events	0	>0
	Number of 50-year or Greater Flow Events	Max flow <50-year return interval discharge.	Max flow >50-year return interval discharge.
	Number of Bankfull Events	≤2	>2
	Change in Mean Annual Discharge	No changes in discharge have occurred during the period of record or discharge has improved.	Discharge has declined, particularly in recent years.
Stream Channel Geomorphology	Sinuosity	≤10% change	>10% change
	Cross-sectional Area	≤10% change in any one cross-section, or of the total cross-sectional area.	>10% change in any one cross-section, or of the total cross-section area.
	Dominant Particle Size	No change in one type to another.	Change from one type to another.
	Particle Size Assessment	Fine particle size increase of no more than 10%.	Fine particle size increase >10%.

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).

Research has shown that a maximum depth of 3.2 m (10.5 ft) and 5.1 m (16.7 m) is required to sustain mature willow (*Salix* spp.) and cottonwood (*Populus* spp.) trees, respectively (Stromberg et al. 1996, Stromberg 2013). For juvenile willows and cottonwoods, a maximum depth of 2.0 m (6.6 ft) is required (Stromberg et al. 1996). To ensure the persistence of woody riparian plants at all life stages, we conservatively set the good reference condition at a depth of 2.0 m (6.6 ft) or less. For mean annual discharge, a stable or improving discharge would indicate good condition, while a decline in discharge would indicate moderate/significant concern depending on the strength of the trend.

Condition and Trend

At the three wells monitored for Tuzigoot NM, depth to groundwater never fell below 2.0 m (6.6 ft) (Figures 13 and 14). For Montezuma Castle NM, depth to groundwater at the USGS well and at the water supply well also never fell below 2.0 m (6.6 ft) (Figures 15 and 16). At the ADWR index well, depth to groundwater was recorded as 0.0 m on only two occasions (Figure 15). Simple linear regression analyses for the automated data collected at the State Land Department well (R^2 = 0.22, t = 61.90, $p < 0.05$) and the USGS well (R^2 = 0.70, t = 36.76, $p < 0.05$) exhibited a slight but significant increase in depth the groundwater, which indicates a deteriorating trend. Regressions were only done for

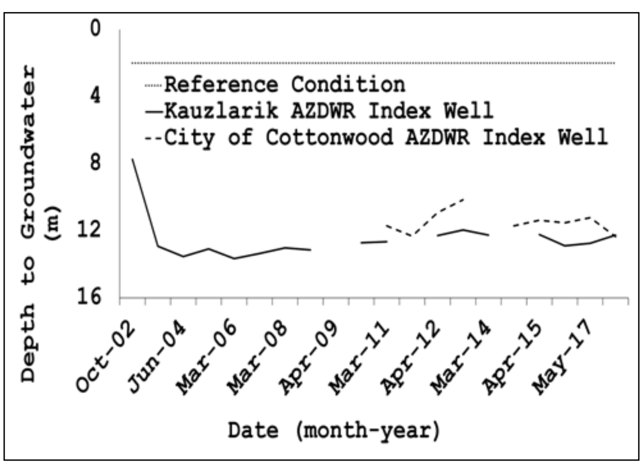


Figure 13. **Depth to groundwater at the Kauzlarik and City of Cottonwood Arizona Department of Water Resources wells for Tuzigoot NM (2002-2018).**

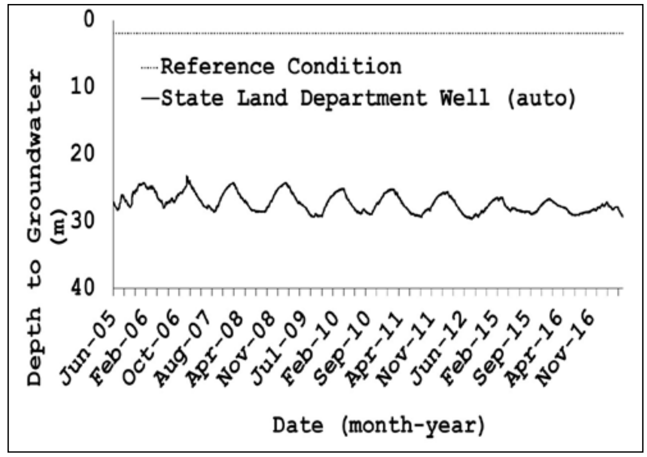


Figure 14. **Automated depth to groundwater at the State Department of Land well for Tuzigoot NM (2005-2018).**

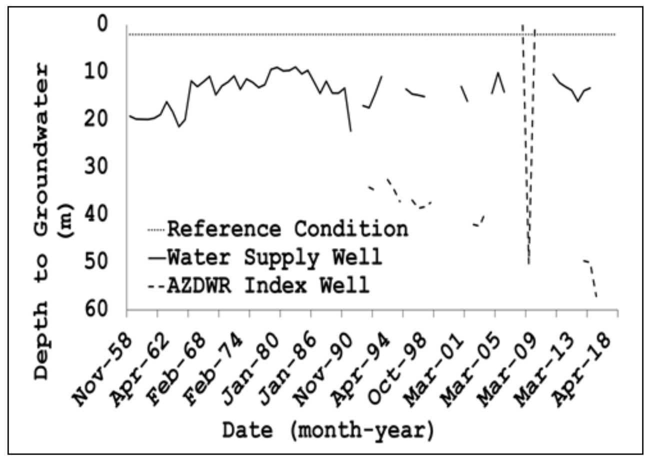


Figure 15. **Depth to groundwater at Arizona Department of Water Resources well and the supply well for Montezuma Castle NM (1958-2018).**

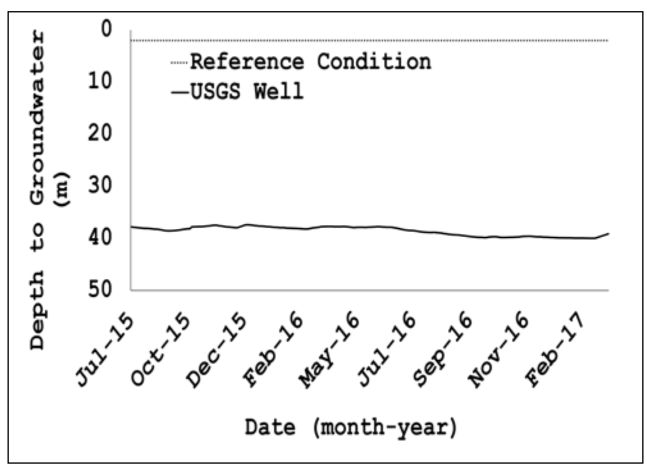


Figure 16. **Depth to groundwater at the USGS well for Montezuma Castle NM (2015-2018).**

these two wells because they provided the longest dataset.

These data warrant moderate/significant concern for both monuments. Trend is deteriorating. However, confidence is low because only one well was located within monument boundaries, and this well captured only annual measurements.

According to the USGS daily mean discharge data for the Verde River and Wet Beaver Creek, there were zero no-flow events for the period of record. The condition for this measure is good, trend is unchanging. Confidence is high for Montezuma Castle NM and low for Tuzigoot NM because of the agricultural diversion on the Verde River between the stream gage and the monument.

The USGS stream gage at the Verde River (Figure 17) and Wet Beaver Creek (Figure 18) recorded one 50-year flood event during their respective period of record during the same year (1993). Since only one 50-year flood event occurred in each of these stream reaches during the 99- (Tuzigoot NM) and 43- (Montezuma Castle NM) year record, the condition for this measure is good. Trend is unchanging. Confidence is high for Montezuma Castle NM and low for Tuzigoot NM because of the agricultural diversion on the Verde River between the stream gage and the monument.

Instantaneous peak flow data indicated that there were at least 24 bankfull events recorded at the Verde River stream gage and 23 bankfull events recorded at the Wet Beaver Creek stream gage (Figures 17 and 18). Daily mean data for Tuzigoot NM indicated more than two bankfull events in five of the 24 years (Table 27). For Wet Beaver Creek, daily mean data indicated no more than two bankfull events in the 23 years. However, daily mean data may not accurately reflect the total number of bankfull events because they are means of instantaneous discharge measurements. For example, daily mean data for Wet Beaver Creek indicated bankfull events in only three years, but instantaneous data show bankfull events in 23 years. Therefore, the condition for this measure is unknown. Because the condition is unknown trend is unknown and confidence is low.

Mean annual discharge in the Verde River exhibited a slight but significant decline from WY 1966 to WY 2017 ($R^2 = 0.08$, $t = -2.31$, $p = 0.03$) (Figure 19).

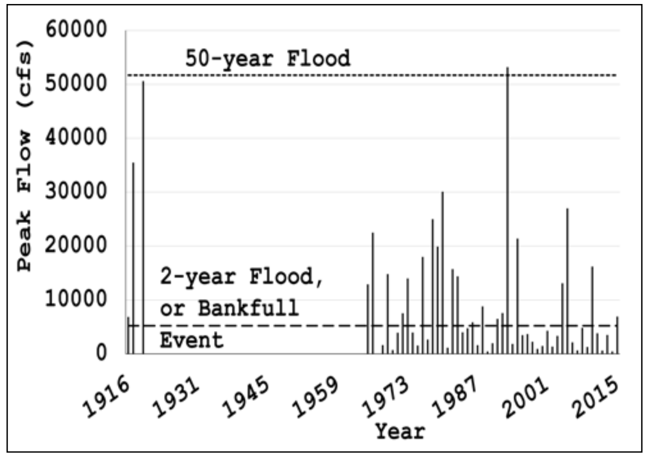


Figure 17. Instantaneous peak annual flow at the Verde River USGS stream gage (1916-2015).

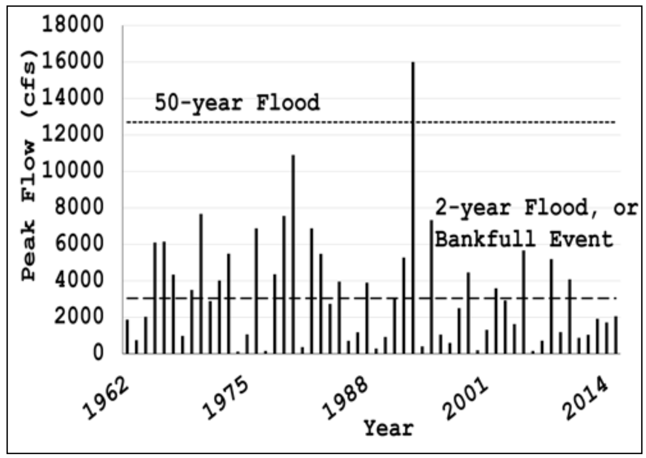


Figure 18. Instantaneous peak annual flow at the Wet Beaver Creek USGS stream gage (1962-2015).

Table 27. Summary of years with more than two bankfull events recorded at the USGS Verde River stream gage.

Water Year	# of Events
1978	6
1980	8
1993	11
2004	3
2005	7

In contrast, there was no change in mean annual discharge in Wet Beaver Creek ($R^2 = 0.01$, $t = -1.26$, $p = 0.21$) (Figure 19). When examining trends by season, a simple linear regression on log transformed data revealed a significant decline in spring ($R^2 = 0.11$, $t = -2.69$, $p = 0.009$), summer ($R^2 = 0.20$, $t = -3.66$, $p = 0.001$), and the monsoon ($R^2 = 0.09$, $t = -2.4$, $p = 0.020$) season discharge for the Verde River (Figure 20). In Wet Beaver Creek, discharge exhibited a significant

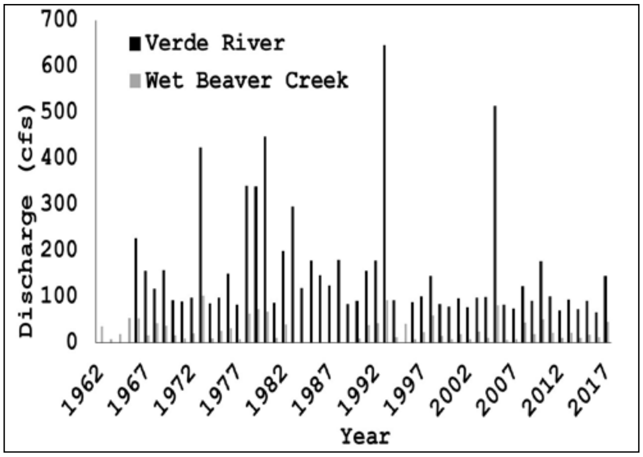


Figure 19. Mean annual discharge at the Verde River (1966-2017) and Wet Beaver Creek (1962-2017) stream gages in Tuzigoot NM and Montezuma Castle NM, respectively.

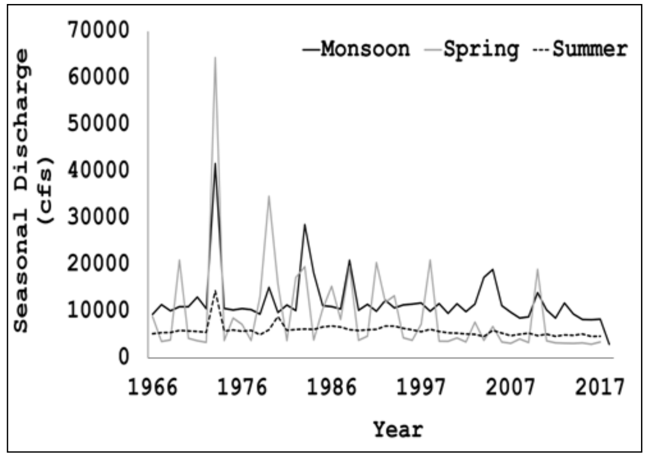


Figure 20. Total monsoon, spring, and summer discharge at the Verde River stream gage (1966-2017).

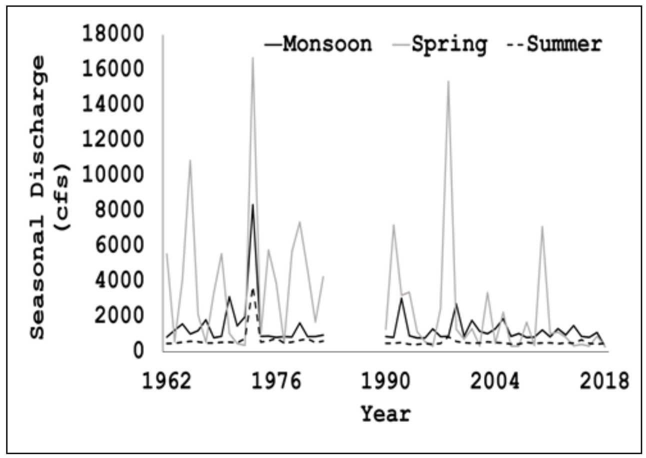


Figure 21. Total monsoon, spring, and summer discharge at the Wet Beaver Creek stream gage (1962-2017).

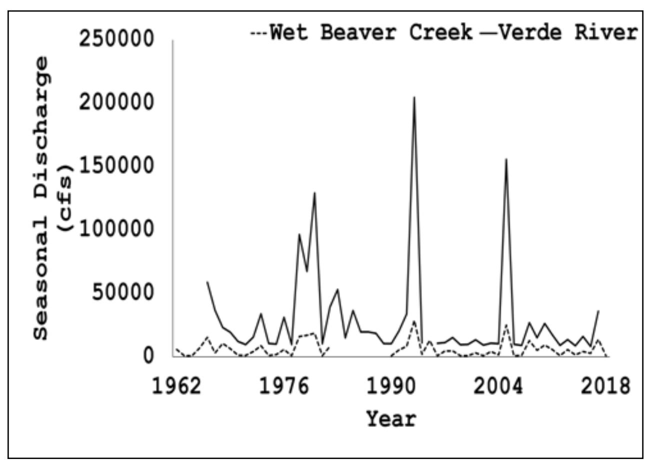


Figure 22. Total winter discharge at the Verde River (1966-2017) and Wet Beaver Creek (1962-2017) stream gages (1962-2017).

decline during the spring season only ($R^2 = 0.16$, $t = -3.16$, $p = 0.003$) (Figure 21). For both streams, winter exhibited the highest discharge (Figure 22).

The deteriorating trend in Tuzigoot NM warrants moderate/significant concern according to reference conditions, but because the trends are weakly significant, we assigned a condition of moderate concern with a deteriorating trend. Confidence in the condition rating is low, however, because the USGS gage for the Verde River is located upstream of an agricultural dam, which diverts approximately 86% of all surface flows. Discharge in the Verde River flowing through the monument is likely much lower than these data suggest. This condition is supported by the U.S. Forest Service's (USFS) watershed condition assessment for the Mescal Gulch-Verde River, which includes Tuzigoot NM. The watershed was listed as "Functioning at Risk" with "poor" water quantity (USFS 2017).

For Montezuma Castle NM, the results indicate good condition. Although there was a significant decline in discharge during the spring season, the trend was marginally significant. Therefore, the condition is good, the trend is unchanging, and confidence is high. This is supported by the USFS watershed condition assessment for the Lower Wet Beaver Creek watershed that includes the Well Unit. While the overall watershed condition was listed as "Impaired," water quantity was rated as "good" (USFS 2017).

Since precipitation is an important input for surface and groundwater, we include graphs of the interpreted precipitation average compared to long-term results for Tuzigoot and Montezuma Castle NMs (Climate Analyzer 2019). Precipitation data for Tuzigoot NM have been collected from 1977 - present at Cooperative Observer Program (COOP) weather/climate station ID #28904 at an elevation of 1,058 m (3,471 ft) (Figure 23) and for Montezuma Castle NM from 1938 - present at COOP station ID #25635 at an elevation of 969 m (3,179 ft) (Figure 24). The five-year running means show multi-year precipitation fluctuations at both stations, with recent (1-3 year) averages higher than the running means after long-term (14-19 years) below average precipitation amounts.

The canyon tree frog inhabits perennial riparian areas throughout northern Arizona. Photo Credit: NPS.

To date, SODN staff have measured stream channel geomorphology at Beaver Creek once (NPS, E. Gwilliam, ecologist, e-mail message, 6 February 2018). Sinuosity measured 2.1 at Beaver Creek, which indicates that the stream channel distance as measured between two points along the index reach was slightly more than twice the straight-line distance between the same two points (Gwilliam et al. 2013). Cross-sectional area was measured at 11 locations along Beaver Creek and ranged from 1,066 m^2 to 10,516 m^2 (Gwilliam et al. 2013). Since reference conditions for these two measures are based on change over time, the conditions and trends for sinuosity and cross-sectional area are unknown. Confidence is low because of the unknown condition rating. Trend is also unknown.

Cobble was the dominant particle size for Beaver Creek in 2009-2011 (Gwilliam et al. 2013). Across all 11 sample points, a range of particle sizes were present from silt to large limestone bedrock outcroppings (Gwilliam et al. 2013). Data for the Verde River and Wet Beaver Creek were not available for inclusion in this assessment. Since reference conditions for these two measures are based on change over time, the conditions and trends are unknown. Confidence is low because of the unknown condition rating.

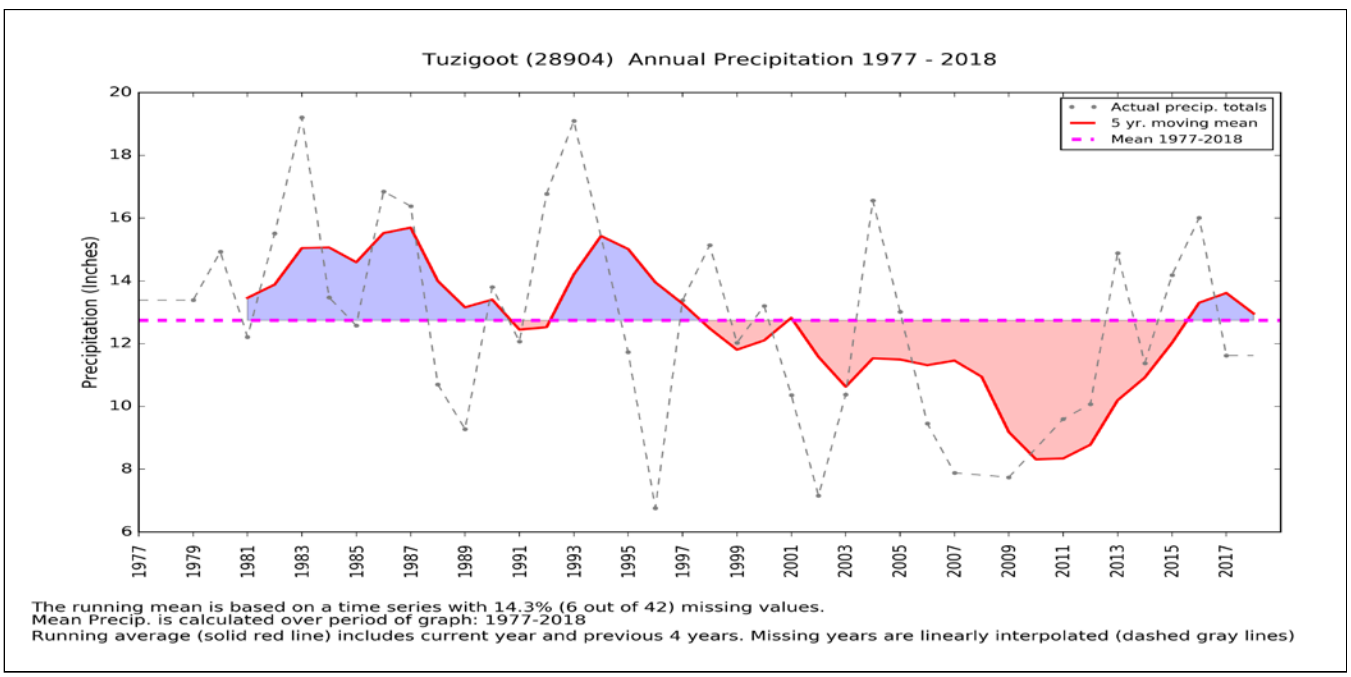


Figure 23. Annual precipitation at COOP station 28904 (1977-2018), Tuzigoot NM. Figure Credit: Climate Analyzer 2019.

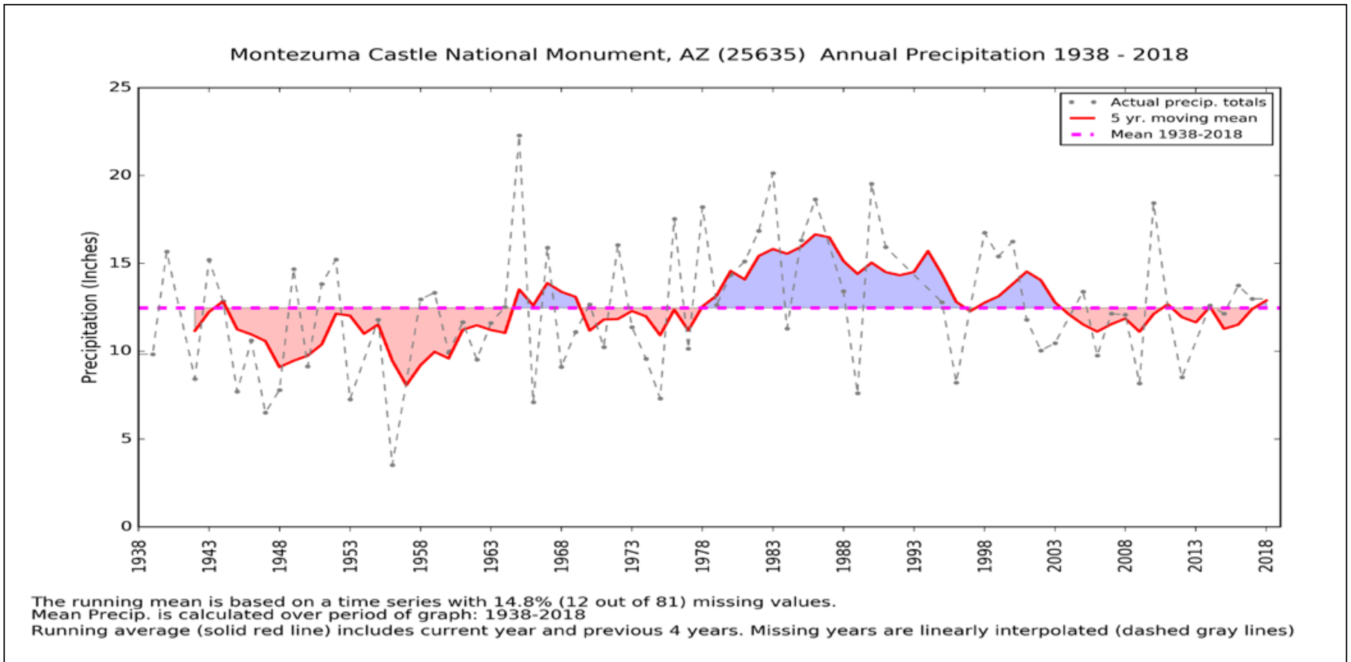


Figure 24. Annual precipitation at COOP station 25635 (1938-2018), Montezuma Castle NM. Figure Credit: Climate Analyzer 2019.

Overall Condition, Threats, and Data Gaps

Based on the measures used in this assessment, the condition of hydrologic resources at Montezuma Castle is good but with an unchanging trend. Confidence in the condition rating is high (Table 28). For Tuzigoot NM, the overall condition warrants moderate concern and the trend is deteriorating. Confidence in the condition rating is medium. Measures with high confidence were given more weight in the overall condition rating than measures with medium or low confidence, and measures without a condition rating were not used to assess overall condition.

There are several key uncertainties, one of which is the lack of data to determine historic, pre-European groundwater and streamflow. Although groundwater pumping and surface water diversions have altered the hydrology of the middle Verde River watershed, it is unclear to what extent. Another key uncertainty is whether the USGS gage near Clarkdale, Arizona used to determine surface flows through Tuzigoot NM accurately reflects conditions within the monument given the diversion dam located between the gage and the monument. Lastly, the water table may be closer to the Earth's surface than the well data indicate.

Groundwater supplies the base flow in the Verde River (Pawlowski 2013). The base flow is supplemented by tributaries and surface water runoff from precipitation (Pawlowski 2013). The Verde River is one of the last remaining perennial rivers in Arizona, but portions of the Verde River are losing base flows and are at risk of becoming intermittent (Pawlowski 2013). Several rivers in Arizona that were once perennial now flow intermittently, including portions of the Salt, Gila, Little Colorado, Santa Cruz, and San Pedro rivers (Pawlowski 2013). Conserving groundwater supplies to support natural flows in the Verde River and its tributaries is critical to sustaining health wildlife and plant populations in these monuments.

However, climate projections (Backlund et al. 2008) for the American Southwest include higher temperatures, increased drought, and more intense thunderstorms, with implications for soil erosion, vegetative cover, streamflow, and stream channel morphology. In fact, since 2000, southern Arizona has been in a drought (Gwilliam et al. 2017). As temperature and precipitation patterns affect the abundance, type, and distribution of vegetation cover in watersheds, changes in flood magnitude and duration, sediment loads, and water chemistry will occur. These changes may result in increased sediment loads and stream channel erosion.

Changes in stream flow and groundwater will also reduce the available habitat for obligate and facultative wetland plants (such as willows and cottonwoods),

Table 28. **Summary of hydrology indicators, measures, and condition rationale.**

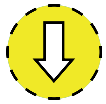
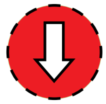
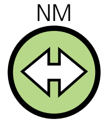
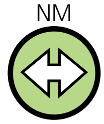
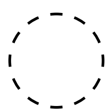
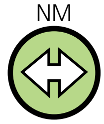
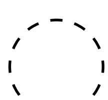
Indicators	Measures	Condition/Trend/ Confidence	Rationale for Condition
Groundwater	Depth to Groundwater	 	Depth to groundwater at all six wells indicate sufficient water levels to maintain cottonwood and willow trees. Confidence in the condition rating is low because only one of the six wells was located within monument boundaries. These off-site wells may not accurately reflect groundwater along the streams in the monuments. Trend data indicate a deterioration in depth to groundwater.
Surface Water Quantity	Number of No-Flow Events	Tuzigoot NM  Montezuma Castle NM 	There were zero no-flow events over the period of record at either monument (~1960s-2017). Trend is unchanging. Confidence in the condition rating is low for Tuzigoot NM because of a dam between the gage and the monument. Confidence in the condition rating for Montezuma Castle is high because the stream gage is representative of flows through the monument.
	Number of 50-year or Greater Flow Events	Tuzigoot NM  Montezuma Castle NM 	There was one 50-year or greater flood events during WY 1993 at each monument. Since only one 50-year flood event occurred during the 99 (Tuzigoot NM) and 43 (Montezuma Castle NM) year record, the condition is good. Trend is unchanging. Confidence in the condition rating is low for Tuzigoot NM because of a dam between the gage and the monument. Confidence in the condition rating for Montezuma Castle is high because the stream gage is representative of flows through the monument.
	Number of Bankfull Events		There were at least 24 and 23 bankfull events over the period of record at Tuzigoot NM and Montezuma Castle NM, respectively. Because this measure was derived from instantaneous peak data for the year and the daily data are means of discharge, we could not determine whether more than one bankfull event occurred during those years. Therefore, the condition is unknown. Because the condition is unknown the trend is unknown and confidence is low
	Change in Mean Annual Discharge	Tuzigoot NM  Montezuma Castle NM 	At the Verde River stream gage overall mean annual discharge declined (1966-2017). Declines were significant for all seasons except for winter. These results warrant moderate concern. Trend has deteriorated. Confidence is low because there is a dam between the USGS gage and the index site in Tuzigoot NM. Therefore, the gage may not serve as an index to streamflow within the monument. There was no trend in mean annual discharge at the Wet Beaver Creek stream gage (1962-2017), but discharge during spring declined slightly. These results indicate good condition with an unchanging trend. Confidence in the condition rating is high because the stream gage is representative of flows through the monument.
Stream Channel Geomorphology	Sinuosity		Reference conditions were based on change over time, and only one sample has been collected to date. Sinuosity for Beaver Creek was 2.1. Data for the Verde River and Wet Beaver Creek were not available for this assessment. Therefore, the condition is unknown, trend could not be determined, and confidence is low due to the unknown condition.

Table 28 continued. ***Summary of hydrology indicators, measures, and condition rationale.***

Indicators	Measures	Condition/Trend/ Confidence	Rationale for Condition
Stream Channel Geomorphology *continued*	Cross-sectional Area		Reference conditions were based on change over time, and only one sample has been collected to date. Cross-sectional area for Beaver Creek ranged from 1,066 m^2 to 10,516 m^2. Data for the Verde River and Wet Beaver Creek were not available. Therefore, the condition is unknown, trend could not be determined, and confidence is low due to the unknown condition.
	Dominant Particle Size		Cobble was the dominant particle size in Beaver Creek during 2009-2011. Data for the Verde River and Wet Beaver Creek were not available for inclusion in this assessment. Therefore, the condition is unknown, trend could not be determined, and confidence is low due to the unknown condition.
	Particle Size Assessment		Across all 11 sample points, a range of particle sizes were present from silt to large limestone bedrock outcroppings. Data for the Verde River and Wet Beaver Creek were not available for inclusion in this assessment. Therefore, the condition is unknown, trend could not be determined, and confidence is low due to the unknown condition.
Overall Condition	Summary of All Measures	Tuzigoot NM Montezuma Castle NM	The condition of hydrology in the two monuments differed. In Tuzigoot, the condition based on the measures used indicate moderate concern with a declining trend. However, confidence is low because the stream gage and well data may not accurately reflect conditions in the monument. The condition of hydrology in Montezuma Castle NM is good with an unchanging trend and high confidence. Although confidence in the condition based on well data was low, confidence was high for the stream gage data for Montezuma Castle NM.

increase the susceptibility of invasion by non-native species, and promote encroachment by upland species (Stromberg et al. 1996). For example, the cottonwood/mesquite (*Prosopis velutina*) woodland vegetation type mapped along the Verde River in 1993-1995 indicate a past hydrologic regime that supported cottonwood species and a current hydrologic regime that favors upland species such as mesquite (Rosenberg et al. 1995). While woody riparian plants have persisted in both monuments (Gwilliam et al. 2013), prolonged drought stress will eventually cause mortality if groundwater levels do not improve. Although, the well data used in this assessment were located outside of monument boundaries. It's possible that these wells do not accurately reflect groundwater levels along the riparian zones. Alternatively, regular flooding of the riparian zone as a result of surface flows could be enough to maintain riparian woody species.

In addition to climate change, human activities in and near rivers affect streams in a variety of ways. For example, historic aggregate extraction within the flood channel of the Verde River resulted in the lowering of the low-flow channel (Pearthree 2008). Crop cultivation and agricultural activities on the low terraces and within the floodplain can alter morphology through artificial structures (Pearthree 2008). Construction activities, such as bank protection for erosion prevention, alters morphology by decreasing or eliminating channel migration, bank erosion, and overbank flooding. Impervious surfaces, such as paved roads, prevent precipitation from infiltrating into the ground. Because impervious surfaces decrease infiltration, an increase in impervious surfaces typically results in reduced percolation to the aquifer and flashier streamflow due to faster runoff into streams.

Sources of Expertise

Assessment author is Lisa Baril, biologist and science writer, Utah State University. Reviewers for this assessment are listed in Appendix A.

Water Quality

Background and Importance

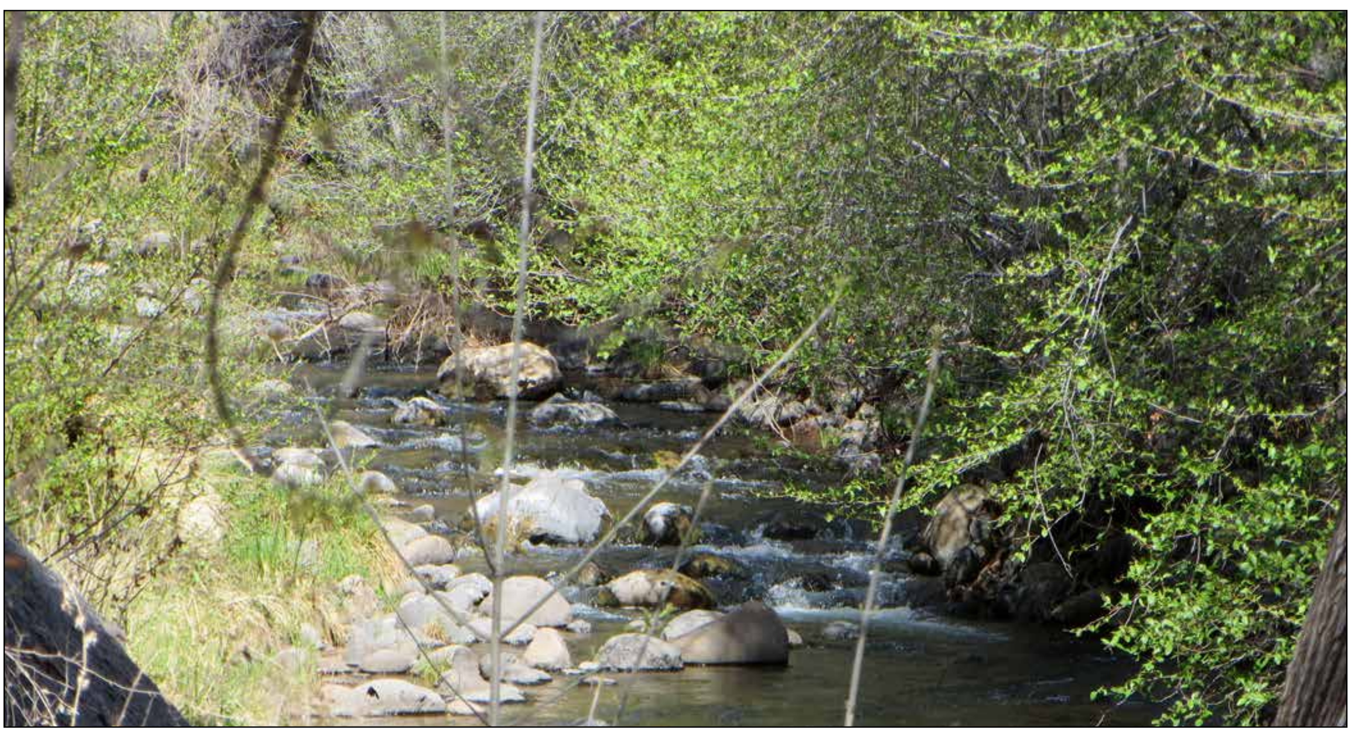
In Tuzigoot and Montezuma Castle National Monuments (NM), streams, rivers, and associated riparian vegetation provide habitat for a variety of fish, amphibians, mammals, and bird species (Schmidt et al. 2005, 2006). In Tuzigoot NM 0.4 km (0.2 mi) of the Verde River flows through the monument, and in Montezuma Castle NM, a combined 6.9 km (4.3 mi) of stream flow through the monument's two units (Gwilliam et al. 2014). Beaver Creek, a major tributary of the Verde River, flows through the Castle Unit, and Wet Beaver Creek, a tributary of Beaver Creek, flows through the Well Unit (Gwilliam et al. 2014). Like many watersheds in Arizona and across the western U.S., the Verde River watershed has a long history of development and resource extraction, including ranching, agriculture, and mining that have and continue to influence water quality and quantity in the Verde River and its tributaries (Black et al. 2005, Garner et al. 2013).

This assessment focuses on water quality, which includes measures of the chemical properties of aquatic systems. Aquatic ecosystems depend on the maintenance of particular water chemistry conditions to sustain life-supporting biochemical processes in plant and animal communities.

Data and Methods

Six indicators were used to assess the current condition of water quality at Tuzigoot and Montezuma Castle NMs. The indictors were selected to be consistent with the Sonoran Desert Network's (SODN) monitoring objectives at the two monuments (Gwilliam et al. 2014, 2017) and are as follows: core water quality, metals and metalloids, nutrients, microbiological organisms, inorganics and general water quality, and benthic macroinvertebrates. SODN collects dozens of individual measures within the indicators of metals and metalloids, nutrients, and inorganics and general water quality. For a complete list of water quality measures collected during Water Years (WY) 2009-2011 and 2016 refer to Gwilliam et al. (2013, 2017). In this assessment, we used only those water quality measures that are associated with Arizona State or SODN water quality standards. A water year begins October 1 and ends September 30.

Water quality samples were collected at one index site located within a 100-300-m (328-984-ft) reach in each of the three streams (see Gwilliam et al. 2014 for maps of each location). Water samples were collected on one day during each season from WY 2011 through WY 2017. E. Gwilliam provided (26 March 2018 via e-mail) data summaries for the samples collected during this time period. The Gwilliam et al. (2014, 2017) reports provided additional data and interpretation. The



Wet Beaver Creek in Montezuma Castle NM. Photo Credit: NPS.

importance of each indicator/measure for assessing water quality is described in the following sections.

The core water quality indicator included two measures: pH and dissolved oxygen. The pH of water 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 2018e). Dissolved oxygen measures the amount of gaseous oxygen (O_2) dissolved in the stream (USGS 2018e). Because oxygen is required for fish and other 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, and the time of day and season (USGS 2018e).

The metals and metalloids indicator included arsenic, lead, uranium, and others. Dissolved metal concentrations were also measured because they are more easily absorbed by aquatic organisms (USGS 2018e). In high concentrations metals and metalloids cause major disruption of aquatic ecosystems by lowering reproductive success, interfering with normal growth and development, and, in extreme cases, causing death (USGS 2018e). Metals may accumulate in aquatic food webs posing long-term threats to all organisms in the aquatic environment.

The nutrients indicator included the measures nitrogen, phosphorus, and ammonia. Nitrogen and phosphorus are essential for wildlife and plants, but excess nutrients from agricultural practices and pollution can cause overgrowth of aquatic plants and algae (USGS 2018e). While many nutrients occur naturally in the environment, they can also be limiting in certain environments. Maintaining a healthy balance is critical to ecological function (USGS 2018e).

SODN uses one measure of the microbiological organisms indicator—Escherichia coli (*E. coli*). E. *coli* is one of the main species of bacteria living in the lower intestines of mammals, and its presence in water is an indication of fecal contamination (USGS 2018e). High levels of *E. coli* act as proxies for organic pollution, providing an early warning for potential risks to aquatic and terrestrial biota.

The inorganics and general water quality indicator included a variety of measures. Some of the measures are alkalinity as $CaCO_3$, bicarbonate alkalinity as $CaCO_3$, fluoride, anion-cation balance, and total hardness (Gwilliam et al. 2014, 2017). Measures of alkalinity provide an index to water's ability to neutralize acid. Fluoride occurs naturally in water bodies but is also added to municipal water supplies (USGS 2018e). In high levels, fluoride ions can act as enzymatic poisons, inhibit enzyme activity, and interrupt metabolic processes in aquatic invertebrates and fish (Camargo 2003). Hardness is the result of metallic ions dissolved in water. Anion/cation balance is a measure of water's ability to conduct electricity (USGS 2018e). Even a small amount of salts (cations) can cause water to conduct electricity.

Finally, SODN uses two measures of the benthic macroinvertebrate indicator. These measures (or indices) are: the Arizona Index of Biological Integrity (AZIBI) and the U.S. Environmental Protection Agency's (USEPA) multi-metric index (ADEQ 2015, Stoddard et al. 2005). These are commonly used as indicators of water quality in Arizona because macroinvertebrates are easy to collect and differ in their response to pollution in predictable ways. A high variety and abundance of benthic macroinvertebrates indicates higher water quality, particularly if certain taxonomic groups are present. Thus, these two indices serve as proxies for water pollution (USEPA 2017c), with the understanding that because differences in benthic macroinvertebrates are measured, doesn't mean that the water is polluted. Instead, it could be the norm for that particular water body.

Reference Conditions

Reference conditions are shown in Table 29. Reference conditions are described for resources in good, moderate concern, and significant concern conditions. Reference conditions for nearly all measures were derived from water quality criteria developed by the State of Arizona's Department of Environmental Quality as reported in Gwilliam et al. (2013, 2017) and (ADEQ 2009). Criteria differ depending on whether the measure is acute (occurring over a short time) or chronic (occurring over months or longer). Although samples collected by SODN were single grab samples, SODN used chronic criteria, which are more conservative than acute criteria (Gwilliam et al. 2014). Criteria also differ depending on the beneficial use category. There are at least seven beneficial use

Table 29. Reference conditions used to assess water quality.

Indicators	Measures	Good	Moderate Concern	Significant Concern	Arizona Beneficial Use or Other Criteria*
Core Water Quality	pH (SU)	6.5 to 9.0	–	< 6.5 or > 9.0	A&W Warm
	Dissolved Oxygen (mg/L)	>6	–	≤6	A&W Warm
Metals and Metalloids	Arsenic, Barium, Boron, Chromium, Copper, Lead, Manganese, Nickel, Uranium, Zinc, and Others (mg/L)	There were no exceedences of standards or measures that exceeded standards were acute occurrences and were the result of natural causes.	–	There were either acute or chronic exceedences for some measures as the result of unnatural causes.	FBC, Park-specific
Nutrients	Ammonia, Phosphorus, and Nitrogen (mg/L)	There were no exceedences of standards or measures that exceeded standards were acute occurrences and were the result of natural causes.	–	There were either acute or chronic exceedences for some measures as the result of unnatural causes.	FBC, Park-specific
Microbiological Organisms	*E. coli* (cfu/100ml)	<235	–	≥235	FBC
Inorganics and General Water Quality	Alkalinity, Fluoride, Sulfate, Chloride, and Others (mg/L)	There were no exceedences of standards or measures that exceeded standards were acute occurrences and were the result of natural causes.	–	There were either acute or chronic exceedences for some measures as the result of unnatural causes.	FBC, Park-specific
Benthic Macroinvertebrates	Arizona Index of Biological Integrity	≥50	40-49	≤39	Warm Water
	EPA Multi-metric Index	≥71	≥57 but <71	<57	Mountains

* A&W warm: aquatic and wildlife warm water beneficial use; FBC: full body contact recreational use; Park-specific: SODN assessment points.

categories that apply to streams in both monuments. However, SODN used the beneficial use with the most stringent standard (Gwilliam et al. 2017). Usually, the most stringent criteria were associated with Aquatic and Wildlife (A&W), but Full-Body Contact (FBC) criteria were also used. For some measures without state standards, park-specific criteria were developed by SODN (refer to Table 2-4 in Gwilliam et al. 2014 for SODN specific standards).

Due to the complexity and volume of water quality data, we generally used the proportion of samples that exceeded state or SODN standards as a reference condition within an indicator. If measures did not meet state or SODN standards, we attempted to determine if these were the result of natural causes. If not, exceedences may warrant significant concern. If measures met state standards, then the condition was reported as good. Reference conditions for the AZIBI that applies to warm water streams and USEPA multi-metric index that applies to mountain streams were derived from ADEQ (2015) and Stoddard et al. (2005), respectively. For some measures, we reported specific state thresholds in Table 29, but for indicators with many measures (i.e., metals/metalloids, nutrients, inorganics and general water quality), the narrative reference conditions are shown rather than the numerical standards. Unless otherwise noted, condition, trend, and confidence levels apply to both monuments.

Condition and Trend

For each WY, between 97 and 100 discrete water sample analyses were associated with standards (state or SODN). Of these, the vast majority (≥95%) met water quality standards for each of the three streams during all seven water years (Tables 30, and 31).

Both core water quality measure are in good condition for all three stream reaches in both monuments. All samples for the three reaches sampled during WYs 2011 through 2017 met standards for pH. Although state standards for dissolved oxygen were not met in five samples collected at Beaver Creek (Table 30) and in two samples collected at the Verde River (Table 32), this was likely the result of seasonal variability in flow

Table 30. Water quality measures not attained in Beaver Creek (Montezuma Castle NM).

Water Year	# Samples with Standards	# Non-attaining Samples	% Compliant Samples	Measure
2011	100	1	99	Arsenic
2012	98	4	96	Total Nitrogen, Lead, *E. coli*, Dissolved Oxygen
2013	98	2	98	Arsenic, Dissolved Oxygen
2014	98	2	98	Arsenic, Dissolved Oxygen
2015	98	4	96	Arsenic (2), Dissolved Oxygen, *E. coli*
2016	98	3	97	*E. coli* (2), Arsenic
2017	98	4	96	*E. coli* (2), Arsenic, Dissolved Oxygen

Source: E. Gwilliam, SODN aquatic ecologist.

Table 31. Water quality measures not attained in Wet Beaver Creek (Montezuma Castle NM).

Water Year	# Samples with Standards	# Non-attaining Samples	% Compliant Samples	Measure
2011	100	2	98	Arsenic (2)
2012	98	3	97	Arsenic (3)
2013	98	1	99	Arsenic
2014	98	1	99	Arsenic
2015	98	2	98	Arsenic (2)
2016	98	0	100	None
2017	98	1	99	Arsenic

Source: E. Gwilliam, SODN aquatic ecologist.

rate and temperature (Gwilliam et al. 2014). Warm and slow moving water tends to hold less dissolved oxygen than colder and faster flowing water (USGS 2018e). In Wet Beaver Creek, all water samples met state standards (Table 31). Confidence in the condition rating for pH is high because of the length and volume of the dataset, and trend appears unchanging based on the persistence of the good condition rating for each

Table 32. Water quality measures not attained in the Verde River (Tuzigoot NM).

Water Year	# Samples with Standards	# Non-attaining Samples	% Compliant Samples	Measure
2011	100	0	100	None
2012	97	2	98	Dissolved Oxygen, *E. coli*
2013	98	1	99	Dissolved Oxygen
2014	98	0	100	None
2015	98	0	100	None
2016	98	1	99	*E. coli*
2017	98	0	100	None

Source: E. Gwilliam, SODN aquatic ecologist.

year sampled. Note that we did not evaluate trend in actual values.

Although the condition rating for dissolved oxygen in both monuments is also good based on SODN's data, the State of Arizona has listed a 40.5-km (25.2-mi) stretch of the Verde River from Oak Creek south of the monuments to Sycamore Creek north of the monuments as impaired for dissolved oxygen since 2016 (ADEQ 2017, 2018). Despite the impaired status of the Verde River, dissolved oxygen did not appear to be an issue in the two monuments. Neither Beaver nor Wet Beaver creeks were listed as impaired. Therefore, confidence in the good condition rating is medium. As with pH, trends appear unchanging.

There were no exceedences for metals or metalloids in the Verde River (Table 32). In Wet Beaver and Beaver Creeks, state standards for arsenic were exceeded in 16 total samples across the two streams in multiple water years (Table 30 and 31). Although arsenic is highly toxic to both humans and wildlife, its presence is not cause for concern because arsenic occurs naturally in the surrounding rocks (Gwilliam et al. 2017). The only other exceedence was for lead in Beaver Creek, but this is not cause for concern since only one of the hundreds of samples tested over the seven water years exceeded state standards. Based on these data, the condition for metals and metalloids is good. Trend appears to be unchanging based on the persistence of condition ratings over time. We did not evaluate trend in actual values. Confidence is high.

Standards were met for all nutrient water samples in all water years in Wet Beaver Creek and in the Verde River. Standards for total nitrogen were not met in only one sample during WY 2012 at Beaver Creek (Table 30). Based on these results, the condition for nutrients is good. Trend appears unchanging based on the persistence of the good condition rating for each season and year sampled. We did not evaluate trend in actual values. Confidence is high.

In Beaver Creek, water samples exceeded *E. coli* state standards for six samples collected during WY 2012, 2015, 2016 (2 samples), and 2017 (2 samples) (Table 30). None of the samples collected in Wet Beaver Creek exceeded *E. coli* standards. Only one sample collected in the Verde River during WY 2016 exceeded state standards for *E. coli* (Table 32). Observed exceedences were associated with heavy rainfall in the watershed (Gwilliam et al. 2017). Heavy rainfall washes waste containing *E. coli* into streams. The source could either be from wild or domestic mammals. Because these occurrences were acute, or related to specific events, the condition for this measure is good. Trend appears relatively stable. However, confidence is medium because the State of Arizona listed the same stretch of the Verde River described for dissolved oxygen as impaired for *E. coli* as well (ADEQ 2017).

None of the inorganics and general water quality measures with state standards were exceeded in the three streams sampled. SODN developed their own criteria for some inorganics and general water quality measures. As noted in Gwilliam et al. (2013, 2017), all samples were within the range of expected values for WYs 2009, 2010, 2011, and 2016. Other years could not be evaluated based on the data used in this assessment. The overall condition for these measures is good. Trend appears to be unchanging based on the persistence of condition ratings over time, at least for measures with standards. Confidence in the condition rating is high.

In Wet Beaver Creek, three of the six water years met the standard (good condition) for AZIBI (Figure 25). The remaining three years were considered "inconclusive" (moderate concern). Over time the trend deteriorated somewhat. At Beaver Creek there was no apparent trend in AZIBI, and in all but two years, the AZIBI reached the "attaining" standard (Figure 25). The two remaining years were considered "inconclusive." The average AZIBI over the six years was 55 for Beaver Creek and 50 for Wet Beaver Creek (both considered good). Overall, these results indicate good condition at Montezuma Castle NM. However, the overall trend has deteriorated somewhat and index values are approaching the "inconclusive" rating. In the Verde River, AZIBI attained state standards for good condition in only the first two WYs (2012 and 2013) (Figure 25). For the remaining years, AZIBI was rated as "inconclusive." But since the index averaged 50 (good condition) over the six water years, the condition is good. However, the trend in values deteriorated.

The non-attaining values were largely the result of an increase in midge larvae, which indicate poor water quality (Gwilliam et al. 2017). However, Gwilliam et al. (2017) speculated that the increase in midge larvae could be due to physical processes rather than chemical water quality issues. Data show that there has been a slight shift in particle size from gravel and cobble to more boulders and sand/silt since WY 2011, which may favor Chironomid midges (Gwilliam et al. 2017). Therefore, confidence in the good condition rating is medium.

None of the three streams attained the "least disturbed" or good condition rating during the years in which data were collected for the EPA multi-metric index (Figure 26). In Beaver Creek, all but WY 2015 fell within the "moderate disturbance" (moderate concern) condition rating (WY 2015 was considered "most disturbed" (significant concern). At Wet Beaver Creek, all years except WY 2015 fell within the "most disturbed" condition rating. In the Verde River, years alternated between "moderate disturbance" and "most disturbed." These results indicate persistent water quality issues that may be related to dissolved oxygen, arsenic, *E. coli*, some other factor, or a change in stream substrate as mentioned above. The overall condition at Montezuma Castle NM warrants moderate concern since the average index value was 59 across the two stream reaches. At Tuzigoot NM, the overall condition for the Verde River also warrants moderate concern, but the average index over the six years was 57, which is at the cusp of significant concern. Trend is unchanging for all three streams. Confidence is medium for the reasons given for AZIBI.

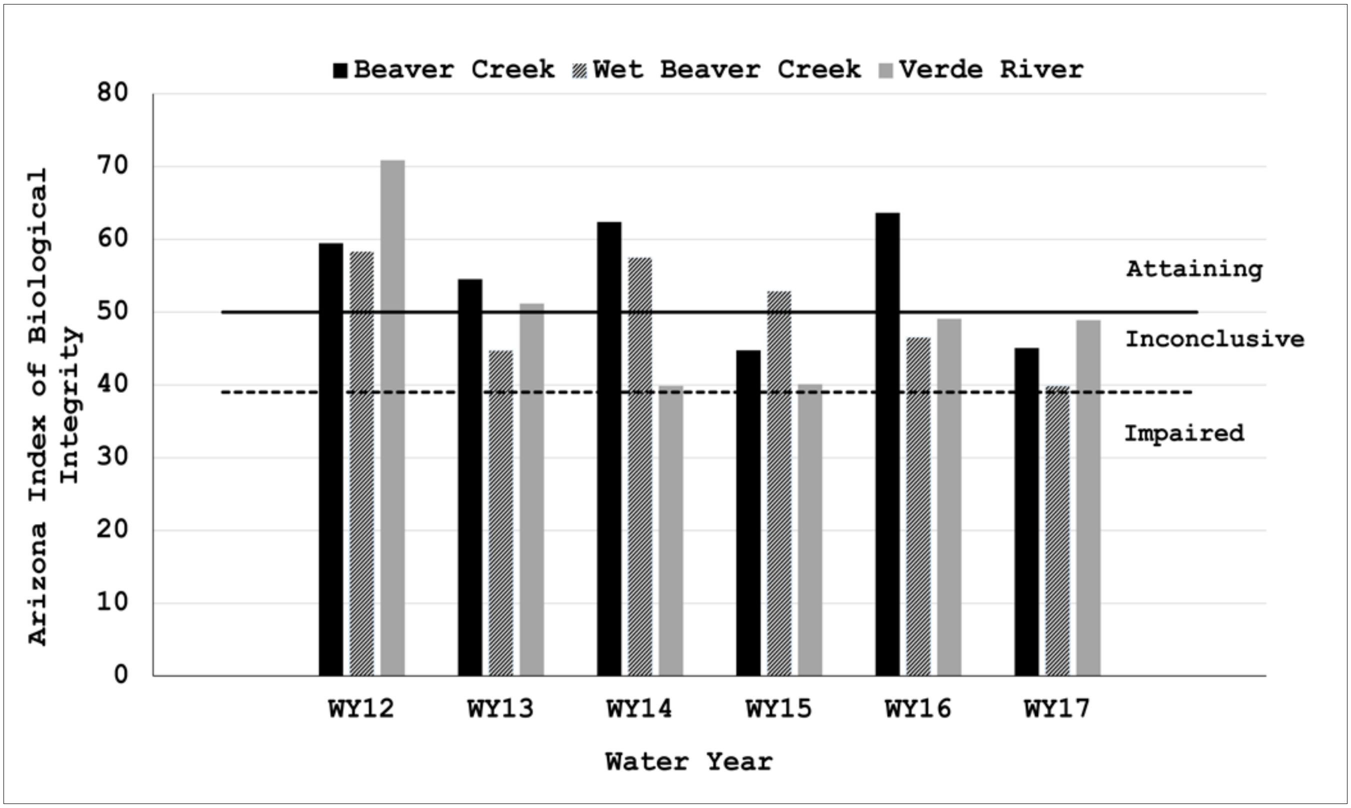


Figure 25. **The Arizona Index of Biological Integrity for Montezuma Castle NM and Tuzigoot NM streams during water years 2012 through 2017.**

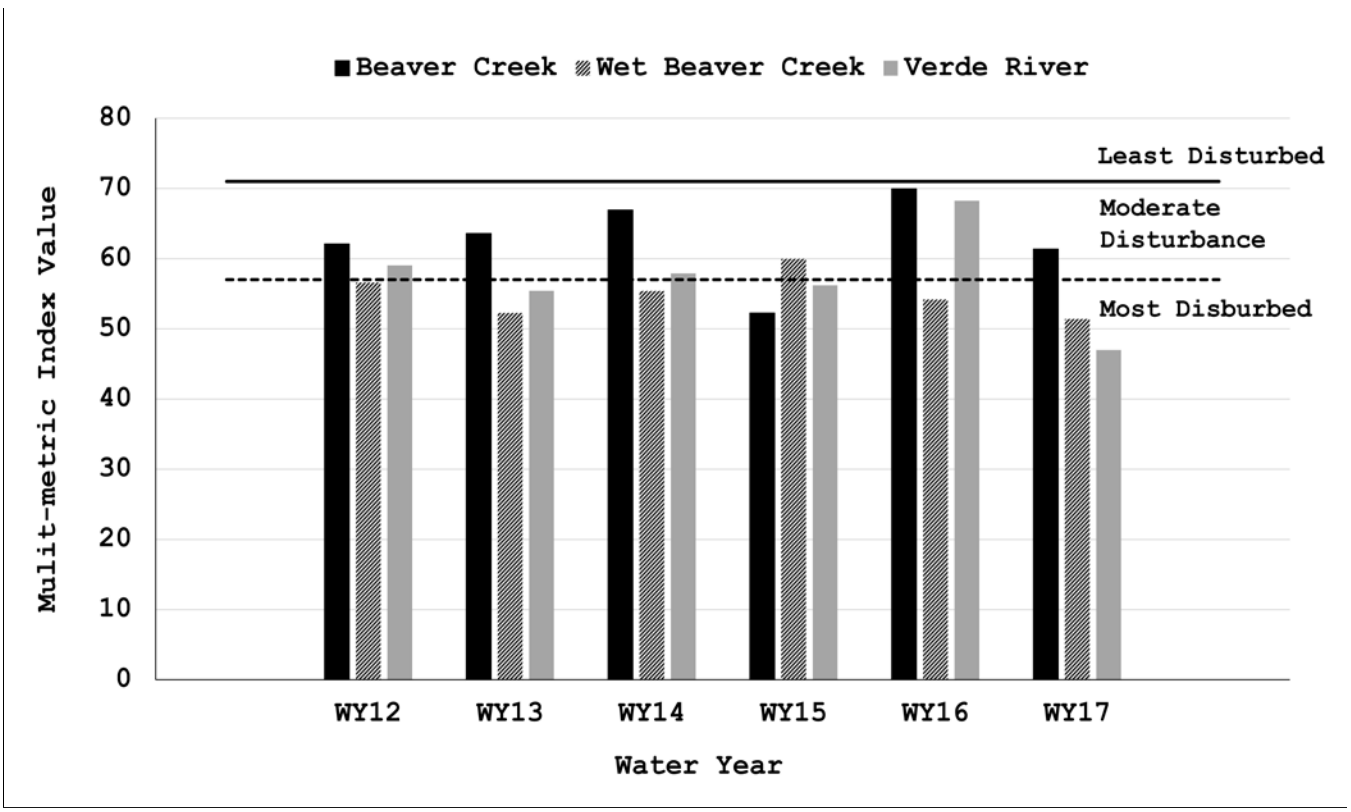


Figure 26. **The EPA multi-metric index for Montezuma Castle NM and Tuzigoot NM streams during water years 2012 through 2017.**

Overall Condition, Threats, and Data Gaps

Table 33 summarizes the condition rating and rationale used for each indicator and measure. Nearly all measures included in this assessment were in good condition. For simplicity, condition ratings were applied to the indicators metals and metalloids, nutrients, and inorganics and general water quality rather than to individual measures within those indicators. Nearly all measures rated as good were assigned high confidence except for dissolved oxygen, *E. coli*, and the two measures of benthic macroinvertebrates. Because most measures indicated good condition, the overall condition is considered good for both monuments. However, confidence is medium because of uncertainties regarding the causes for low dissolved oxygen, low indices of the EPA multi-metric index and some values for the AZIBI, in addition to sources of *E. coli*.

A key uncertainty is determining the range of natural variability for the various water quality measures specific to streams in both monuments. For example, arsenic exceeded state standards in several samples in Montezuma Castle NM during most water years. However, the values observed appear to be typical for those sites and not cause for concern since arsenic is sourced from the natural geology of the landscape (Gwilliam et al. 2017). While Arizona State water quality standards provide a useful benchmark, park-specific values (some of which have been developed by SODN) would be useful in identifying emerging concerns for measures without state standards.

The Verde River is one of the few remaining perennial rivers in Arizona, supporting one of the last remaining Freemont cottonwood-Gooding willow (*Populus fremontii-Salix gooddingii*) gallery forests, diverse native wildlife, and abundant recreational opportunities (Pawlowski 2012). As such, numerous stakeholders are invested in the health of the watershed, including the ADEQ (2018), the Verde River Institute, Friends of the Verde River, and the Sierra Club (Pawlowski 2012), among others. However, there are many demands on water resources along this 314-km (195-mi) river.

Although the Verde River is fed by numerous tributaries, including Beaver Creek, much of the river's base flows are recharged via groundwater. Groundwater withdrawals and other human stressors are a primary threat to water quality in the watershed (Garner et al. 2013). Low flows affect water quality by increasing stream temperature and lowering dissolved oxygen levels. Warmer stream temperatures affect a wide variety of water quality measures that affect aquatic life. Climatic conditions in both monuments have already shifted beyond the range of historical variability (Monahan and Fisichelli 2014a,b).

Rising temperatures and reduced water availability has and will continue to alter stream conditions for aquatic life. Warmer temperatures could increase the risk of invasion by aquatic species. Invasive crayfish (*Orcontectes* spp.) and several non-native fish are already altering aquatic food webs in the monuments (Schmidt et al. 2005, 2006). Furthermore, riparian vegetation is expected to decline as the climate warms, which could lead to an increase in erosion and in-stream sedimentation (Stromberg et al. 2010). Stream vegetation also provides shade and cools water temperature.

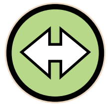
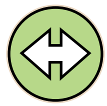
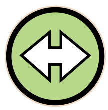
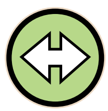
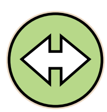
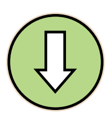
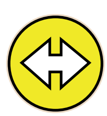
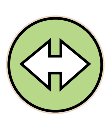
On a more local scale, sources of pollution include abandoned mines, increased urbanization, new developments, road construction, livestock grazing, and residential septic system failures (Black et al. 2005). Livestock and urbanization are likely sources for *E. coli* in monument waters, but native wildlife may also contribute to observed exceedences. The Verde River Institute initiated a study to pinpoint the sources of *E. coli* and low dissolved oxygen in the river (Verde River Institute 2018).

Since 2009, SODN has collected hundreds of water samples to monitor changes in dozens of water quality measures in both monuments. Because of this large volume of data, there are few data gaps. However, many measures do not have numerical state standards, which makes evaluating their potential effects on the aquatic ecosystem difficult. As previously mentioned, determining what is "normal" for this system is key to identifying water quality issues. But in a changing climate, "normal" is a moving target. Since water quality in both monuments is closely monitored by SODN, and other agencies outside the monuments, the likelihood that water quality issues will be detected early is high.

Sources of Expertise

Assessment author is Lisa Baril, biologist and science writer, Utah State University. Subject matter expert reviewers for this assessment are listed in Appendix A.

Table 33. Summary of water quality indicators, measures, and condition rationale.

Indicators	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Core Water Quality	pH (SU)		All samples attained Arizona State criteria. Confidence is high due to the seven years of sampling and multiple annual sampling periods. The trend is unchanging based on the annual condition rating.
	Dissolved Oxygen (mg/L)		The vast majority of samples were within the range of normal for dissolved oxygen, but there were five samples that did not meet standards in Beaver Creek and two in the Verde River. Sonde deployment data for two weeks per quarter during WY 2016 did not indicate any issues related to dissolved oxygen. However, there is some uncertainty as to the cause of low oxygen levels and the Verde River is listed as impaired for this measure, which accounts for the medium confidence level.
Metals and Metalloids	Arsenic, Barium, Boron, Chromium, Copper, Lead, Manganese, Nickel, Uranium, Zinc, and Others (mg/L)		Arsenic persistently exceeded state standards in Montezuma Castle NM, but this metalloid is found naturally in the surrounding rocks. Lead also exceeded state standards but only for one of hundreds of samples. Confidence is high due to the seven years of sampling and multiple annual sampling periods. The trend is unchanging based on the annual condition rating.
Nutrients	Ammonia, Phosphorus, and Nitrogen (mg/L)		All but one sample for total nitrogen in Beaver Creek during WY 2012 attained Arizona State standards. Confidence is high due to the seven years of sampling and multiple annual sampling periods. The trend is unchanging based on the annual condition rating.
Inorganics	Alkalinity, Fluoride, Sulfate, Chloride, and Others (mg/L)		All samples with criteria attained standards. Confidence is high due to the seven years of sampling and multiple annual sampling periods. The trend is unchanging based on the annual condition rating.
Microbiological Organisms	*E. coli* (cfu/100 ml)		Relatively few samples exceeded state standards for *E. coli* in Beaver Creek and the Verde River. Exceedences were associated with heavy rainfall that washed bacteria into these streams. Therefore, exceedences appear to be acute occurrences based on specific events rather than a persistent issue. However, the Verde River is listed as impaired for *E. coli*, which accounts for the medium confidence level.
Benthic Macroinvertebrates	Arizona Index of Biological Integrity		About half of all years across the three streams attained state standards. The remaining years were rated as inconclusive. The average AZIBI over the six years was 55 for Beaver Creek and 50 for Wet Beaver Creek (good condition). However, the trend at Beaver Creek deteriorated somewhat. In the Verde River, the index averaged 50 (good condition), but the trend deteriorated.
	USEPA Multi-metric Index		None of the values were considered good at either monument. Averages of the index for both monuments fell within the moderate concern condition. Because this index could have been influenced by physical changes in the streambed rather than pollutants, the confidence in the condition rating is medium. The trend is unchanging.
Overall Condition	Summary of All Measures		Although the overwhelming majority of measures indicate good condition, there are a few specific concerns, such as low indices of benthic macroinvertebrates. Although there are reasonable natural explanations for these concerns, the cause(s) are unknown. Therefore, the condition was rated as good, but the confidence was medium. Trend appears unchanging based on the trends assigned to the various measures and indicators.

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 10 of its 11 network parks, including Montezuma Castle National Monument (NM) (Hubbard et al. 2012). Terrestrial vegetation comprises 99% of the earth's biomass, and plants are the primary producers of life on Earth (Hubbard et al. 2012). Monitoring vegetation and soils can help scientists recognize subtle shifts in ecosystem structure and function, such as changes in water availability, disturbances, and climatic conditions (Hubbard et al. 2012). Taking a holistic community perspective can inform underlying processes that are difficult to monitor directly, while monitoring specific species can inform changes in abundance and demography (Hubbard et al. 2012). Both aspects are important for understanding vegetation and soils dynamics.

Although Montezuma Castle NM is part of SODN, the monument is located northeast of the Sonoran Desert in the Apache Highlands ecoregion (NPS SODN 2017). The monument is situated at an elevation range of approximately 963-1,103 m (3,159-3,619 ft) and lies within the thornscrub biome, which is the second driest and lowest elevation biome in the network after desert scrub (Hubbard et al. 2012). Common plant species include velvet mesquite (*Prosopis velutina*), acacias (*Acacia* spp.), and creosote bush (*Larrea tridentata*) (Hubbard et al. 2012). Montezuma Castle NM also supports riparian vegetation, which is addressed in a separate assessment in this report (NPS SODN 2017).

Climate in the region is characterized by long, hot summers and highly variable precipitation, about half of which falls during summer in localized, intense rainstorms (NPS SODN 2017). Annual precipitation averages 33.3 cm (13.1 in). Temperatures reach an average high of 38 °C (101 °F) in July and drop to an average minimum of -3 °C (26 °F) in December and January (Mau-Crimmins et al. 2005). Nearby Tuzigoot NM also occurs within the thornscrub biome, but because this small monument lies along the Verde River, it supports mostly riparian and wetland vegetation with little upland habitat (NPS SODN 2017). Thus, SODN does not monitor upland vegetation in Tuzigoot NM but has surveyed the monument for erosion, which is included in this assessment.

Data and Methods

Vegetation has been well studied at Montezuma Castle NM. Schmidt et al. (2006) report that several surveys and species lists were developed during the mid-1900s (Spangle and Sutton 1949, McDougall and Haskell 1960, Clark and Burgess 1966). Schmidt et al. (2006) also report that in the 1990s and early 2000s, a

Cactus and globemallow growing in the uplands at Montezuma Castle NM. Photo Credit: NPS.

second round of inventories and mapping efforts were conducted by Reichenbacher (1990), Jenkins et al. (1991), Brian and Rowlands (1994), Rowlands (1999), Halvorson and Guertin (2003), Mau-Crimmins et al. (2009). This assessment is based on the most recent monitoring efforts conducted by SODN as described in Hubbard et al. (2012). SODN's overall goal is to "ascertain broad-scale changes in vegetation and dynamic soils properties in the context of changes in other ecological drivers, stressors, and processes, and focal resources of interest" (McIntyre et al. 2014). The indicators SODN uses to assess upland vegetation in the monument include erosion hazard, erosion features, site resilience, fire hazard, perennial plant community composition and structure, and non-native plants.

SODN's protocol employs a random, spatially balanced sampling design with plots allocated by elevation class and soil type (Hubbard et al. 2012). Because of low topographic variability in the monument, all 11 plots were established in the thornscrub stratum within Montezuma NM's Castle Unit. Plots were further stratified by underlying geology: four plots were allocated to the Terrace Gravel geologic unit and seven plots were allocated to the Verde Limestone geologic unit (McIntyre et al. 2014).

The Verde Limestone stratum occurs above and more distant from Beaver Creek than the Terrace stratum (McIntyre et al. 2014). Typical thornscrub vegetation with widely spaced grasses and shrubs occurs in the Verde Limestone stratum and is the dominant upland community type in the monument. The Terrace stratum occurs in lower elevation areas closer to Beaver Creek, and vegetation there is influenced by the creek and alluvium soils. The Terrace stratum serves as a transitional area between riparian vegetation and the more typical thornscrub vegetation common to the region (McIntyre et al. 2014). Terrace stratum plots were more similar to the northern Sonoran Desert, "with a greater abundance of large, shrubby mesquite and acacia, and patches of creosote dominating the sandy flats" (McIntyre et al. 2014). However, as a whole, the monument is most similar to Great Basin conifer woodlands, semi-desert grasslands, and interior chaparral (McIntyre et al. 2014). The monument lies at the intersection of three ecoregions, and thus exhibits vegetation from each of these areas (McIntyre et al. 2014). High levels of past disturbance, especially in riparian areas and the Terrace stratum, have also influenced vegetation in the monument (McIntyre et al. 2014).

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. Transects were used for measures of cover. The transects divided the plot into five subplots, which were used for measures of frequency and extent. Vegetation and soils were measured in all of the following three 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]). Plots were surveyed during July and August. The first round of sampling occurred between 2010 and 2012 and the second round of sampling occurred in 2015 and 2016. Six of the eleven plots were surveyed twice during 2010 to 2016, while the remaining five plots were surveyed once during the same period. In general, plots are scheduled for sampling every five years (Hubbard et al. 2012). Data for all years of sampling were provided by K. Bonebrake, SODN data manager, via e-mail on 8 December 2017. Data collection methods for each measure are described in the following section, but see Hubbard et al. (2012) for further details.

The first measure of erosion hazard 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.

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).

The third measure of erosion hazard is the cover of mature biological soil crusts. Mature biological soil crusts are comprised of dark cyanobacteria, lichens, and moss (McIntyre et al. 2014). 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).

For the erosion feature type indicator there are two measures: estimated soil loss by feature type and extent of area by feature type. These measures were assessed as described below.

Erosion was identified as a "leading concern" during the initial Natural Resource Condition Assessment (NRCA) scoping process (Nauman 2010). To address these concerns, erosion in Tuzigoot NM and Montezuma Castle NM, including the Well Unit, were mapped using a handheld GPS (Global Positioning System) in 2009 (Nauman 2010). All upland areas exhibiting evidence of active sheet erosion, rills, and gullies were mapped in both monuments (Nauman 2010). Rills are small runoff channels that can be obliterated by conventional tillage, while gullies are large runoff channels that cannot be obliterated by conventional tillage (Nauman 2010). Sheet erosion is a process whereby soil loss occurs evenly across a surface, often evidenced by bare soil exposure and raised or pedestalled plants and lack of soil crusts (Nauman 2010). Rills, gullies, and sheet erosion were mapped as point features and the estimated soil loss was recorded by feature type. Rills, gullies, and sheet erosion provide direct evidence of active erosion (Nauman 2010).

Beginning in 2010, SODN began monitoring erosion in the 11 plots at Montezuma Castle NM. The extent of affected area by feature type was surveyed as described 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. Sheet, rill, and gully features are direct indicators of erosion, while the other features are precursors to water erosion or signs of susceptibility. Erosion observations were used to indicate site stability and help identify any other measured features that might be associated with increased erosion.

There are two measures of site resilience (foliar cover of dead perennial plants in the field layer and foliar cover of dead perennial plants in the subcanopy layer), which we consider together for simplicity. These two measures address resilience, or the ability of plant communities to recover after a disturbance, maintain natural processes, and resist invasion by non-native plants in the field and subcanopy layers. Dead 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.

Grass and forb cover is a measure of fire hazard. Thornscrub vegetation is not fire-adapted (Hubbard et al. 2012). Historically, fires were rare in this habitat type because of the low accumulation of fine fuels, such as grasses and forbs. Introduced species, however, are often tolerant of or even thrive following a fire. This creates a positive feedback loop whereby non-native grasses invade causing increased fire frequency, which then results in greater spread of non-native species followed by more widespread fires (Hubbard et al. 2012). Determining the amount of accumulated fine fuels (e.g., forbs and grasses) informs fire hazard.

The ratio of annuals to total plant cover is also an important measure of fire hazard in thornscrub communities because in years of high precipitation, annuals may fill in the spaces between perennials creating a continuous source of fuels (Rao et al. 2015). However, native annuals are common in the understory but generally do not provide a continuous layer of fine fuels as non-native annual grasses do. Non-native annual grasses, such as red brome (*Bromus rubens*), are particularly problematic. Furthermore, biomass of annual grasses tend to persist longer than annual forbs (Rao et al. 2015).

The indicator perennial plant community composition and structure was evaluated using two measures. The first measure is cover of common species. This measure is an effective approach for monitoring plant populations as a whole as well as trends in individual species, especially keystone species (Hubbard et al. 2012). Monitoring cover for a suite of species allows for changes in future management direction (Hubbard et al. 2012). This measure was limited to perennial species exhibiting >10% absolute canopy cover, including non-native plants and all plant lifeforms (e.g., trees, shrubs, forbs) (Hubbard et al. 2012). We included non-native plant cover for both annuals and perennials under the non-native plants indicator.

The second measure of perennial plant community composition and structure is the frequency of uncommon species. Frequency provides an index of change over time and space (Hubbard et al. 2012). It is useful for species that are uncommon or have high year-to-year variability in occurrence (Hubbard et al. 2012). Frequency for uncommon species were perennials exhibiting <10% absolute canopy cover, including non-native plants (Hubbard et al. 2012). We included non-native plant extent for both annuals and perennials under the non-native plants indicator.

Non-native plants were assessed using three measures. The first measure is extent, which refers to the frequency of non-native plants encountered across monitoring plots (Hubbard et al. 2012). It is an effective way to monitor changes in the spread of non-native plants over time. The second measure is total cover, which is the area over which a species or group of plants occurs. It is useful for monitoring which species are dominant in a particular site. The third measure is the ratio of non-native plants to total plant cover. This measure is useful for determining what proportion of the total plant cover is composed of non-native species and, like total cover, is useful for determining dominance.

Reference Conditions

Reference conditions are described for resources in good and moderate/significant concern conditions for each of the 14 measures (Table 34). All reference

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

Indicators	Measures	Good	Moderate/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	Average surface soil aggregate stability is ≥ Class 3.	Average surface soil aggregate stability is < Class 3.
	Mature Biological Soil Crust Cover	Mature biological soil crust cover is ≥ 10% of available habitat.	Mature biological soil crust cover is < 10% of available habitat.
Erosion Features	Estimated Soil Loss by Feature Type*	No reference conditions established.	No reference conditions established.
	Extent of Area by Erosion Feature Type	No reference conditions established.	No reference conditions established.
Site Resilience	Foliar Cover of Dead Perennial Plants (field layer)	Foliar cover of dead perennial plants is ≤ 15%.	Foliar cover of dead perennial plants is > 15%.
	Foliar Cover of Dead Perennial Plants (subcanopy layer)	Foliar cover of dead perennial plants is ≤ 15%.	Foliar cover of dead perennial plants is > 15%.
Fire Hazard	Grass and Forb Cover (field layer)	Grass and forb cover is ≤ 30%.	Grass and forb cover is > 30%.
	Ratio of Annual Plant Cover to Total Plant Cover (field layer)	Annual plant cover: total plant cover is ≤ 1:4 (≤ 25%).	Annual plant cover: total plant cover is > 1:4 (> 25%).
Perennial Plant Community Composition and Structure	Cover for Common Species (all layers)	No reference conditions established.	No reference conditions established.
	Frequency for Uncommon Species	No reference conditions established.	No reference conditions established.
Non-native Plants	Extent	Extent of non-native plants is ≤ 50%.	Extent of non-native plants is > 50%.
	Total Cover (field)	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 (field layer)	Non-native plant cover: total plant cover is ≤ 1:4 (≤ 25%).	Percent of total plant cover that is non-native is > 1:4 (> 25%).

* This measure also applies to Tuzigoot NM and is the only measure for the monument.

Source: McIntyre et al. (2014).

conditions apply to both strata except for mature biological soil crusts, which refers to the Verde Limestone stratum only. Reference conditions were based on Management Assessment Points (MAPS) developed by SODN and reported in McIntyre et al. (2014). 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). MAPS were developed for all measures except for the two measures of erosion features and the two measures of plant community composition and structure. However, those measures were cited as objectives in Hubbard et al. (2012) and Nauman (2010), respectively.

Condition and Trend

For all of the following measures, differences between rounds of sampling were generally only highlighted if the data between the two rounds resulted in different condition ratings. There were not sufficient data to assess trends in all of the following measures since only two rounds of data have been collected as of the writing of this assessment. Therefore, trend is unknown for all measures.

Bare ground cover (a measure of erosion hazard) with no overhead vegetation in both strata averaged well below the 20% MAP (Table 35). Bare ground cover was on average greater in Terrace plots than in Verde Limestone plots. Since both strata averaged less than 20% bare ground cover, this measure of erosion hazard indicates good condition. Confidence in the condition rating is high.

Average soil aggregate stability (a measure of erosion hazard) exceeded class 3 for both strata (Table 35). These data indicate good condition for this measure of erosion hazard at the monument. Confidence in the condition rating is high.

The total mature biological soil crust cover (a measure of erosion hazard) in available habitat (areas not covered by duff, bedrock, rock, and vegetation) was approximately 2% in Terrace plots (Table 36). In Verde Limestone plots, the total cover of mature biological

Table 35. Bare ground cover and soil stability at Montezuma Castle NM.

Unit	Measures	Round 1 Mean (SE)	Round 2 Mean (SE)
Terrace	Bare Ground Cover (%)	10.69 (4.47)	8.86 (3.24)
	Soil Aggregate Stability (Class)	3.31 (0.46)	3.54 (0.19)
Verde Limestone	Bare Ground Cover (%)	5.08 (1.11)	7.01 (1.07)
	Soil Aggregate Stability (Class)	3.18 (0.54)	3.35 (0.32)

Table 36. Mature biological soil crust cover at Montezuma Castle NM.

Unit	Measures	Round 1 % Mean (SE)	Round 2 % Mean (SE)
Terrace	Dark Cyanobacteria	1.24 (1.06)	1.24 (0.95)
	Lichen	0 (0)	0.26 (0.32)
	Moss	0.66 (0.66)	0.37 (0.37)
	Total	1.9 (0.86)	1.86 (2.02)
Verde Limestone	Dark Cyanobacteria	0.32 (0.14)	2.11 (1.84)
	Lichen	1.86 (1.36)	0.34 (0.34)
	Moss	1.59 (0.45)	0.24 (0.15)
	Total	3.78 (1.27)	2.69 (2.29)

soil crusts was between 2.69% and 3.78%. The MAP applies to the Verde Limestone stratum only. Since mature soil crust cover was less than 10% in this stratum, these results warrant moderate/significant concern at Montezuma Castle NM. Confidence in the condition rating is high.

The condition for estimated soil loss by feature type is unknown at both monuments because no reference conditions were established for this measure. Confidence in the condition rating is low because of the unknown condition. The available data for Montezuma Castle NM however, show that 3.9% of the 139 ha (343 ac) surveyed in the Castle Unit showed signs of accelerated erosion. Just under half of the features mapped were sheet erosion, one-third were rills, and under twenty percent were gullies (Table 37). Nauman (2010) estimated that the 486 unique features represented nearly 11,000 m^3 (388,461 ft^3) of soil loss with the gullies accounting for the majority of this loss.

Table 37. Erosion features and estimated associated soil loss at Montezuma Castle and Tuzigoot NMs.

Park and Unit	Feature	Number of Features	Estimated Soil Loss (m^3)	% of Total Soil Loss
Montezuma Castle NM, Castle Unit	Sheet erosion	225	1,584	14
	Rills	165	810	7
	Gullies	96	8,557	78
	Total	486	10,951	100
Montezuma Castle NM, Well Unit	Sheet erosion	103	549	27
	Rills	99	386	19
	Gullies	24	1,136	55
	Total	226	2,071	100
Tuzigoot NM	Sheet erosion	118	889	9
	Rills	250	3,426	33
	Gullies	50	5,959	58
	Total	418	10,274	100

Source: Nauman (2010).

At Montezuma Castle's Well Unit, Nauman (2010) surveyed approximately 65 ha (160 ac) for erosion features. He found just over 2 ha (5 ac) (3%) showed signs of active erosion. Gullies were less common than at the main unit and accounted for about 10% of the 226 mapped erosion features (Table 37). Just under half of the features were sheet erosion. Nauman (2010) estimated that the features represented an estimated 2071 m^3 (73,137 ft^3) of soil loss. While only 10% of the erosion features were gullies, they accounted for over 50% of the estimated soil loss. The largest erosion features were found in an area described as the northeast fan (Nauman 2010).

Nauman (2010) surveyed 79 ha (195 ac) at Tuzigoot NM and found that nearly 4 ha (10 ac) (5%) of the survey area exhibited active signs of erosion. Rills were the dominant erosion feature and accounted for 60% of the mapped features (Table 37). The 4 ha (10 ac) with active erosion at Tuzigoot NM had nearly as much soil loss (10,274 m^3 [362,823 ft^3]) as the 5 ha (13 ac) of active erosion at the main unit of Montezuma Castle NM (10,951 m^3 [386,731 ft^3]). The main ridge at Tuzigoot NM, showed signs of extensive sheet erosion and rills (Nauman 2010).

The condition for extent of erosion by feature type is unknown at Montezuma Castle NM because reference conditions for this measure have not been developed. Confidence in the condition rating is low because of the unknown condition. However, in Terrace plots the available data suggests relatively low erosion (Table 38). The estimated degraded area (sheet, rill, and gully) in most plots was 0%, but two plots showed a slight increase in erosion from round 1 to round 2. Despite the slight increase, the degraded area in these two plots was estimated at only 2.5%. Some evidence of precursors to erosion (i.e., tunneling, pedestals, terracettes, and burrowing) were observed in some plots but were generally low in extent (<5%).

The estimated degraded area in Verde Limestone plots was greater than in Terrace plots, especially during round 2 (Table 39). Sheet, rill, and gully erosion was estimated at 2.5% in only one plot during round 1, but during round 2 half of the plots exhibited evidence of active erosion. In one plot the estimated degraded area exceeded 15%. Tunneling and burrowing were also observed in some plots, especially during round 1.

The two measures of site resilience are in good condition and confidence is high since average measurements were less than the 15% MAP. Foliar cover of dead perennial plants in the field layer did not

Creosote after a monsoon. Photo Credit: NPS.

Table 38. Erosion area class by feature type as observed in Terrace plots at Montezuma Castle NM.

Round	Plot	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	201-006	<5	0	0	<5	0	0	0	0
	201_008	0	<5	0	<5	0	0	0	0
	201-010	0	0	0	0	0	0	0	0
2	201_006	0	0	0	0	<5	0	0	2.5
	201-008	0	0	0	0	0	0	0	0
	201-009	0	0	0	0	0	0	0	0
	201_010	0	0	0	<5	0	<5	0	2.5

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

Table 39. Erosion area class by feature type as observed in Verde Limestone plots at Montezuma Castle NM.

Round	Plot	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	202_001	<5	0	0	<5	0	0	0	0
	202_002	0	0	0	<5	0	0	0	0
	202-003	<5	0	0	<5	0	0	0	0
	202-005	0	0	0	0	0	<5	0	2.5
	202-006	0	0	0	<5	0	0	0	0
2	202_002	<5	0	0	0	0	0	0	0
	202-003	0	0	0	0	0	<5	0	2.5
	202-005	0	0	0	0	0	6-25	0	15.5
	202-006	0	0	0	0	0	<5	0	2.5
	202-009	0	0	0	0	0	0	0	0
	202-011	0	0	0	<5%	0	0	0	0

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

exceed 7% for either or strata, and most values were <3% (Table 40). And in the subcanopy layer, foliar cover of dead perennials did not exceed 1% in either strata (Table 40).

The following summarizes the two fire hazard measures. Grass and forb cover averaged less than the 30% MAP for both strata (Table 41). Since percent cover was less than 30%, this measure of fire hazard is in good condition. Confidence is high. The proportion of total cover represented by annuals was substantially lower in Verde Limestone plots than in Terrace plots (Table 41). The MAP of 25% was not exceeded in the Verde Limestone stratum. In Terrace plots however, the proportion of total cover represented by annuals averaged nearly 20% in round 1 and 27% in round 2. Therefore, the condition for this measure of fire hazard is good in the Verde Limestone stratum but

Table 40. Measures of site resilience at Montezuma Castle NM.

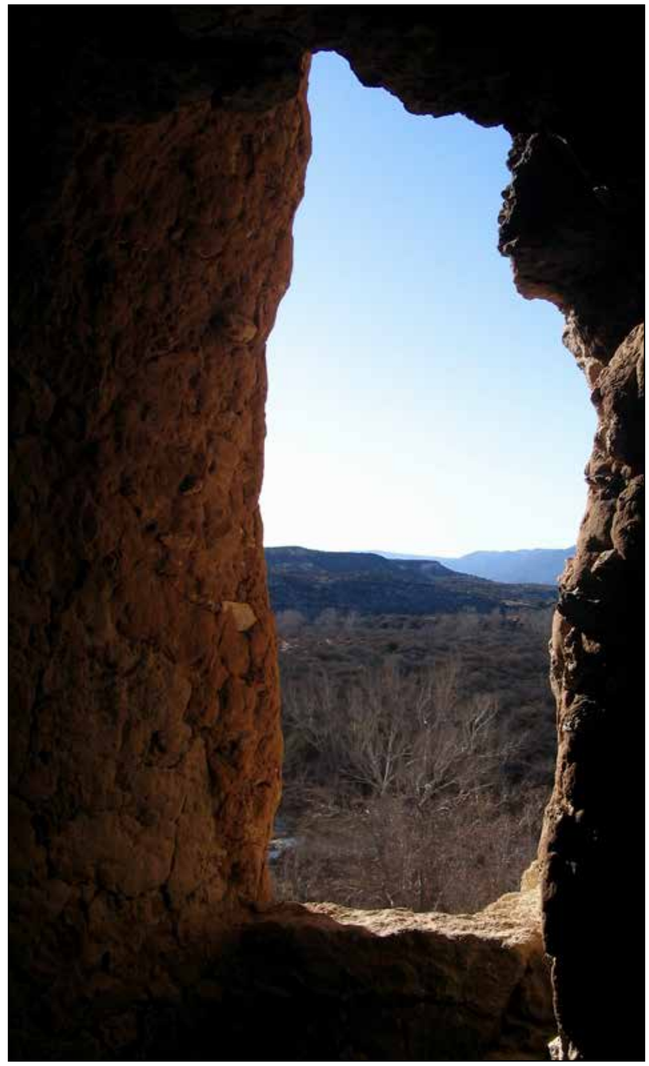
Unit	Measure by Stratum	Round 1 % Mean (SE)	Round 2 % Mean (SE)
Terrace	Foliar Cover of Dead Plants (field)	2.22 (1.60)	0.42 (0.29)
	Foliar Cover of Dead Perennial Plants (subcanopy)	0.42 (0.24)	0.00 (0.00)
Verde Limestone	Foliar Cover of Dead Plants (field)	6.75 (2.31)	0.97 (0.30)
	Foliar Cover of Dead Perennial Plants (subcanopy)	0.25 (0.17)	0.07 (0.07)

Table 41. Measures of fire hazard at Montezuma Castle NM.

Unit	Measure by Stratum	Round 1 % Mean (SE)	Round 2 % Mean (SE)
Terrace	Grass and Forb Cover (field)	12.92 (4.25)	17.39 (5.46)
	Ratio of Annual Cover to Total Cover (field)	19.17 (7.29)	26.63 (7.56)
Verde Limestone	Grass and Forb Cover (field)	11.42 (1.66)	10.01 (2.92)
	Ratio of Annual Cover to Total Cover (field)	11.35 (5.94)	2.45 (1.66)

warrants moderate/significant concern in the Terrace stratum. Confidence in the condition rating is high.

For the measure of cover for common species, eighteen perennial species or genera were encountered along line transects in the Terrace stratum, including all lifeforms except for vines (Table 42). Both succulents and forbs/herbs were rare, however. The greatest cover across lifeforms occurred in the field layer, while cover in the canopy layer was low. Terrace plots were composed mostly of shrubs dominated by creosote bush, catclaw acacia (*Senegalia greggii*), broom snakeweed (*Gutierrezia sarothrae*), and fourwing saltbush (*Atriplex canescens*). Velvet mesquite was the dominant and only tree species. Mesquite was relatively short in stature with most cover occurring in the subcanopy layer. Bush muhly (*Muhlenbergia porteri*) was the most common grass species. Although cover was generally low, most species occurred in at least half of all plots (extent in Table 42).



View looking south from inside Montezuma Castle. Photo Credit: NPS.

Table 42. Percent cover and extent for common perennial species in the Terrace stratum in Montezuma Castle NM.

Plant Group	Species	Round 1 Field %Mean (SE)	Round 1 Subcanopy % Mean (SE)	Round 1 Canopy % Mean (SE)	Round 1 Extent (%)	Round 2 Field % Mean (SE)	Round 2 Subcanopy % Mean (SE)	Round 2 Canopy % Mean (SE)	Round 2 Extent (%)
Forbs/Herbs	*Astragalus tephrodes* (ashen milkvetch)	0.28 (0.28)	0 (0)	0 (0)	25	0 (0)	0 (0)	0 (0)	0
	Melampodium leucanthum (plains blackfoot)	0 (0)	0 (0)	0 (0)	0	0.11 (0.11)	0 (0)	0 (0)	25
Graminoids	*Aristida purpurea* (purple threeawn)	0.70 (0.50)	0 (0)	0 (0)	75	0.42 (0.42)	0 (0)	0 (0)	50
	Elymus elymoides (squirreltail)	0.14 (0.14)	0 (0)	0 (0)	50	0 (0)	0 (0)	0 (0)	0

Table 42 continued. Percent cover and extent for common perennial species in the Terrace stratum in Montezuma Castle NM.

Plant Group	Species	Round 1 Field %Mean (SE)	Round 1 Subcanopy % Mean (SE)	Round 1 Canopy % Mean (SE)	Round 1 Extent (%)	Round 2 Field % Mean (SE)	Round 2 Subcanopy % Mean (SE)	Round 2 Canopy % Mean (SE)	Round 2 Extent (%)
Graminoids continued	*Muhlenbergia porteri* (bush muhly)	4.17 (3.15)	0 (0)	0 (0)	75	4.17 (3.2)	0 (0)	0 (0)	100
Shrubs/ Subshrubs	*Atriplex canescens* (fourwing saltbush)	2.78 (2.78)	1.67 (1.67)	0 (0)	25	1.77 (1.77)	0.52 (0.52)	0 (0)	50
	Berberis haematocarpa (red barberry)	0.42 (0.42)	2.22 (1.47)	0.69 (0.69)	75	1.15 (0.46)	1.67 (0.9)	0.21 (0.12)	100
	Chaetopappa ericoides (rose heath)	0.14 (0.14)	0 (0)	0 (0)	25	0.21 (0.21)	0 (0)	0 (0)	25
	Dalea formosa (featherplume)	0 (0)	0 (0)	0 (0)	0	0.42 (0.42)	0 (0)	0 (0)	25
	Ephedra sp. (jointfir)	0.14 (0.14)	0 (0)	0 (0)	25	0 (0)	0 (0)	0 (0)	0
	Ephedra viridis (mormon tea)	1.25 (1.25)	0 (0)	0 (0)	50	0.73 (0.6)	0.42 (0.29)	0 (0)	100
	Gutierrezia sarothrae (broom snakeweed)	3.75 (1.5)	0 (0)	0 (0)	75	4.79 (1.69)	0 (0)	0 (0)	100
	Krameria erecta (littleleaf ratany)	0.56 (0.56)	0 (0)	0 (0)	50	0.94 (0.94)	0 (0)	0 (0)	75
	Larrea tridentata (creosote bush)	4.31 (2.16)	6.8 (3.57)	0 (0)	50	10.83 (5.75)	11.67 (5.83)	0.11 (0.11)	75
	Senegalia greggii (catclaw acacia)	3.19 (1.45)	3.61 (1.39)	0 (0)	75	3.23 (1.29)	4.58 (2.61)	0.63 (0.40)	100
Succulents	*Cylindropuntia leptocaulis* (Christmas cactus)	0 (0)	0 (0)	0 (0)	0	0 (0)	0.11 (0.11)	0 (0)	75
	Yucca elata (soaptree yucca)	0.55 (0.28)	0 (0)	0 (0)	75	0.52 (0.31)	0 (0)	0 (0)	100
Trees	*Prosopis velutina* (velvet mesquite)	6.81 (3.75)	13.06 (7.42)	2.36 (2.16)	75	4.06 (2.42)	9.27 (5.76)	1.77 (1.77)	75

In the Verde Limestone stratum, forty species or genera of perennial plants were encountered along line transects (Table 43). As with the Terrace stratum, all lifeforms except for vines were represented, and forbs/herbs and succulents were rare. The Verde Limestone stratum, however, contained roughly twice as many species than the Terrace stratum. Velvet mesquite and three species of juniper (*Juniperus* spp.) occurred as small trees. Common shrubs included crucifixion thorn (*Canotia holacantha*), creosote bush, catclaw acacia, and mariola (*Parthenium incanum*). The grass purple threeawn (*Aristida purpurea*) dominated the understory. Cover across all lifeforms was highest in the field layer and lowest in the canopy layer. As with the Terrace stratum, most species occurred in more than half of the plots (extent in Table 43).

View from Montezuma Castle NM's Well unit. Photo Credit: NPS.

Table 43. Percent cover and extent for common perennial species in the Verde Limestone stratum in Montezuma Castle NM.

Plant Group	Species	Round 1				Round 2			
		Field %Mean (SE)	Subcanopy % Mean (SE)	Canopy % Mean (SE)	Extent (%)	Field % Mean (SE)	Subcanopy % Mean (SE)	Canopy % Mean (SE)	Extent (%)
Forbs/Herbs	*Astragalus calycosus* (Torrey's milkvetch)	0.17 (0.17)	0 (0)	0 (0)	29	0 (0)	0 (0)	0 (0)	0
	Astragalus tephrodes (ashen milkvetch)	0.08 (0.08)	0 (0)	0 (0)	14	0.21 (0.14)	0 (0)	0 (0)	43
	Melampodium leucanthum (plains blackfoot)	0 (0)	0 (0)	0 (0)	0	0.14 (0.09)	0 (0)	0 (0)	71
	Polygala scoparioides (broom milkwort)	0 (0)	0 (0)	0 (0)	0	0.14 (0.14)	0 (0)	0 (0)	29
Graminoids	*Achnatherum hymenoides* (Indian ricegrass)	0 (0)	0 (0)	0 (0)	0	0.07 (0.07)	0 (0)	0 (0)	14
	Aristida purpurea (purple threeawn)	5.25 (2.66)	0 (0)	0 (0)	71	2.99 (1.08)	0 (0)	0 (0)	86
	Bouteloua curtipendula (sideoats grama)	0.08 (0.08)	0 (0)	0 (0)	14	0.07 (0.07)	0 (0)	0 (0)	14
	Dasyochloa pulchella (low woollygrass)	0.08 (0.08)	0 (0)	0 (0)	14	0.63 (0.48)	0 (0)	0 (0)	57
	Eragrostis intermedia (plains lovegrass)	0 (0)	0 (0)	0 (0)	0	0.07 (0.07)	0 (0)	0 (0)	14
	Erioneuron pilosum (hairy woollygrass)	0 (0)	0 (0)	0 (0)	0	0.07 (0.07)	0 (0)	0 (0)	29
	Hesperostipa neomexicana (New Mexico feathergrass)	0 (0)	0 (0)	0 (0)	0	1.67 (0.77)	0 (0)	0 (0)	57
	Muhlenbergia porteri (bush muhly)	0.42 (0.42)	0 (0)	0 (0)	43	1.04 (0.96)	0 (0)	0 (0)	71
	Tridens muticus (slim tridens)	0.50 (0.50)	0 (0)	0 (0)	14	1.81 (0.89)	0 (0)	0 (0)	71
Shrubs/ Subshrubs	*Aloysia wrightii* (Wright's beebrush)	0.17 (0.17)	0.08 (0.08)	0 (0)	14	0 (0)	0 (0)	0 (0)	0
	Berberis haematocarpa (red barberry)	0 (0)	0.08 (0.08)	0 (0)	57	0.42 (0.21)	0.56 (0.3)	0 (0)	71
	Brickellia atractyloides (spearleaf brickellbush)	0.08 (0.08)	0 (0)	0 (0)	29	0 (0)	0 (0)	0 (0)	
	Canotia holacantha (crucifixion thorn)	3.17 (1.45)	6.42 (3.18)	1.58 (0.92)	57	5.00 (1.88)	7.22 (2.89)	1.46 (0.83)	57
	Chaetopappa ericoides (rose heath)	0 (0)	0 (0)	0 (0)	0	0.07 (0.07)	0 (0)	0 (0)	14
	Dalea formosa (featherplume)	0 (0)	0 (0)	0 (0)	0	0.07 (0.07)	0 (0)	0 (0)	57
	Encelia farinosa (brittlebush)	0.17 (0.17)	0 (0)	0 (0)	14	0 (0)	0 (0)	0 (0)	0
	Encelia frutescens (button brittlebush)	0 (0)	0 (0)	0 (0)	0	0.21 (0.21)	0 (0)	0 (0)	29
	Ephedra sp. (jointfir)	0.17 (0.17)	0 (0)	0 (0)	29	0 (0)	0 (0)	0 (0)	0

Table 43 continued. ***Percent cover and extent for common perennial species in the Verde Limestone stratum in Montezuma Castle NM.***

Plant Group	Species	Round 1				Round 2			
		Field %Mean (SE)	Subcanopy % Mean (SE)	Canopy % Mean (SE)	Extent (%)	Field % Mean (SE)	Subcanopy % Mean (SE)	Canopy % Mean (SE)	Extent (%)
Shrubs/ Subshrubs *continued*	*Eriogonum fasciculatum* (Eastern Mojave buckwheat)	0 (0)	0 (0)	0 (0)	0	0.42 (0.42)	0 (0)	0 (0)	29
	Gutierrezia sarothrae (broom snakeweed)	2 (1.07)	0 (0)	0 (0)	71	2.22 (0.66)	0 (0)	0 (0)	86
	Krameria erecta (littleleaf ratany)	2.5 (0.84)	0 (0)	0 (0)	71	2.22 (0.53)	0 (0)	0 (0)	86
	Larrea tridentata (creosote bush)	2.92 (0.75)	3.5 (1.57)	0 (0)	71	3.96 (0.79)	4.79 (1.5)	0.14 (0.14)	86
	Parthenium incanum (mariola)	8.5 (2.45)	0.33 (0.2)	0 (0)	57	10.28 (3.34)	0.07 (0.07)	0 (0)	71
	Purshia mexicana (Mexican cliffrose)	0 (0)	0 (0)	0 (0)	0	0.14 (0.14)	0 (0)	0 (0)	29
	Senegalia greggii (catclaw acacia)	1.92 (1.62)	1.17 (1.17)	0.42 (0.42)	43	1.04 (1.04)	0.9 (0.9)	0.42 (0.42)	57
	Thymophylla acerosa (pricklyleaf dogweed)	0 (0)	0 (0)	0 (0)	0	0.35 (0.27)	0 (0)	0 (0)	29
	Tiquilia canescens (woody crinklemat)	0 (0)	0 (0)	0 (0)	0	0.83 (0.54)	0 (0)	0 (0)	71
	Tiquilia sp. (crinklemat)	0.25 (0.25)	0 (0)	0 (0)	29	0 (0)	0 (0)	0 (0)	0
	Ziziphus obtusifolia (lotebush)	0 (0)	0 (0)	0 (0)	0	0 (0)	0.35 (0.35)	0 (0)	71
Succulents	*Cylindropuntia leptocaulis* (Christmas cactus)	0.5 (0.5)	0 (0)	0 (0)	43	0.21 (0.21)	0 (0)	0 (0)	43
Trees	*Juniperus coahuilensis* (redberry juniper)	0 (0)	0 (0)	0 (0)	0	1.53 (0.9)	3.33 (2.01)	2.50 (1.32)	43
	Juniperus monosperma (oneseed juniper)	1.17 (0.72)	4.25 (2.36)	2.67 (1.21)	57	0 (0)	0 (0)	0 (0)	0
	Juniperus osteosperma (Utah juniper)	0 (0)	0 (0)	0 (0)	0	0.14 (0.14)	0.83 (0.83)	0.35 (0.35)	14
Trees *continued*	*Prosopis velutina* (velvet mesquite)	0.58 (0.58)	0.67 (0.67)	0 (0)	14	0.42 (0.42)	0.70 (0.70)	0 (0)	14
Not Specified	*Brickellia* sp. (brickellbush)	0.08 (0.08)	0 (0)	0 (0)	14	0 (0)	0 (0)	0 (0)	0
	Krameria sp. (ratany)	0.42 (0.42)	0 (0)	0 (0)	14	0 (0)	0 (0)	0 (0)	0

No reference conditions were established for this measure. Therefore, the condition is unknown and confidence is low. Data for this measure will be used to monitor plant populations and species of interest over time.

For the frequency of uncommon species, an additional 22 species or genera were observed in subplots in the Terrace stratum, none of which were non-native perennials (Table 44). In Verde Limestone plots 40 additional species or genera were recorded in subplots that were not recorded on line transects, two of which were non-native perennials (Table 45). No reference conditions were established for this measure. Therefore, the condition is unknown and confidence is low. The purpose of this measure is to

Table 44. Within-plot frequency for uncommon species in the Terrace stratum in Montezuma Castle NM.

Plant Group	Species	Round 1 % Mean (SE)	Round 2 % Mean (SE)
Forbs/Herbs	*Abutilon parvulum* (dwarf Indian mallow)	6.67 (6.67)	0 (0)
	Astragalus wootonii (halfmoon milkvetch)	6.67 (6.67)	0 (0)
	Senna bauhinioides (twinleaf senna)	26.67 (26.67)	20.00 (20.00)
	Solanum elaeagnifolium (silverleaf nightshade)	0 (0)	20.00 (20.00)
Graminoids	*Bouteloua curtipendula* (sideoats grama)	0 (0)	5.00 (5.00)
	Dasyochloa pulchella (low woollygrass)	0 (0)	15.00 (9.57)
	Hesperostipa neomexicana (New Mexico feathergrass)	0 (0)	5.00 (5.00)
	Sporobolus cryptandrus (sand dropseed)	0 (0)	5.00 (5.00)
Shrubs/ Subshrubs	*Eriogonum wrightii* (bastardsage)	0 (0)	10.00 (10.00)
	Menodora scabra (rough menodora)	0 (0)	10.00 (10.00)
	Rhus aromatica (fragrant sumac)	6.67 (6.67)	5.00 (5.00)
	Sphaeralcea ambigua (desert globemallow)	0 (0)	5.00 (5.00)
	Tiquilia canescens (woody crinklemat)	0 (0)	10.00 (10.00)
	Tiquilia sp. (crinklemat)	13.33 (13.33)	0 (0)
	Ziziphus obtusifolia (lotebush)	6.67 (6.67)	10.00 (5.77)
Succulents	*Echinocereus fasciculatus* (pinkflower hedgehog cactus)	6.67 (6.67)	0 (0)
	Echinocereus sp. (hedgehog cactus)	0 (0)	5.00 (5.00)
	Opuntia macrorhiza (twistspine pricklypear)	0 (0)	5.00 (5.00)
	Opuntia phaeacantha (tulip pricklypear)	6.67 (6.67)	0 (0)
Trees	*Juniperus coahuilensis* (redberry juniper)	0 (0)	10.00 (5.77)
	Juniperus monosperma (oneseed juniper)	6.67 (6.67)	0 (0)
Not Specified	*Hoffmannseggia* sp. (rushpea)	33.33 (33.33)	0 (0)

Table 45. Within-plot frequency for uncommon species in the Verde Limestone stratum in Montezuma Castle NM.

Plant Group	Species	Round 1 % Mean (SE)	Round 2 % Mean (SE)
Forbs/Herbs	*Acourtia nana* (dwarf desertpeony)	0 (0)	13.33 (9.89)
	Acourtia sp. (desertpeony)	16.00 (11.66)	0 (0)
	Acourtia wrightii (brownfoot)	0 (0)	16.67 (16.67)
	Allionia incarnata (trailing windmills)	4.00 (4.00)	0 (0)
	Chamaesaracha coronopus (greenleaf five eyes)	0 (0)	3.33 (3.33)
	Delphinium scaposum (tall mountain larkspur)	8.00 (8.00)	0 (0)
	Euphorbia fendleri (Fendler's sandmat)	0 (0)	13.33 (9.89)
	Evolvulus nuttallianus (shaggy dwarf morning-glory)	0 (0)	3.33 (3.33)
	Hoffmannseggia drepanocarpa (sicklepod holdback)	0 (0)	13.33 (13.33)
	Marrubium vulgare (horehound)*	4.00 (4.00)	0 (0)
	Mirabilis albida (white four o'clock)	0 (0)	6.67 (6.67)
	Mirabilis multiflora (Colorado four o'clock)	4.00 (4.00)	6.67 (6.67)
	Nicotiana obtusifolia (desert tobacco)	12.00 (12.00)	0 (0)
	Senna bauhinioides (twinleaf senna)	0 (0)	10.00 (6.83)
	Solanum elaeagnifolium (silverleaf nightshade)	0 (0)	10.00 (10.00)
	Stephanomeria tenuifolia (narrowleaf wirelettuce)	0 (0)	3.33 (3.33)
Graminoids	*Bouteloua eriopoda* (black grama)	0 (0)	3.33 (3.33)
	*Eragrostis lehmanniana** (Lehmann lovegrass)	4.00 (4.00)	3.33 (3.33)
	Leptochloa dubia (green sprangletop)	4.00 (4.00)	0 (0)
	Sporobolus contractus (spike dropseed)	0 (0)	3.33 (3.33)
Shrubs/ Subshrubs	*Abutilon incanum* (pelotazo)	0 (0)	3.33 (3.33)

* Non-native species.

Table 45 continued. Within-plot frequency for uncommon species in the Verde Limestone stratum in Montezuma Castle NM.

Plant Group	Species	Round 1 % Mean (SE)	Round 2 % Mean (SE)
Shrubs/ Subshrubs *continued*	*Atriplex canescens* (fourwing saltbush)	4.00 (4.00)	6.67 (6.67)
	Brickellia californica (California brickellbush)	0 (0)	10.00 (10.00)
	Brickellia microphylla (littleleaf brickellbush)	12.00 (12.00)	0 (0)
	Calliandra humilis (dwarf stickpea)	4.00 (4.00)	0 (0)
	Eriogonum microthecum (slender buckwheat)	4.00 (4.00)	6.67 (4.22)
	Eriogonum wrightii (bastardsage)	0 (0)	6.67 (4.22)
	Lycium pallidum (pale desert-thorn)	4.00 (4.00)	3.33 (3.33)
	Purshia mexicana (Mexican cliffrose)	4.00 (4.00)	0 (0)
	Rhus aromatica (fragrant sumac)	12.00 (8.00)	23.33 (13.08)
	Sphaeralcea ambigua (desert globemallow)	0 (0)	23.33 (16.67)
	Thymophylla pentachaeta (fiveneedle pricklyleaf)	0 (0)	3.33 (3.33)
Succulents	*Echinocereus fasciculatus* (pinkflower hedgehog cactus)	16.00 (16.00)	6.67 (6.67)
	Echinocereus sp. (hedgehog cactus)	0 (0)	6.67 (6.67)
	Escobaria vivipara (spinystar)	0 (0)	3.33 (3.33)
	Opuntia engelmannii (cactus apple)	0 (0)	3.33 (3.33)
	Opuntia macrocentra (purple pricklypear)	0 (0)	3.33 (3.33)
	Opuntia macrorhiza (twistspine pricklypear)	0 (0)	6.67 (4.22)
	Opuntia phaeacantha (tulip pricklypear)	12.00 (12.00)	0 (0)
	Yucca elata (soaptree yucca)	20.00 (8.94)	13.33 (6.67)

* Non-native species.

track uncommon species over time, especially species that exhibit high annual variability in occurrence.

The following summarizes the three measures of the non-native plant indicator. Six non-native plant species were encountered across all 11 plots (Table 46). All six species occurred in the Verde Limestone stratum and three species occurred in the Terrace stratum. In the Terrace stratum, at least one non-native species occurred in each plot, but frequency varied by species. Red brome, however, occurred in all plots and exhibited the highest cover (4-9%) of all non-native species. In the Verde Limestone stratum, overall non-native plant frequency averaged between 86% and 100%. Again, red brome was widespread, occurring in more than 60% of plots. Although red brome exhibited the highest cover of the two species that occurred along line transects, cover was lower in Verde Limestone plots (0.5-2%) than in the Terrace plots (4-9%). Species listed in Table 46 without cover values occurred in subplots where cover was not measured. Since overall frequency for each stratum exceeded 50%, the condition warrants moderate/ significant concern in Montezuma Castle NM. Confidence in the condition rating is high.

Total non-native plant cover did not exceed the 10% MAP in the Terrace stratum, but during round 2 non-native plant cover averaged 9.06%, which is approaching the MAP (Table 47). In the Verde Limestone stratum, total non-native plant cover averaged 2.58% during round 1 and only 0.49% during round 2. Because none of the measurements exceeded 10%, the condition is good. Confidence in the condition rating is high. Trend is unknown.

Overall, the proportion of total plant cover represented by non-native plants was well below the 25% MAP in the Verde Limestone stratum and was substantially lower during round 2 (1.08%) than during round 1 (7.71%) (Table 47). In the Terrace stratum, however, the proportion of total plant cover represented by non-native plants was higher than in the Verde Limestone stratum, with between 17.26% and ~20% cover represented by non-natives. However, none of the values exceeded the 25% management assessment point. These results indicate good conditions for both strata. Confidence in the condition rating is high. Trend could not be determined.

Table 46. Extent and cover of non-native species at Montezuma Castle NM.

Unit	Species	Round 1 % Extent (SE)	Round 1 % Mean Cover (SE)	Round 2 % Extent (SE)	Round 2 % Mean Cover (SE)
Terrace	*Bromus rubens* (red brome)	100 (0)	4.03 (1.41)	100 (0)	9.06 (3.40)
	Erodium cicutarium (redstem stork's bill)	66.67 (33.33)	2.92 (1.97)	0 (0)	0 (0)
	Salsola sp.(Russian thistle)	0 (0)	–	25.00 (25.00)	–
	Tamarix ramosissima (saltcedar)	14.3 (14.3)	–	0 (0)	–
Verde Limestone	*Bromus hordeaceus* (soft brome)	20.00 (20.00)	–	0 (0)	–
	Bromus rubens (red brome)	60.00 (24.49)	2.08 (1.00)	66.67 (21.08)	0.49 (0.27)
	Eragrostis lehmanniana (Lehmann lovegrass)	20.00 (20.00)	–	16.67 (16.67)	–
	Erodium cicutarium (redstem stork's bill)	40.00 (24.49)	0.50 (0.33)	0 (0)	0 (0)
	Marrubium vulgare (horehound)	20.00 (20.00)	–	0 (0)	–
	Salsola sp. (Russian thistle)	0 (0)	–	16.67 (16.67)	–

Note: Species without cover values occurred in subplots where cover was not recorded.

Table 47. Non-native plant cover in Montezuma Castle NM.

Unit	Measures	Round 1 % Mean (SE)	Round 2 % Mean (SE)
Terrace	Total Non-native Plant Cover (field)	6.94 (3.05)	9.06 (3.40)
	Ratio of Non-native Cover to Total Cover (field)	17.26 (7.19)	20.21 (8.06)
Verde Limestone	Total Non-native Plant Cover (field)	2.58 (1.17)	0.49 (0.27)
	Ratio of Non-native Cover to Total Cover (field)	7.71 (3.67)	1.08 (0.59)

Overall Condition, Threats, and Data Gaps

We used six indicators and 14 measures (summarized in Table 48) to assess the condition of upland vegetation and soils at Montezuma Castle NM. Of the 14 measures, 10 were assigned a condition rating based on SODN's MAPs. Only two measures warranted significant/moderate concern (mature biological soil crusts and extent of non-native plants), while seven measures were considered in good condition. The ratio of annual plant cover to total plant cover, which is an indicator of fire hazard, was in good condition for the Verde Limestone stratum but warranted moderate/significant concern for the Terrace stratum. Measures with high confidence were given more weight in the overall condition rating than measures with medium or low confidence, and measures without a condition rating were not used to assess overall condition. In this assessment, all measures with a condition rating were assigned high confidence. Given that seven of 10 measures were in good condition, the overall condition for upland vegetation and soils at Montezuma Castle NM was considered good. According to McIntyre et al. (2014), vegetation in Montezuma Castle NM is within the range of natural variability. Confidence in the overall condition rating was high, but because only two sampling periods have occurred to date, trends could not be determined.

Landscapes in both monuments are naturally erosive, although the overall mapped area of accelerated erosion was low in both areas (Nauman 2010). Nevertheless, these particular sites have the potential be become degraded. While erosion is a natural process, it can adversely affect infrastructure and the cultural resources for which these monuments were established (Nauman 2010). In Tuzigoot NM erosion levels along the main ridge and in mesquite shrublands were higher than expected and may result in undercutting of walkways. Off-trail travel, however, is restricted in this area, which may help reduce erosion there (Nauman 2010). In the main unit of Montezuma Castle NM, the northeast fan was described as "caught in an intense accelerated erosional cycle" with most sediment eroding into Beaver Creek (Nauman 2010). Although there are some localized concerns at Montezuma Castle NM, measures of soil stability and bare ground cover suggest stable soils, but the

Table 48. Summary of upland vegetation and soils indicators, measures, and condition rationale.

Indicators	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Erosion Hazard	Bare Ground Cover		Bare ground cover averaged well below the 20% MAP in both strata. On average, bare soil cover was higher in Terrace plots (~9-11%) than in Verde Limestone plots (~5-7%).The condition is good. Confidence is high, but trend could not be determined based on only two rounds of surveys.
	Soil Aggregate Stability		Soil stability in both strata slightly exceeded class 3. Soils in class 3 are considered stable and meet the MAP for good condition. Confidence in the condition rating is high. Trend could not be determined based on two rounds of surveys.
	Mature Biological Soil Crust Cover (Verde Limestone)		In Verde Limestone plots, mature soil crusts averaged between 2.69% and 3.78%. Since mature soil crust cover was less than 10%, these results warrant moderate/ significant concern. Confidence is high. Trend is unknown.
Erosion Features	Estimated Soil Loss by Feature Type		In Montezuma Castle NM, rills and sheet erosion accounted for the majority (80-90%) of features mapped, but estimates of soil loss were greatest for gullies (55-78%). In Tuzigoot NM, rills and sheet erosion accounted for 88% of the features mapped, but gullies accounted for 58% of soil loss. Overall, 5% of Tuzigoot NM exhibited signs of active erosion, while 3-4% of Montezuma Castle NM exhibited signs of active erosion. Condition is unknown because reference conditions have not been established. Because condition is unknown, confidence is low. Trend could not determined.
	Extent of Area by Erosion Feature Type		Data for Terrace plots suggest relatively low erosion although two plots showed a slight increase in erosion from round 1, the degraded area in these two plots was only 2.5% during round 2. The estimated degraded area in Verde Limestone plots was greater than in Terrace plots. Sheet, rill, and gully erosion was estimated at 2.5% in only one plot during round 1, but during round 2 half of the plots exhibited evidence of active erosion. No reference conditions were established for this measure so the condition is unknown. Confidence is low because the condition is unknown. Trend could not be determined.
Site Resilience	Foliar Cover of Dead Perennial Plants (field)		Foliar cover of dead plants in the field layer did not exceed 7% for either strata, and most values were <3%. Since all measurements were less than the 15% MAP, the condition for this measure is good. Trend could not be determined. Confidence is high.
	Foliar Cover of Dead Perennial Plants (subcanopy)		Foliar cover of dead plants in the subcanopy did not exceed 1% in either strata. Since all measurements were less than the 15% management assessment point, the condition for this measure is good. Trend could not be determined. Confidence is high.
Fire Hazard	Grass and Forb Cover (field)		Grass and forb cover averaged less than the 30% MAP for both strata. Since percent cover was less than 30%, this measure of fire hazard is in good condition. Trend could not be determined. Confidence is high.
	Ratio of Annual Plant Cover to Total Plant Cover (field)	Terrace	In Terrace plots, the proportion of total cover represented by annuals averaged between ~20% and 27%. Therefore, the condition for this measure of fire hazard warrants moderate/significant concern in the Terrace stratum. Confidence is high. Trend is unknown.

Table 48 continued. ***Summary of upland vegetation and soils indicators, measures, and condition rationale.***

Indicators	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Fire Hazard *continued*	Ratio of Annual Plant Cover to Total Plant Cover (field)	Verde Limestone	The MAP of 25% was not exceeded in the Verde Limestone stratum. Therefore, this measure of fire hazard is good in the Limestone Verde stratum. Confidence is high. Trend is unknown.
Perennial Plant Community Composition and Structure	Cover for Common Species (all layers)		Eighteen perennial species or genera occurred in the Terrace stratum and 40 perennial species or genera occurred in the Verde Limestone stratum. All lifeforms except vines were represented. The greatest cover across lifeforms occurred in the field layer, while cover on the canopy layer was low in both strata. In Terrace plots, common shrubs included creosote bush, catclaw acacia, broom snakeweed, and fourwing saltbush. Velvet mesquite was the dominant and only tree species and bush muhly was the most common grass species. In Verde Limestone plots, common shrubs included crucifixion thorn, creosote bush, catclaw acacia, and mariola. The grass purple threeawn dominated the understory. No reference conditions were established for this measure so condition is unknown
	Frequency for Uncommon Species		An additional 22 species or general not observed along line transects were observed in subplots in the Terrace stratum. In the Verde Limestone stratum there were 40 additional species or genera. Only 3 species exhibited greater than 10% frequency in Terrace plots. In Verde Limestone plots, 16 species exhibited >10% frequency. No reference conditions were established for this measure so condition is unknown.
Non-native Plants	Extent		In the Terrace stratum, overall non-native plant extent was 100% during both sampling periods, but frequency varied by species. Red brome occurred in all plots during both sampling periods. In the Verde Limestone stratum, overall non-native plant extent averaged between 86% and 100%. As with the Terrace stratum, red brome was fairly widespread. Since overall extent for each stratum exceeded 50%, the condition warrants moderate/significant concern. Confidence is high. Trend is unknown.
	Total Cover (field)		Total non-native plant cover did not exceed the 10% MAP in the Terrace stratum, but during round 2 the non-native plant cover averaged 9.06, which is approaching the MAP. In the Verde Limestone stratum, total non-native plant cover was low at 2.58% during round 1 and only 0.49% during round 2. Because none of the measurements exceeded 10%, the condition is good. Confidence is high. Trend is unknown.
	Ratio of Non-native Plants to Total Plant Cover (field)		Overall, the proportion of total plant cover represented by non-native plants was well below the 25% MAP in the Verde Limestone stratum and was substantially lower during round 2 (1.08%) than during round 1 (7.71%). In the Terrace stratum, however, the proportion of total plant cover represented by non-native plants was higher with 17.26% cover represented by non-natives in round 1 and just over 20% in round 2. However, none of the values exceeded the 25% MAP. These results indicate good conditions for both strata. Trend could not be determined. Confidence is high.
Overall Condition	Summary of All Measures		Most measures indicate good conditions for upland vegetation and soils at Montezuma Castle NM, at least in the main unit. However, mature biological soil crust cover was low in the Verde Limestone stratum. Although a few non-native species appear widespread, their cover was generally low and only six non-native species were encountered across the two strata. The ratio of annuals to total plant cover suggest possible issues in the Terrace stratum. Confidence is high. Trend is unknown.

low cover of mature biological soil crusts indicates possible concerns.

While desert soils and biological soil crusts are well adapted to harsh environments, crusts are not well adapted to disturbances, especially compressional disturbances. Trampling by humans and livestock and vehicle tracks break apart crusts and inhibit ecological functions such as nitrogen fixation and soil stabilization (Hubbard et al. 2012). Disturbances in nearby areas can result in the transport of soil particles that can bury crusts; deep burial will kill crusts. Fire, invasive plants, and climate change can also negatively impact the biological soil crust community. The recovery of biological soil crusts from disturbance depends on factors such as the climatic regime and type of disturbance. Generally, crusts recover slowly in areas with high annual temperature and low annual precipitation (Belnap and Eldridge 2003 as cited in Hubbard et al. 2012).

The western U.S., and especially the Southwest, has experienced increasing temperatures and decreasing rainfall during the last 50 years (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). In an analysis of climate variables in Montezuma Castle NM, Monahan and Fisichelli (2014a) found that recent climate conditions in the monument indicate a shift from the natural range of variability toward higher temperatures and increased drought conditions. More intense rainstorms will influence patterns of erosion in the monument. Most erosion is caused by water, and more intense rainstorms may accelerate the deterioration of cultural resources (NPS 2016a).

Climate change will also influence the pattern and distribution of both native and non-native plants. Red brome has become well established at Montezuma Castle NM, although total non-native plant cover was relatively low. The five other non-native species in Montezuma Castle NM as recorded by SODN varied substantially in extent and some of them may not be well established. Alteration of fire patterns, precipitation, temperature, and other factors may influence the future extent and cover of non-native species at the monument. Red brome is particularly resilient to disturbances and can increase available fuels for wildfire (McIntyre et al. 2014). Historically, fire was rare in the thornbscrub biome, but non-native species encroachment coupled with climate change may change this pattern (Hubbard et al. 2012). Once established, invasive plants can be extremely difficult to control and most will never be completely eradicated (Mack et al. 2000).

Sources of Expertise

This assessment was written by science writer and wildlife biologist, Lisa Baril, Utah State University.

Riparian Vegetation

Background and Importance

Riparian habitat in the southwestern U.S. is a rare but critically important resource for birds, invertebrates, mammals, fish, and other wildlife (Poff et al. 2011). Many species depend on riparian vegetation, particularly on woody plants, for breeding, foraging, and during migration. Riparian plants also provide important ecosystem services by stabilizing streambanks and regulating stream temperature. Additional beneficial riparian attributes include erosion control, nutrient cycling, flood mitigation, increased groundwater recharge, and improved water quality, in part by buffering pollutants. If functioning properly, these attributes make riparian areas highly productive systems.

Over the last 100 years however, woody riparian habitat in the arid southwestern U.S. has declined as a result of agriculture, resource extraction, and development (Stromberg 2001). The National Park Service's (NPS) Sonoran Desert Inventory and Monitoring Network (SODN) surveys riparian vegetation in Montezuma Castle National Monument (NM) and Tuzigoot NM to better understand current condition and patterns of change over time (Gwilliam et al. 2013). Monitoring riparian vegetation is one aspect of SODN's comprehensive streams monitoring program, which also includes hydrology, stream channel morphology, water quality, and aquatic wildlife surveys (Gwilliam et al. 2018). These topics are addressed in separate assessments in this report.

In Tuzigoot NM 0.4 km (0.2 mi) of the Verde River flows through the monument, and in Montezuma Castle NM, a combined 6.9 km (4.3 mi) of stream flow through the monument's two units—the Castle unit and the Well unit (Gwilliam et al. 2013). Beaver Creek, a major tributary of the Verde River, flows through the Castle unit, and Wet Beaver Creek, a tributary of Beaver Creek, flows through the Well unit (Gwilliam et al. 2013). Deciduous woody riparian vegetation growing along the banks of the three stream reaches include Fremont cottonwood (*Populus fremontii*), Arizona sycamore (*Platanus wrightii*), velvet ash (*Fraxinus velutina*), and several species of willow (*Salix* spp.) (Gwilliam et al. 2013). The persistence of riparian vegetation is critical for maintaining ecosystem processes and supporting the wildlife that depend on this habitat type.

Data and Methods

This assessment is based on two indicators (loss of obligate wetland plants and non-native plant dispersal and invasion) with a total of three measures. Riparian vegetation was sampled in three vegetation zones along all three stream reaches in both monuments. The three zones are the aquatic, greenline, and the

Woody riparian plants growing along Wet Beaver Creek in Montezuma Castle NM's Well unit. Photo Credit: NPS.

riparian zone. The aquatic zone includes vegetation with roots embedded in the stream channel. The greenline includes "vegetation found in the first line of perennial vegetation from the stream wetted edge, usually within 10 m (33 ft)" (Gwilliam et al. 2013). The riparian zone "extends from the active river channel out to an indeterminate point where the transition to uplands is complete" (Gwilliam et al. 2013). Data for the aquatic zone were only available for one year at Beaver Creek. Therefore, we restricted this assessment to the greenline and riparian zone. All data except frequency data were provided by E. Gwilliam via email on 28 August 2018. Frequency data were provided by S. Studd via email on 27 February 2019.

Along the Verde River, vegetation was surveyed during July 2010 and June 2014. Twelve transects were established along the greenline, all of which were surveyed during both rounds of sampling. In the riparian zone, 31 transects were surveyed in 2010, and 10 of those transects were surveyed in 2014.

In Montezuma Castle NM's Castle unit (Beaver Creek), 22 transects were surveyed along the greenline during 2009 and 2014. In the riparian zone, 86 transects were surveyed in 2009, and 20 of those transects were surveyed in 2014. In Montezuma Castle NM's Well unit (Wet Beaver Creek), 14 transects were surveyed along the greenline during 2010, thirteen of which were surveyed in 2014. In the riparian zone, 39 transects were surveyed in 2010, 15 of which were surveyed in 2014.

For all three stream reaches, the sample size in the riparian zone was substantially reduced because "the initial round of surveys was oversampled" and the reduced number of samples during the second round was found to be sufficient (NPS, S. Studd, ecologist, comments to draft assessment, 29 January 2019).

Vegetation was surveyed in each zone using the point-intercept method (Gwilliam et al. 2018). Transects were 20-m (65.6-ft) long perpendicular to stream channel cross-sections (i.e., transects were parallel to the stream channel). Vegetation cover was measured using a fiberglass rod approximately 1.5 m × 8 mm (4.9 ft x 0.3 in) in diameter. Sampling occurred at 1.0 m (3.2 ft) intervals along the transect, starting at 1.0 m (3.2 ft) for a total of 20 sampling points. Vascular plants in contact with the rod were identified in each of three structural layers. The layers were as follows: herbaceous (1 cm–0.5 m [0.4 in–1.6 ft]), subcanopy (0.5–2 m [1.6–6.6 ft]) and canopy (>2 m [>6.6 ft]).

Richness and distribution is the single measure of loss of obligate wetland plants. Richness is the number of species that occur in a given area. The purpose of this measure is to determine the number of obligate wetland plants in each vegetation zone. Obligate wetland plants depend on near surface groundwater for growth, reproduction, and survival, and their presence can be a good indicator of stream health. In contrast, the loss of obligate wetland plants can illuminate issues on declining water tables and/or reduced streamflow. Changes in the lateral distribution of obligate wetland plants across stream vegetation zones help scientists determine changes in stream vegetation width and the amount of habitat available for obligate wetland species.

For each native 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 wetlands (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). Finally, we only included plants identified to species since species from the same genus may differ in wetland indicator status.

Percent frequency is one of two measures of non-native plant dispersal and invasion. The purpose of this measure is to determine the extent to which non-native species have invaded stream zones. Scientists can determine if non-native species are widespread throughout the stream channel or if species are concentrated within a particular zone. These data will help managers better address non-native species in both monuments. Frequency data were collected within a 2.0-m (6.6-ft) wide frequency plot, centered around the transect (1.0 m [3.2 ft] on either side except along greenline transects where the 2.0 m [6.6 ft] plots were all inland from the stream). Frequency is the presence of any non-native annual species that is rooted within the frequency plot but that was not already recorded during the point-intercept sampling. Although frequency data were collected in 2009/2010, they had not been checked for errors as of the writing of this assessment. Data for 2014, however, were available.

Percent cover (the second measure of non-native plant dispersal and invasion) complements the frequency measure. Cover informs how much ground surface area a particular species or group of species represents. A particular species may be widespread, as indicated by high frequency, but exhibit low cover. Or a species may exhibit low frequency but high cover, or even both high frequency and cover. Along with frequency, cover data can help managers prioritize which non-native species are in most need of control. Percent cover was calculated by summing the number of point-intercept "hits" for a particular taxon by structural layer and then dividing the number of hits by the number of total possible hits (n = 20 per transect).

Reference Conditions

Reference conditions are described for resources in good and moderate/significant concern conditions for each of the three measures (Table 49). Reference conditions were based on Management Assessment Points (MAPS) developed by SODN for Montezuma Castle NM and Tuzigoot NM (Gwilliam 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). The 95% confidence intervals for richness were calculated based on mean richness for obligate wetland taxa across plots within each zone.

Cattails at Tavasci Marsh in Tuzigoot NM. Photo Credit: NPS.

Condition and Trend

Unless otherwise noted, confidence in the condition rating is medium because the last round of sampling occurred five years ago. However, confidence in condition ratings was also influenced by differences in sample size between rounds for the riparian zone. No trends were identified for any of the measures because there have been only two rounds of sampling.

Table 49. Reference conditions used to assess riparian vegetation.

Indicators	Measures	Good	Moderate Concern/Significant Concern
Loss of Obligate Wetland Plants	Richness and Distribution	Within baseline 95% confidence interval for wetland obligate taxa richness and distribution.	Outside baseline 95% confidence interval for wetland obligate taxa richness and distribution.
Non-native Plant Dispersal and Invasion	Percent Frequency	≤ 50% of sample sites	> 50% of sample sites
	Percent Cover	% total plant cover is ≤ 10% non-native in any structural layer.	% total plant cover is >10% non-native in any structural layer.

Source: Gwilliam et al. (2014).

Thirty-nine native species were documented along the Verde River during the two rounds of sampling (refer to Appendix B for a complete list of native species), four of which are considered obligate wetland species (Table 50). All four species were encountered in both zones during at least one of the sample rounds. Mean species richness for obligate wetland taxa was greater along the greenline than in the riparian zone but was still relatively low in both zones. Because obligate wetland species were generally rare, the 95% baseline confidence interval for 2010 was wide and included the mean richness for the second round of sampling in each zone. Although this indicates good condition for richness and distribution, confidence is low because 1) 2010 may not accurately reflect baseline conditions; 2) sampling effort between rounds was substantially greater for the riparian zone during round 1 than during round 2; and 3) because the confidence intervals for round 1 were large relative to the means.

At Montezuma Castle NM, a total of 82 native species (Appendix B) were encountered along Beaver Creek, eight of which are obligate wetland species (Table 51). All eight obligate wetland species occurred along the greenline, while only two occurred in the riparian zone. Average richness was higher in both zones during round 2 but was still low overall. The means for both zones during round 2 were greater than the upper confidence level for the baseline condition in 2010.

Along Wet Beaver Creek, a total of 56 native species were encountered (Appendix B), including only three obligate wetland species (Table 52). All three species were present along the greenline during round 2 but none were recorded during round 1. As a result, mean richness was greater during round 2 than during round 1. For the riparian zone, only one obligate species was present, and this species was recorded during round 2 only.

These results indicate good condition for richness and distribution at both streams in Montezuma Castle NM. Although these data indicate good condition, confidence is low because 1) 2009/2010 may not accurately reflect baseline conditions; 2) sampling effort between rounds was substantially greater for the riparian zone during round 1 than during round 2; and 3) because the confidence intervals for round 1 were large relative to the means at Beaver Creek.

Table 50. Obligate wetland species by zone and year along the Verde River in Tuzigoot NM.

Species	Common Name	Greenline		Riparian	
		2010 (*n* = 12)	2014 (*n* = 12)	2010 (*n* = 31)	2014 (*n* = 10)
Carex senta	Swamp carex	X	X	X	–
Hydrocotyle verticillata	Whorled marshpennywort	–	X	X	–
Schoenoplectus americanus	Chairmaker's bulrush	X	X	X	–
Typha domingensis	Southern cattail	X	X	X	–
Mean Richness (95% Confidence Interval)		1.2 (0.60)	1.4 (0.6)	0.2 (0.21)	0 (0)

Note: X = species present.

Table 51. Obligate wetland species by zone and year along Beaver Creek in Montezuma Castle NM.

Species	Common Name	Greenline		Riparian	
		2009 (*n* = 22)	2014 (*n* = 22)	2009 (*n* = 86)	2014 (*n* = 20)
Bidens laevis	Smooth beggartick	X	–	–	–
Carex aquatilis	Water sedge	X	–	X	–
Carex senta	Swamp carex	–	X	–	–
Eleocharis palustris	Common spikerush	–	X	–	X
Hydrocotyle verticillata	Whorled marshpennywort	X	X	–	–
Leersia oryzoides	Rice cutgrass	–	X	–	–
Typha domingensis	Southern cattail	–	X	–	–
Typha latifolia	Broadleaf cattail	–	X	–	–
Mean Richness (95% Confidence Interval)		0.2 (0.22)	0.7 (0.44)	0.01 (0.02)	0.05 (0.10)

Note: X = species present.

Table 52. Obligate wetland species by zone and year along Wet Beaver Creek in Montezuma Castle NM.

Species	Common Name	Greenline		Riparian	
		2010 (n = 14)	2014 (n = 13)	2010 (n = 39)	2014 (n = 15)
Carex senta	Swamp carex	–	X	–	–
Juncus xiphiodes	Irisleaf rush	–	X	–	X
Typha domingensis	Southern cattail	–	X	–	–
Mean Richness (95% Confidence Interval)		0 (0)	0.8 (0.33)	0 (0)	0.1 (0.14)

Note: X = species present.

Overall, the apparent rarity of obligate wetland plants along all three stream reaches across both monuments suggests that more intensive sampling may be required to adequately survey these species.

Twenty-two non-native species were documented along the Verde River during 2014—15 species along the greenline and 14 species in the riparian zone (Table 53). Frequency averaged 67% in the greenline zone (8 of 12 plots) and 90% (9 of 10 plots) in the riparian zone. Because average frequency exceeded 50% in both the greenline and the riparian zone, the condition warrants moderate/significant concern.

At Montezuma Castle NM, thirty-two non-native species were documented at Beaver Creek—24 species along the greenline and 20 species in the riparian zone (Table 54). At least one non-native species occurred in 20 of the 22 frequency plots in the greenline (91% frequency). In the riparian zone, at least one non-native species was encountered in 16 of 20 plots (80% frequency). Frequency by species varied, but did not exceed 35% in either zone. Along Wet Beaver Creek, twenty-one non-native species were encountered—16 species along the greenline and 10 species in the riparian zone (Table 55). Along the greenline, 85% of plots contained at least one

Table 53. Non-native plant frequency by zone along the Verde River in Tuzigoot NM during 2014.

Species	Common Name	Greenline (%) (n = 12)	Riparian (%) (n = 10)
Agrostis stolonifera	Creeping bentgrass	8	–
Ailanthus altissima	Tree of heaven	–	20
Bromus diandrus	Ripgut brome	17	30
Bromus japonicus	Field brome	33	30
Bromus rubens	Red brome	8	40
Bromus tectorum	Cheatgrass	8	10
Cynodon dactylon	Bermudagrass	25	–
Eragrostis lehmanniana	Lehmann lovegrass	–	30
Hordeum murinum	Barley	–	10
Kochia scoparia	Burningbush	–	10
Lactuca serriola	Prickly lettuce	8	10
Lotus corniculatus	Bird's-foot-trefoil	8	–
Mathiola longipetala	Night-scented stock	–	10
Melilotus alba	Sweetclover	8	30
Paspalum dilatatum	Dallisgrass	8	–
Plantago lanceolata	Narrowleaf plantain	17	–
Plantago major	Common plantain	25	–
Polypogon monspeliensis	Annual rabbitsfoot grass	25	10
Salsola tragus	Prickly Russian thistle	–	10
Sonchus asper	Spiny sowthistle	25	–
Tamarix ramosissima	Saltcedar	17	–
Verbascum thapsus	Common mullein	–	20

Table 54. Non-native plant frequency by zone along Beaver Creek in Montezuma Castle NM in 2014.

Species	Common Name	Greenline (%) (n = 22)	Riparian (%) (n = 20)
Ailanthus altissima	Tree of heaven	5	–
Avena fatua	Wild oat	–	5
Bromus diandrus	Ripgut brome	14	15
Bromus japonicus	Field brome	18	5
Bromus rubens	Red brome	–	20
Bromus tectorum	Cheatgrass	32	35
Centaurea melitensis	Maltese star-thistle	–	5
Cirsium vulgare	Bull thistle	5	–
Cynodon dactylon	Bermudagrass	23	–
Eragrostis curvula	Weeping lovegrass	–	5
Eragrostis lehmanniana	Lehmann lovegrass	–	5
Erodium cicutarium	Redstem stork's bill	–	5
Hordeum murinum	Mouse barley	5	5
Kochia scoparia	Burningbush	5	–
Lactuca serriola	Prickly lettuce	5	15
Linaria dalmatica	Dalmatian toadflax	–	5
Lolium perenne	Perennial ryegrass	5	–
Lotus corniculatus	Bird's-foot trefoil	14	–
Marrubium vulgare	Horehound	5	–
Melilotus alba	Sweetclover	32	15
Melilotus officinalis	Sweetclover	27	5
Nasturtium officinale	Watercress	5	–
Plantago major	Common plantain	5	–
Polypogon monspeliensis	Annual rabbitsfoot grass	18	10
Polypogon viridis	Beardless rabbitsfoot grass	5	5
Rumex crispus	Curly dock	5	–
Salsola tragus	Prickly Russian thistle	9	25
Sisymbrium altissimum	Tall tumblemustard	5	5
Sonchus asper	Spiny sowthistle	14	–
Sorghum halepense	Johnsongrass	23	10
Tamarix ramosissima	Saltcedar	5	–
Tragopogon dubius	Yellow salsify	–	5

non-native species (11 of 13 plots). In the riparian zone, 60% of plots (9 of 15 plots) contained at least one non-native species. These results indicate moderate/significant concern condition for both stream reaches.

Along the Verde River at Tuzigoot NM, percent total cover by vegetation layer was higher along the greenline than in the riparian zone during both rounds of sampling (Table 56). Non-native species cover declined with increasing vegetation height, indicating that most non-native species are short-statured grasses and forbs. Non-native cover exceeded 10% in the herbaceous layer only in both zones during 2010. In 2014, non-native cover more than doubled along the greenline's herbaceous layer and averaged 26% in the subcanopy. In the riparian zone, non-native species cover remained about the same during both rounds of sampling. Since non-native cover exceeded 10% in the herbaceous layer during both rounds and in both zones, including the greenline's subcanopy in 2014, the condition warrants moderate/significant concern.

As with the Verde River, total cover by layer was generally higher along the greenline than in the riparian zone at Beaver Creek in Montezuma Castle NM (Table

Table 55. Non-native plant frequency by zone along Wet Beaver Creek in Montezuma Castle NM in 2014.

Species	Common Name	% Frequency (SE)	
		Greenline (n = 13)	Riparian (n = 15)
Agrostis stolinifera	Creeping bentgrass	15	–
Bromus diandrus	Ripgut brome	31	7
Bromus japonicus	Field brome	15	7
Bromus rubens	Red brome	31	13
Bromus tectorum	Cheatgrass	–	7
Cynodon dactylon	Bermudagrass	8	–
Dactylis glomerata	Orchardgrass	–	7
Eragrostis lehmanniana	Lehmann lovegrass	–	7
Linaria dalmatica	Dalmatian toadflax	–	7
Marrubium vulgare	Horehound	–	13
Melilotus alba	Sweetclover	46	7
Melilotus officinalis	Sweetclover	15	7
Mentha spicata	Spearmint	15	–
Myriophyllum spicatum	Eurasian watermilfoil	15	–
Nasturtium officinale	Watercress	8	–
Paspalum dilatatum	Dallisgrass	15	–
Persicaria maculosa	Spotted ladysthumb	15	–
Polypogon monspeliensis	Annual rabbitsfoot grass	15	–
Rubus discolor	Himalayan blackberry	8	–
Sonchus asper	Spiny sowthistle	8	–
Sorghum halepense	Johnsongrass	31	–

Table 56. Percent total cover and cover of non-native species by zone, layer, and year along the Verde River in Tuzigoot NM.

Zone	Layer	2010		2014	
		% Total Cover (SE)	% Non-native Cover (SE)	% Total Cover (SE)	% Non-native Cover (SE)
Greenline	Herbaceous	70 (7.6)	12 (4.9)	68 (8.9)	28 (1.0)
	Subcanopy	52 (4.1)	5 (2.3)	62 (7.4)	26 (8.1)
	Canopy	40 (5.6)	0 (0)	60 (7.0)	0 (0)
Riparian	Herbaceous	29 (4.6)	12 (2.7)	26 (4.1)	10 (3.9)
	Subcanopy	16 (2.7)	1 (0.6)	26 (5.9)	3 (2.5)
	Canopy	31 (5.5)	0 (0)	27 (7.6)	0 (0)

57). Cover was also higher during round 2 than during round 1, especially for the herbaceous and subcanopy layers. In the greenline non-native plant cover averaged about 30% in the herbaceous layer during both time periods. In the subcanopy, non-native plant cover averaged between 9% and 11%. In the riparian zone, non-native plant cover averaged 22% and 34% in the herbaceous layer during 2010 and 2014, respectively. At Wet Beaver Creek, total cover was generally higher along the greenline than in the riparian zone (Table 58). Furthermore, cover was greater during round 2 than during round 1. Non-native cover exceeded 10% in the herbaceous layer of both zones during both time periods except for the greenline in 2014. In 2010, non-native cover along the greenline's subcanopy also exceeded 10%. These results warrant moderate/significant concern at Montezuma Castle NM.

Overall Condition, Threats, and Data Gaps

We used two indicators and three measures (summarized in Table 59) to assess the condition of riparian vegetation along the Verde River, Beaver

Table 57. Percent total cover and cover of non-native species by zone, layer, and year along Beaver Creek in Montezuma Castle NM.

Zone	Layer	2009		2014	
		% Total Cover (SE)	% Non-native Cover (SE)	% Total Cover (SE)	% Non-native Cover (SE)
Greenline	Herbaceous	51 (4.9)	30 (4.7)	74 (3.6)	29 (5.4)
	Subcanopy	39 (4.9)	9 (2.7)	58 (4.9)	11 (2.6)
	Canopy	33 (6.2)	1.6 (1.6)	30 (6.7)	0.2 (0.2)
Riparian	Herbaceous	41 (3.0)	22 (2.7)	48 (5.4)	34 (6.6)
	Subcanopy	27 (2.4)	2 (1.0)	37 (4.2)	2 (1.1)
	Canopy	35 (3.6)	0 (0)	36 (7.0)	0 (0)

Table 58. Percent total cover and cover of non-native species by zone, layer, and year along Wet Beaver Creek in Montezuma Castle NM.

Zone	Layer	2010		2014	
		% Total Cover (SE)	% Non-native Cover (SE)	% Total Cover (SE)	% Non-native Cover (SE)
Greenline	Herbaceous	48 (7.8)	31 (7.8)	61 (6.1)	9 (3.2)
	Subcanopy	41 (5.1)	11 (4.0)	52 (7.5)	6 (2.3)
	Canopy	56 (9.6)	0 (0)	72 (8.0)	0 (0)
Riparian	Herbaceous	38 (4.1)	17 (4.2)	55 (4.9)	19 (5.4)
	Subcanopy	20 (3.2)	1 (0.7)	28 (4.3)	1 (0.5)
	Canopy	48 (5.7)	1 (0.5)	42 (8.8)	0 (0)

Creek, and Wet Beaver Creek. Measures with high confidence were given more weight in the overall condition rating than measures with medium or low confidence. Based on these criteria, the overall condition warrants moderate/significant concern. Although the measure of richness and distribution of obligate wetland species does not indicate loss over time for any of the three stream reaches, the confidence in the condition rating was low because a baseline condition is unknown. Furthermore, obligate wetland taxa were rare, and rare species may require more targeted sampling efforts. The two measures of non-native plants indicate moderate/significant concern. Not only was overall frequency high, but cover in the herbaceous layer and even the subcanopy exceeded 10% for all three stream reaches. Confidence in the overall condition rating is medium because data were collected five years ago and because sample sizes were lower during round 2 than during round 1. The third round of sampling is scheduled for spring/summer 2019. Trends could not be determined based on only two rounds of sampling. A key uncertainty is whether the transects captured all species (native and non-native) present.

A key driver to the persistence of riparian vegetation is access to groundwater. In the groundwater assessment in this report, depth to groundwater indicated insufficient conditions for seedling recruitment or for maintaining mature cottonwood and willow trees (Stromberg 2013). Furthermore, trends in groundwater have deteriorated over time. The three stream reaches, however, remain perennial. The Verde River is one of the last remaining perennial rivers in Arizona, but some reaches have been losing base flows and are at risk of becoming intermittent (Pawlowski 2013). For example, the cottonwood/mesquite (*Prosopis velutina*) woodland vegetation type mapped along the Verde River in 1993-1995 indicate a past hydrologic regime that supported cottonwood species and a current hydrologic regime that favors upland species such as mesquite (Rosenberg et al. 1995). While woody riparian plants have persisted in both monuments (Gwilliam et al. 2013), prolonged drought stress may eventually cause mortality if groundwater levels do not improve. Alternatively, regular flooding of the riparian zone as a result of surface flows could be enough to maintain riparian woody species.

Two of the greatest threats to riparian vegetation are the introduction and colonization of non-native species

Table 59. Summary of riparian vegetation indicators, measures, and condition rationale.

Indicators	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Loss of Obligate Wetland Plants	Richness and Distribution		Richness of obligate wetland species was generally higher during round two than during round 1, but there were few obligate wetland species overall. The greatest richness of obligate wetland species occurred along Beaver Creek (8), but only three obligate wetland species occurred along Wet Beaver Creek and four along the Verde River. We used 2009/2010 as the baseline condition, and although the results suggest good condition, confidence is low because loss of obligate wetland species may have and probably had occurred prior to the first round of sampling and because many more transects were surveyed in the riparian zone during round 1. Trend could not be determined.
Non-native Plant Dispersal and Invasion	Percent Frequency		Along the greenline and in the riparian zone for all three stream reaches, frequency averaged well above 50%. Frequency averaged 67% along the Verde River, 91% along Beaver Creek, and 85% along Wet Beaver Creek. Frequency in the riparian zone during averaged 90% along the Verde River, 80% along Beaver Creek, and 60% along Wet Beaver Creek.
	Percent Cover		In general, percent cover of non-native species exceeded 10% in the herbaceous layer of both vegetation zones during one or both years of sampling. Non-native cover also occasionally exceeded 10% in the subcanopy. These results warrant moderate/significant concern, but since data were last collected five years ago, confidence in the condition rating is medium. Trend could not be determined based on two years of data.
Overall Condition	Summary of All Measures		Although richness and distribution of obligate wetland species suggests good condition, confidence is low. Therefore, this measure was weighted less in the overall condition rating. The high frequency and cover of non-native species along all three stream reaches warrant moderate/significant concern. Data were collected five years ago so overall confidence in the condition rating is medium, but round three of sampling is scheduled for 2019.

and climate change. The duration and frequency of droughts are likely to increase as the climate continues to warm. The western U.S., and especially the Southwest, has experienced increasing temperatures and decreasing rainfall during the last 50 years (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). Warmer temperatures could reduce the amount of soil moisture available for plants in addition to increasing rates of evapotranspiration. Drier conditions may promote the introduction and spread of non-native species. Once established, they are often extremely difficult to control and most will never be completely eradicated, particularly grasses (Mack et al. 2000). Air quality is another concern for some wetland plants. At both monuments, ozone levels, as they relate to vegetation, warrant significant concern (NPS ARD 2017b). Three facultative wetland species found across the two monuments are ozone-sensitive (Fremont cottonwood, narrowleaf willow (*Salix exigua*), and Goodding's willow (*Salix gooddingii*)) (Bell, In Review).

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 for Montezuma Castle and Tuzigoot National Monuments (NMs) (Beaupré et al. (2013). In the bird monitoring protocol for the Sonoran Desert Network (SODN) and other Inventory and Monitoring 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).

Data and Methods

This assessment focuses on desert scrub upland and riparian monitoring efforts in Montezuma Castle NM and Tuzigoot NM as well as previous inventory and monitoring efforts conducted by park staff, including hummingbird surveys in Montezuma Castle NM, marsh bird surveys in Tuzigoot NM, and surveys for species listed under the Endangered Species Act by the U.S. Fish and Wildlife Service (USFWS 2017). We used one indicator (species occurrence) with two measures (richness and composition, and presence of species of concern) to assess birds in both monuments. For brevity, scientific names for species listed in tables are provided in Appendices C and D.

Photo of a Gambel's quail, a species that breeds in both Montezuma Castle NM and Tuzigoot NM. Photo Credit: © Robert Shantz.

NPSpecies (NPS 2017a,b) served as our foundation list of birds for both monuments. NPSpecies relies on previously published surveys, such as those included in this assessment, and expert opinion. Because NPSpecies may not be updated with the most current surveys, we cross-referenced these lists with SODN's data. Any species reported by SODN that were not reported by NPSpecies were added to the final species list in Appendices C and D.

Richness and composition are measures of community dynamics and are important for assessing changes occurring within bird communities and for determining how individual species respond to changing landscapes (Beaupré et al. 2013). Richness is simply the total number of species in a given area while species composition is the proportion of each species in the community. We considered richness and composition together because richness alone provides limited information about biodiversity. Richness coupled with species composition however, captures both the number of species and the how those species may shift over time (Hillebrand et al. 2018). We compared species richness and composition between two time periods for each monument using the surveys described below.

During the early 2000s, Schmidt et al. (2005) surveyed birds in Tuzigoot NM using a variety of methods designed to document nocturnal, resident, and breeding species. Because SODN monitoring efforts focused on the breeding season, we restricted our comparison to breeding season survey data presented in Schmidt et al. (2005). Schmidt et al. (2005) used the Variable Circular Plot (VCP) method to survey breeding birds along two transects from mid-April through early July of 2003 and 2004. Each transect (one riparian and one upland) included seven point count stations, which were spaced a minimum of 250 m (820 ft) apart. Each point was surveyed for eight minutes, and each point was visited six times each year. Flyovers and birds beyond 75 m (246 ft) from each point count station were excluded from the analysis. We reported species richness by year and habitat type as well as a list of the 20 most commonly detected species over both survey years as a percentage of total detections.

Similar inventory data were not available for Montezuma Castle NM (Schmidt et al. 2006). Instead, we relied on a historical assessment of bird community changes from 1916 to 2009, which included SODN surveys from 2007 to 2009 (Palacios 2013). Comparisons over time were based on presence/absence (Palacios 2013). There was a large break in data between 1963 and 2007, which was used as a threshold for the disappearance of a species in the monument, if it occurred (Palacios 2013). The author compared species occurrence during 1916-1963 to species occurrence post-1963.

SODN conducted bird surveys in both desert scrub and riparian habitat in both monuments from 2007 to 2013 and in 2015 (see Beaupré et al. 2013 for survey location maps). In Tuzigoot NM, birds were surveyed along one transect situated along the Verde River and in Tavasci Marsh as well as along one desert scrub transect. These transects were located in the same areas as the inventory surveys (Schmidt et al. 2005). In Montezuma Castle NM, riparian habitat was surveyed along Beaver Creek in the Castle unit (two transects) and Wet Beaver Creek in the Well unit (one transect). In addition, one desert scrub transect was surveyed in the Castle unit. Between six and eight points were located along each transect in both monuments. Although the number of visits and timing of surveys varied, each point was generally surveyed twice annually between May and June (Beaupré et al. 2013). Throughout the survey some transects were discontinued or replaced. For both monuments, we reported species richness by year as well as a list of the 20 most commonly detected species over all survey years as a percentage of total detections. SODN data were provided by K. Bonebrake, SODN data manager on 16 November 2017 via e-mail.

SODN's protocol was similar to the VCP method described for Tuzigoot NM in that points were spaced 250 m (820 ft) apart, flyovers were eliminated, and birds beyond 75 m (246 ft) from each point count station were excluded (Schmidt et al. 2005). However, there were some differences in data collection methods. Each point was generally surveyed twice by SODN (vs. 6 visits during VCP surveys), counts lasted for six minutes during SODN surveys (vs. 8 minutes for VCP surveys), and SODN surveys were conducted during May and June (vs. mid-April to early July during VCP surveys) (Beaupré et al. 2013). Despite these differences, a comparison between the two studies is useful, especially considering that we only compare richness and composition and not abundance.

Finally, we compared overall richness between the two studies at each monument. We also compared differences in species composition by determining which species were detected during the earlier study but not during the later study. Ideally, we would have longer-term historic data with which to compare species occurrence over time, especially for Tuzigoot NM, but these data were not available. Nevertheless, the comparison used here provides a coarse assessment of persistence and serves as a baseline for which to compare to future studies.

For the second measure (presence of species of concern), we cross-referenced the Arizona Partners in Flight (AZ-PIF) Bird Conservation Plan list of priority species of concern (Latta et al. 1999) with the NPSpecies lists for each monument (NPS 2017a,b) and with SODN monitoring data. In the Bird Conservation Plan, 43 species of concern were identified for the state (Latta et al. 1999). The list was 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 then compared these subset lists to SODN survey data to determine the proportion of species of concern that have been observed relatively recently (i.e., 2007-2015). Because SODN surveys occurred during the breeding season, we determined the proportion using only those species identified as breeding in or resident to the monuments. However, we list all species of concern known to occur in each monument for reference. We also included data from species-specific surveys that were conducted in one or both monuments. These surveys are described below.

Targeted surveys for the endangered southwestern willow flycatcher (*Empidonax traillii extimus*) and the threatened yellow-billed cuckoo (*Coccyzus americanus*) (USFWS 2017) were conducted at both monuments during 2016 and 2017 (data were provided by T. Greenawalt, Chief of Natural Resources, via e-mail on 8 November 2017). Due to the sensitive nature of these species, we included presence/absence information but not information on location.

Ridgway's rail (*Rallus obsoletus*) is listed as endangered by the U.S. Fish and Wildlife Service's Endangered Species Program (USFWS 2017). Surveys for Ridgway's rails and other birds at Tavasci Marsh were conducted during April and May of 2008-2011 and 2015-2017. Four stations were surveyed, each with a five-minute period of passive listening followed by playback calls of Ridgway's rail, least bittern (*Ixobrychus exilis*), sora (*Porzana carolina*), Virginia rail (*Rallus limicola*), and American bittern (*Botaurus lentiginosus*) using standardized North American marsh bird monitoring protocols (Conway 2008, Supplee 2013). Calls were played for 30 seconds followed by 30 seconds of passive listening for each species. From 2008 to 2011 these surveys were conducted by the Arizona Audubon Society and from 2015 to 2017, surveys were conducted by natural resources staff at Tuzigoot NM. The survey is part of a statewide effort coordinated by the Arizona Department of Game and Fish (Supplee 2013) but is no longer conducted for Ridgway's rail. Data were provided by T. Greenawalt, Chief of Natural Resources, on 8 November 2017 via e-mail.

In cooperation with The Hummingbird Monitoring Network (2016), natural resources staff captured and banded hummingbirds in Montezuma Castle NM's Castle unit on 10 days during April to September 2016 and 10 days during May to September 2017 (data provided by T. Greenawalt, Chief of Natural Resources, on 8 November 2017 via e-mail). Data were summarized by the number of each species banded by year.

Reference Conditions

Reference conditions for the two measures are shown in Table 60. Reference conditions are described for resources in good, moderate concern, and significant concern conditions.

Condition and Trend

The following summarizes NPSpecies and the two studies used to assess species richness and composition at Tuzigoot NM. According to NPSpecies, 207 species are confirmed for the monument (NPS 2017a). An additional 55 species are unconfirmed (55) (i.e., species attributed to the park but evidence is weak or absent), or were reported by SODN but not listed in NPSpecies (1) (Appendix C). Swamp sparrow (*Melospiza georgiana*) was the only additional species reported by SODN. In total, there may be as many as 263 species that occur in the monument's 149 ha (373 ac) area, including unconfirmed species and those considered probably present. The high richness is remarkable given the monument's small size. However, four of the 208 confirmed species (including species listed by SODN but not NPSpecies) are non-native. The non-native species are Eurasian collared-dove

Table 60. Reference conditions used to assess birds.

Indicator	Measures	Good	Moderate Concern	Significant Concern
Species Occurrence	Richness and Composition	A majority (>75%) of the species recorded during early surveys/observations in the park were recorded by SODN.	A moderate number (>50% but <75%) of bird species recorded during early surveys were recorded by SODN (with emphasis on species previously considered common).	Fewer than 50% of species recorded during early surveys were recorded by SODN (with emphasis on species previously considered common).
	Presence of Species of Concern	A majority (>75%) of species of concern expected to occur in each monument have been reported by recent surveys or observations.	A moderate number (>50% but <75%) of species of concern expected to occur in each monument have been reported by recent surveys or observations.	Few (<50%) species of concern expected to occur in each monument have been reported by recent surveys or observations.

(*Streptopelia decaocto*), European starling (*Sturnus vulgaris*), house sparrow (*Passer domesticus*), and rock pigeon (*Columba livia*).

During the 2003 and 2004 inventory surveys at Tuzigoot NM, a total of 73 species were observed between riparian (62) and desert scrub (58) habitat. Richness was similar in both years, while richness in riparian habitat was higher in 2003 (55) than in 2004 (43) (Figure 27). No non-native species were reported in either habitat. Although no non-native species were among the top 20, brown-headed cowbirds (*Molthrus ater*), a brood parasite, represented 3.8% of all detections in each habitat type. Among the 20 most commonly detected species in riparian habitat were red-winged blackbird (*Agelaius phoeniceus*), phainopepla (*Phainopepla nitens*), common yellowthroat (*Geothlypis trichas*), and mourning dove (*Zenaida macroura*) (Table 61). Common yellowthroat, song sparrow (*Melospiza melodia*), yellow-breasted chat (*Icteria virens*), Abert's towhee (*Melozone aberti*), and yellow warbler (*Setophaga petechia*) were the four species among the top 20 that are considered riparian obligates, or species that require riparian habitat for breeding (Tweit et al. 1994, Guzy and Ritchison 1999, Lowther et al. 1999, Eckerle and Thompson 2001, and Arcese et al. 2002). In addition, common gallinule (*Gallinula galeata*) (formerly common moorhen)

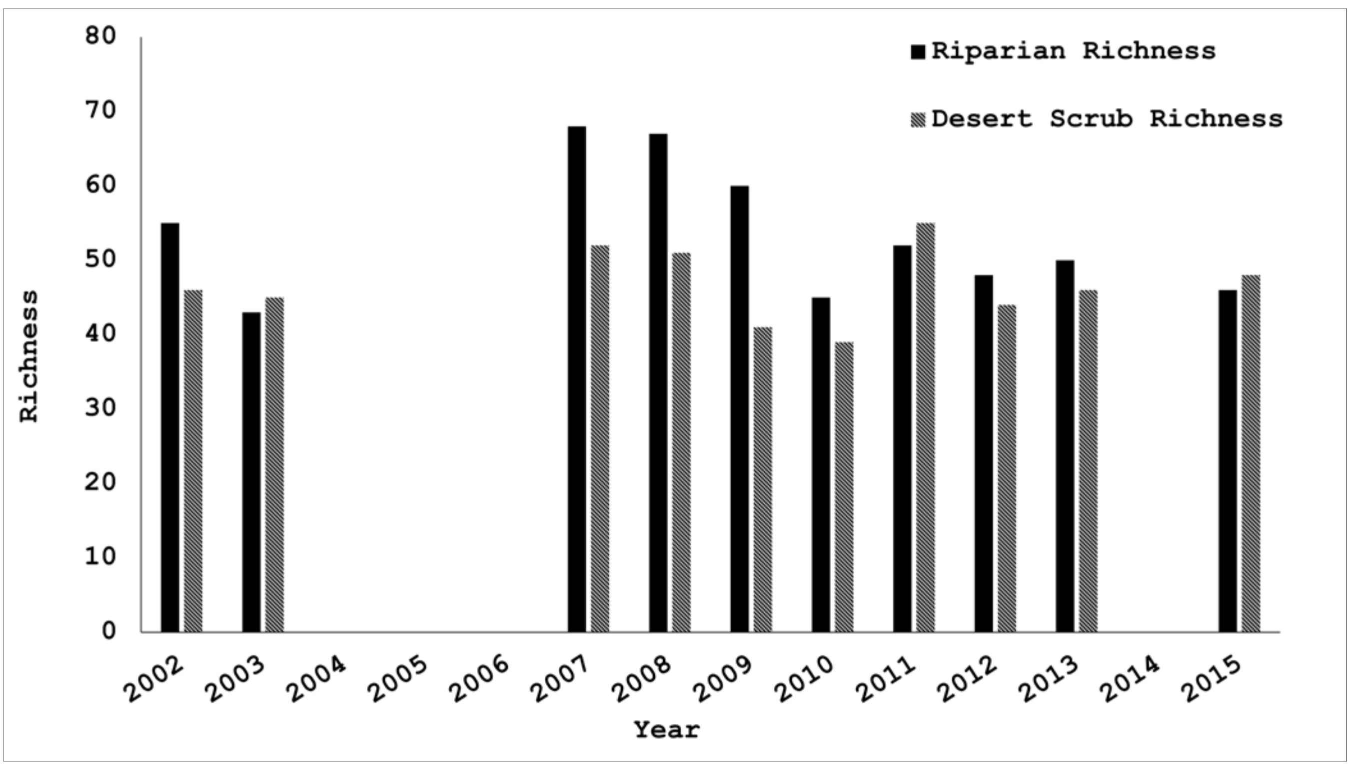


Figure 27. Richness by year and habitat type in Tuzigoot NM.

Table 61. The 20 most commonly detected species by habitat during surveys at Tuzigoot NM as a proportion of all detections.

Species	Riparian (%)		Desert Scrub (%)	
	2003-2004	2007-2015	2003-2004	2007-2015
Abert's towhee*	3.6	2.9	3.0	–
Ash-throated flycatcher	2.0	2.4	1.9	2.5
Bewick's wren	3.9	3.1	2.6	1.5
Black-chinned hummingbird	–	–	2.3	–
Black-throated sparrow	–	–	–	1.7
Blue grosbeak	2.0	1.5	1.4	1.9
Brown-crested flycatcher	–	3.9	–	1.8
Brown-headed cowbird	3.8	2.9	3.8	2.5
Bullock's oriole	2.7	–	1.9	2.6
Bushtit	–	–	1.4	–
Cassin's kingbird	–	–	1.9	1.5
Common gallinule*	1.1	–	5.7	4.9
Common yellowthroat*	7.4	5.6	–	–
Gambel's quail	5.3	3.0	20.7	7.8
Gila woodpecker	2.3	3.5	2.3	1.8
House finch	3.1	2.7	4.7	7.1
Lesser goldfinch	–	–	1.5	1.7
Lucy's warbler	2.9	4.2	–	3.5
Mourning dove	7.0	7.0	5.4	9.4
Northern cardinal	2.7	1.8	1.5	–
Northern mockingbird	–	–	1.9	2.2
Northern rough-winged swallow	–	2.8	–	–
Phainopepla	7.4	7.1	7.7	6.6
Red-winged blackbird	10.4	13.4	7.8	13.5
Song sparrow*	7.0	3.5	–	–
Sora	–	–	1.4	–
Summer tanager	2.3	2.1	–	1.3
Western kingbird	1.1	–	2.2	–
Yellow-breasted chat*	4.4	4.9	–	2.3
Yellow warbler*	1.2	2.8	–	–

* Riparian obligates (Tweit et al. 1994, Guzy and Ritchison 1999, Lowther et al. 1999, Eckerle and Thompson 2001, Arcese et al. 2002, Bannor and Kiviat 2002).

requires wetlands for breeding (Bannor and Kiviat 2002). In uplands, Gambel's quail (*Callipepla gambelii*), red-winged blackbird, phainopepla, and common yellowthroat were among the top 20 species observed (Table 61). The top 20 species accounted for 81.4% (82.7% including one additional species tied for the 20th spot) in uplands. In riparian habitat, the top 20 species accounted for 82.5% (83.6% including the one additional species tied for the 20th spot).

During SODN's 2007-2015 surveys at Tuzigoot NM, 125 species have been documented in riparian (110) and desert scrub (95) habitat across all years. During most years species richness and abundance was greater in riparian habitat than in desert scrub (Figure 27). Annual richness averaged 55 species in riparian habitat and 47 species in desert scrub. The 20 most commonly detected species along riparian transects comprised 80% of all detections across all years of surveys (Table 61). Red-winged blackbird, phainopepla, mourning dove, and common yellowthroat were among the most commonly observed species. All five of the riparian obligate species mentioned above were also among the top 20 during SODN's surveys. In desert scrub, red-winged blackbird, mourning dove, Gambel's quail, and house finch (*Haemorhous mexicanus*) were among the top 20 species detected. The top 20 species accounted for 78% of all observations in desert scrub habitat. Similar to the inventory surveys, no non-native species were among the top 20, but brown-headed cowbirds comprised 2.9% and 2.5% of all observations in riparian and desert scrub habitat, respectively, which is slightly lower than that reported for the earlier study.

In desert scrub habitat average richness was similar during 2003-2004 (46) to 2009-2015 (47). Annual richness fluctuated over time with between 39 species in 2010 to 55 species in 2011. Overall richness was nearly double during SODN surveys (95 species) than during the inventory (58), but this is not surprising since SODN surveys occurred over a longer time period (eight years vs. two years). Of the 99 species reported during both survey efforts combined, four were only reported during 2003-2004 and 41 were only reported during 2007-2015. More than half (54 species) of all species were reported during both studies. When considering only the top 20 species, 15 species were among the top 20 in both studies (Table 61). The four species not reported by SODN were Bell's vireo (*Vireo bellii*), common grackle (*Quiscalus quiscula*), Lincoln's sparrow (*Melospiza lincolnii*), and peregrine falcon (*Falco peregrinus*). Raptors are not well surveyed by point counts, and Lincoln's sparrow and Bell's vireo are typically associated with wetlands and riparian areas so the fact that they were absent during SODN monitoring is not cause for concern (Ammon 1995, Kus et al. 2010). Furthermore, only one observation of each of these species was reported by Schmidt et al. (2005) except for Bell's vireos, which were documented only nine times. Note that NPSpecies lists common grackle as unconfirmed (NPS 2017a,b). Overall 92% of the species reported by the inventory were reported by SODN.

We reviewed Schmidt et al. (2005) for incidental observations of the 41 species not observed during VCP surveys in 2003-2004. We found that thirty-four of the 29 species (71%) were reported by Schmidt et al. (2005) as incidental observations, in riparian habitat, during winter, or during upland VCP surveys but beyond the 75 m (246 ft) threshold use for analysis. Of the 12 species that were not reported in Schmidt et al. (2005) by any of the survey methods used in that study, two where non-native species (i.e., house sparrow and Eurasian collared-dove). Of the remaining 10 species, all but one were observed fewer than four times during SODN's surveys while the vermilion flycatcher was observed 18 times, which is still relatively rare considering that two visits to each of seven points were made over the course of eight years.

In riparian habitat, average richness was greater during SODN's monitoring efforts (55) than during the VCP surveys (49). However, richness in riparian habitat was remarkably high during 2007 to 2009, but then richness stabilized to levels observed during 2003 and 2004 post-2009 (Figure 27). Overall richness was nearly double during SODN surveys (110) than during VCP surveys (62). Again, this is not surprising since SODN surveys occurred over eight years while VCP surveys occurred over only two years. Of the top 20 species, 18 were the same between the two studies. Together, 113 species were reported between the two studies, 59 (52%) of which were reported in both studies. Three species were reported only Schmidt et al. (2005). These were the American kestrel (*Falco sparverius*), Costa's hummingbird (*Calypte costae*), and crissal thrasher (*Toxostoma crissale*). However, all three species were rare as reported by Schmidt et al. (2005) with fewer than six detections reported for each of the three species. Overall, 94% of species reported by inventory surveys were reported by SODN.

In contrast, 51 species were reported by SODN that were not reported during VCP surveys. As with upland habitat, we reviewed Schmidt et al. (2005) for incidental or other observations. Of the 51 species not recorded during VCP surveys, eight were flyovers in riparian habitat, seven were reported in uplands, six were incidental observations, and two were reported as occurring during winter. The remaining 23 species were either reported on other species lists included in Schmidt et al. (2005) or were not listed in the report at all (two species). Of these 23 species, one was non-native (Eurasian collared-dove) and the remaining species were rare as reported by SODN (i.e., fewer than nine reports each).

In summary, the two bird studies for Tuzigoot NM included 212 species. Although survey methods were similar, SODN surveys occurred over a much longer time period than the earlier surveys. Because of the longer time frame, SODN surveys captured more diversity than Schmidt et al. (2005). Although four non-native species occur in the monument, they are not common. Overall richness appears good and the most common species are representative of riparian communities in the region and have been consistent since 2002. Furthermore, the top 20 common species were remarkably similar between the two studies. These results suggest that there have been few changes to the bird community from the earlier surveys to the more recent SODN surveys at Tuzigoot NM. Lastly, more than 90% of the species reported by the inventory surveys were reported by SODN. For these reasons, the condition for this measure is good. Confidence is medium, however, because of methodological differences between the two studies. Trend could not be determined.

The following summarizes NPSpecies and the two studies used to assess species richness and composition at Montezuma Castle NM. According to NPSpecies, 212 species are confirmed for the monument (Appendix D). An additional 75 species are unconfirmed (68), probably present (3), were reported by SODN but not listed in NPSpecies (2), or may occur in the park due to changes in taxonomy (2) (e.g. Cassin's vireo [*Vireo cassinii*] and cordilleran flycatcher [*Empidonax occidentalis*]) (AOS 2017). In total, there may be as many as 287 species for the monument (including unconfirmed and probably present species), which is remarkable considering its small combined area of 347 ha (858 ac) (Beaupré et al. 2013).

For both habitat types and across all years of SODN monitoring, 129 species were detected at the monument (117 in riparian habitat and 99 in desert scrub). This includes solitary vireo (formerly *V. solitarius*), which has since been split into plumbeous vireo (*V. plumbeous*), Cassin's vireo, and blue-headed vireo (*V. solitarius*). Plumbeous vireo was also reported by SODN, while the remaining two species were not. Blue-headed vireo is unlikely to occur in the monument given its eastern range (Morton et al. 2014).

A total of 93 species were observed along the Well unit's riparian transect. In the Castle unit, 108 and 99 species were observed in riparian and desert scrub habitat, respectively. Overall, the Castle unit was more diverse than the Well unit regardless of habitat type. Average annual species richness ranged from 48 species along Wet Beaver Creek (Well unit) to 62 species along Beaver Creek (Castle unit) (Figure 28). An average of 53 species a year occurred in the Castle unit's desert scrub habitat. Because SODN only monitored desert scrub habitat in the Well unit in 2007 and 2008, those data were excluded from these totals; however, species observed during those surveys were included in Appendix D.

The 20 most commonly detected species along riparian transects comprised 61% of all detections across all years of surveys (Table 62). Orange-crowned warbler (*Oreothlypis celata*), dusky-capped flycatcher (*Myiarchus tuberculifer*), and MacGillivray's warbler (*Geothlypis tolmiei*) were among the most commonly detected species. Four of the top 20 species are considered riparian obligates. Although comprising only 2.1% of all detections, the non-native Eurasian collared-dove was also among the top 20 most common species in riparian habitat. In desert scrub, the top 20 species comprised 67% of all detections across all years of surveys (68.6% including one species tied for the 20th spot) (Table 62). The most commonly detected species were house finch, ash-throated flycatcher (*Myiarchus cinerascens*), and black-throated sparrow (*Amphispiza bilineata*).

Six non-native species have been reported for the monument. The non-native species are Eurasian collared-dove, Eurasian wigeon (*Anas penelope*), European starling, house sparrow, ring-necked pheasant (*Phasianus colchicus*), and rock pigeon. The Eurasian wigeon and ring-necked pheasant, however, are unconfirmed (NPS 2017b). The remaining non-native species are considered uncommon or rare by NPSpecies (NPS 2017b). Schmidt et al. (2006) reported three of the four non-native species based on previous species lists and surveys. Eurasian collared dove was not among them, indicating that this species is a relatively new addition to the monument.

Palacios (2013) found that 253 species were reported across all years (1916-2009), 23 of which were reported before 1963 but not during later years; however, half of these are migratory or near the edge of their ranges and the other half were detected only once prior to 1963 and are probably rare occurrences in the monument (Palacios 2013). We cross-referenced the 23 species against recent SODN data that were not included in Palacios (2013) (i.e., 2010-2015) and found that none of the 23 species occurred during the latter years of SODN monitoring. However, as noted previously, many of these species are far outside their ranges (e.g., eastern towhee [*Pipilo erythrophthalmus*]

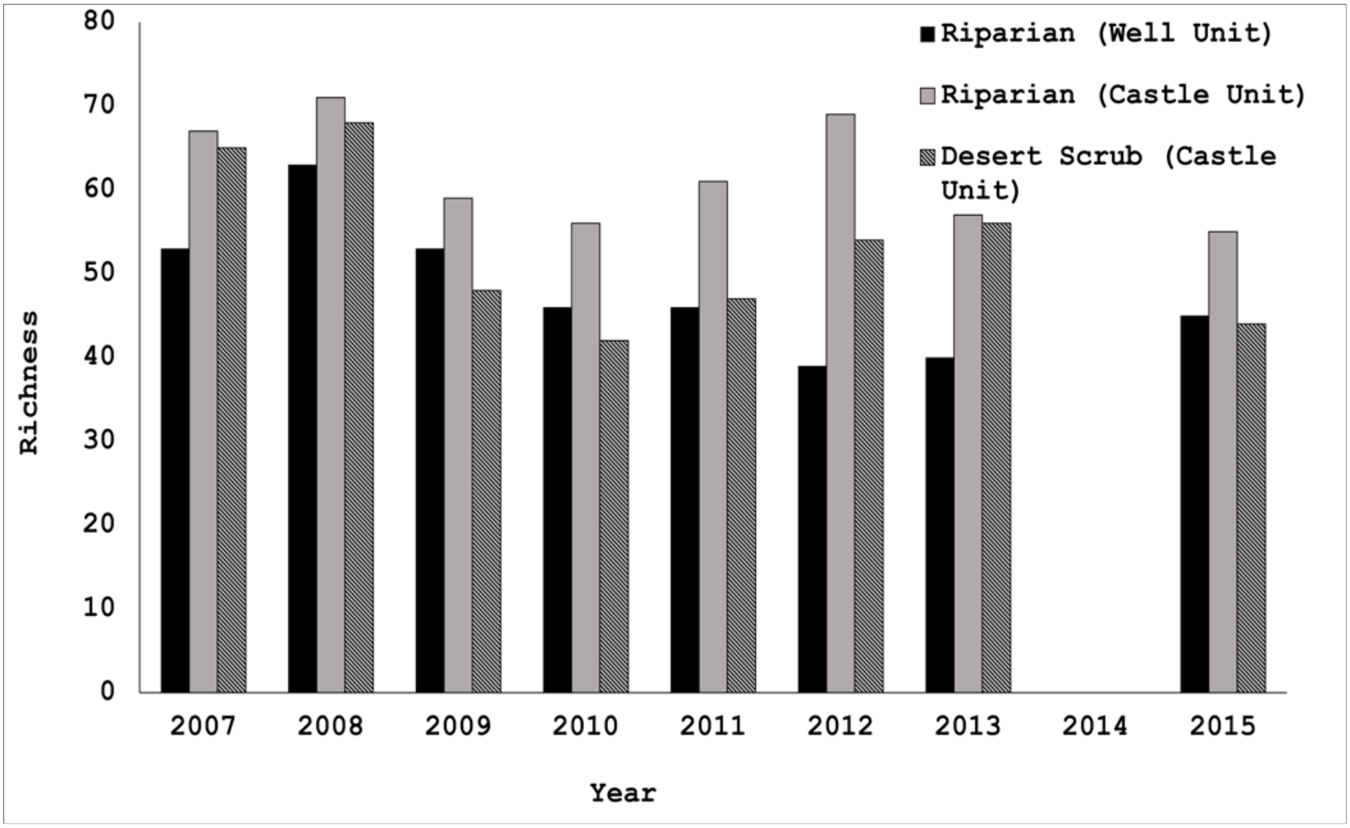


Figure 28. **Richness by year, habitat type, and unit in Montezuma Castle NM.**

Table 62. The 20 most commonly detected species by habitat during 2007 to 2015 surveys at Montezuma Castle as a proportion of all detections.

Species	Riparian (%)	Desert Scrub (%)
Anna's hummingbird	2.9	–
Ash-throated flycatcher	–	5.2
Bewick's wren	2.1	3.5
Black-throated sparrow	2.1	5.1
Brown-crested flycatcher	2.1	3.7
Brown-headed cowbird	–	1.9
Cactus wren	–	1.8
Common yellowthroat*	2.3	–
Dusky-capped flycatcher	4.7	–
Eurasian collared-dove	2.1	–
Gambel's quail	–	5.1
Gila woodpecker	3.9	3.0
Gray flycatcher	–	2.1
House finch	–	7.0
Killdeer	–	2.8
Lesser goldfinch	–	1.9
Lucy's warbler	3.7	4.8

* Riparian obligates (Guzy and Ritchison 1999, Lowther et al. 1999, Eckerle and Thompson 2001, Reed et al. 2013).

Table 62. The 20 most commonly detected species by habitat during 2007 to 2015 surveys at Montezuma Castle as a proportion of all detections continued.

Species	Riparian (%)	Desert Scrub (%)
MacGillivray's warbler	4.1	–
Mourning dove	2.8	4.0
Northern cardinal	–	–
Northern mockingbird	3.9	–
Northern rough-winged swallow	–	4.5
Orange-crowned warbler	5.4	–
Phainopepla	–	4.4
Ruby-crowned kinglet	2.0	–
Say's phoebe	2.9	–
Spotted sandpiper*	4.0	–
Summer tanager	1.8	–
Turkey vulture	–	1.0
Violet-green swallow	–	1.6
Virginia's warbler	2.2	–
Western wood-pewee	–	2.2
Yellow-breasted chat*	1.9	1.7
Yellow warbler*	3.5	

* Riparian obligates (Guzy and Ritchison 1999, Lowther et al. 1999, Eckerle and Thompson 2001, Reed et al. 2013).

or are clearly migratory or vagrant species such as Pacific loon [*Gavia pacifica*]). Even when considering these 23 species, 92% of all species observed during earlier studies were observed during SODN surveys. These results indicate that the bird community in the monument is diverse and has remained relatively unchanged, at least given the data available.

Overall, these results suggest few changes to the bird community at Montezuma Castle NM. The monument exhibited high diversity, especially considering its small size. Overall richness appears good and the most common species in each habitat types are representative of the communities in which they were found. Although, four non-native species are present, all but the Eurasian collared-dove are rare. Based on the available data, the condition of richness and composition is good. Confidence was medium. Trend could not be determined.

In the following text, we summarize the results of the presence of species of concern measure for both monuments. The Arizona Partners in Flight Bird Conservation Plan Version 1.0 lists 43 priority species of conservation concern for the state (Latta et al. 1999). Based on NPSpecies, SODN surveys, and other survey efforts described in this assessment, twenty-four of the 43 species are known to occur in Montezuma Castle NM (21) or Tuzigoot NM (18) (Table 63). All species listed in Table 63 are considered uncommon, occasional, or rare in the monuments in which they were listed, perhaps owing in part to their status as species of concern but also because many of them are migratory. Between the two monuments, 14 of 23 species listed in Table 63 were recorded during SODN surveys and Tavasci Marsh surveys (Appendices C and D). At Tuzigoot NM, four of the five (80%) species considered to breed (including residents) in the monument were observed during SODN's surveys. Red-naped sapsucker (*Sphyrapicus nuchalis*) was not observed. In Montezuma Castle NM, six of eight (75%) species considered to breed in (including residents) the monument were observed during SODN's surveys. Red-naped sapsucker and sage thrasher (*Oreoscoptes montanus*) were not observed. However, of the greatest concern are the three species listed as threatened or endangered by the U.S. Fish and Wildlife Service's Endangered Species Program (UFSWS 2017).

Portions of the Verde River, 0.4 km (0.2 mi) of which flow through Tuzigoot NM, was designated as critical habitat for the southwestern willow flycatcher (USFWS 2013). In Tuzigoot NM, willow flycatchers are considered rare breeders (NPS 2017a), but the southwestern subspecies has not been documented in the monument despite annual surveys (NPS, T. Greenawalt, Chief of Natural Resources, e-mail message, 8 November 2017). However, the southwestern subspecies has been documented just outside the monument in recent years, the closest this species has been to the monument for at least five years (NPS, T. Greenawalt, Chief of Natural Resources, e-mail message, 8 November 2017). Since southwestern willow flycatchers have been detected near the monument's boundary, they may eventually disperse there, especially as recovery efforts continue.

At Montezuma Castle NM, NPSpecies lists willow flycatcher as unconfirmed, but Schmidt et al. (2006) reported the species as occurring in the monument. Although a combined 6.9 km (4.3 mi) of riparian habitat occurs along Wet Beaver Creek and Beaver Creek with NPS boundaries, the perennially wetted willow habitat that flycatchers depend on is lacking along these corridors (Gwilliam et al. 2016). These areas were not designated as critical habitat (USFWS 2013). Furthermore, the riparian zone along these tributaries is extremely narrow, shifting to primarily upland vegetation at 10 m (33 ft) on either side of the stream channel (Gwilliam et al. 2016). Given these

Photograph of a Virginia Rail. Photo Credit: © Robert Shantz.

Table 63. Arizona Partners in Flight bird species of conservation concern that occur or may occur in Montezuma Castle NM and Tuzigoot NM.

Common Name	Montezuma Castle NM		Tuzigoot NM	
	NPSpecies Abundance	NPSpecies Annual Status	NPSpecies Abundance	NPSpecies Annual Status
American bittern[1]	Unconfirmed	–	Unconfirmed	–
Black-throated gray warbler	Uncommon	Migratory	Uncommon	Migratory
Brewer's sparrow	Common	Resident	Uncommon	Migratory
Common black hawk	Uncommon	Breeder	Uncommon	Breeder
Cordilleran Flycatcher[2]	Not Listed	–	Unconfirmed	–
Costa's hummingbird	Rare	Migratory	Rare	Migratory
Elegant trogon	Occasional	Vagrant	Not Listed	–
Ferruginous hawk	Occasional	Migratory	Unconfirmed	–
Gilded flicker	Not Listed	–	Unconfirmed	–
Gray flycatcher	Uncommon	Migratory	Uncommon	Migratory
Gray vireo	Uncommon	Breeder	Uncommon	Migratory
Juniper titmouse	Uncommon	Breeder	Unconfirmed	–
LeConte's thrasher	Unconfirmed	–	Not Listed	–
Lucy's warbler	Uncommon	Breeder	Common	Breeder
MacGillivray's warbler	Uncommon	Migratory	Uncommon	Migratory
Mexican spotted owl	Unconfirmed	–	Not Listed	–
Northern goshawk	Occasional	Migratory	Not Listed	–
Olive-sided flycatcher	Rare	Migratory	Rare	Migratory
Pinyon jay	Occasional	Migratory	Unconfirmed	–
Purple martin	Uncommon	Migratory	Rare	Migratory
Red-faced warbler	Unconfirmed	–	Unconfirmed	–
Red-naped Sapsucker	Uncommon	Resident	Uncommon	Resident
Ridgway's rail[5]	Not Listed	–	Occasional	Vagrant
Sagebrush Sparrow	Uncommon	Migratory	Rare	Migratory
Sage Thrasher	Rare	Resident	Unconfirmed	–
Swainson's Hawk	Uncommon	Migratory	Uncommon	Migratory
Swainson's Thrush	Rare	Migratory	Occasional	Migratory
Willow Flycatcher[3]	Unconfirmed	–	Rare	Breeder
Yellow-billed Cuckoo[4]	Uncommon	Breeder	Uncommon	Breeder

[1] Species reported at Tavasci Marsh in Tuzigoot NM in 2009.

[2] NPSpecies lists western flycatcher, but the species was split into pacific-slope flycatcher and cordilleran flycatcher, both of which possibly occur in the monuments during migration (pacific-slope flycatcher) or breeding and migration (cordilleran flycatcher) (Lowther et al. 2016a,b).

[3] Southwestern subspecies (*E. t. extimus*) is listed by US Fish and Wildlife as endangered (USFWS 2017).Species was listed as for Montezuma Castle NM by Schmidt et al. (2006) but was listed as unconfirmed in NPSpecies (NPS 2017a).

[4] The western distinct population, which includes Arizona, is listed as threatened by U.S. Fish and Wildlife Service (USFWS 2017).

[5] Formerly known as the clapper rail (*R. crepitans*). The species was split into three species, which are the clapper rail (*R. crepitans*), mangrove rail (*R. longirostris*), and Ridgway's rail (*R. obsoletus*) (AOS 2017). The latter species includes three subspecies, one of which (Ridgway's rail [*R. o. yumanensis*]) may occur in the monument and is considered endangered by the U.S. Fish and Wildlife Service (USFWS 2017).

factors, it is unlikely the southwestern subspecies occurs in the monument. However, southwestern willow flycatchers have nested successfully in tamarisk (*Tamarix* spp.) (Sedgwick 2000), and there is a small amount of this non-native species in the monument (Mau-Crimmins et al. 2009).

There is proposed critical habitat for the western distinct population of the yellow-billed cuckoo in Tuzigoot NM and Montezuma Castle NM (USFWS 2014). The Yellow-billed cuckoo is considered an uncommon breeding bird at both monuments. During SODN surveys, yellow-billed cuckoos were recorded in both desert scrub and riparian habitat in Montezuma Castle NM and in riparian habitat only in Tuzigoot NM (Appendices C and D). More recently, several individual cuckoos have been detected in and around Tuzigoot NM and at Montezuma Castle NM during targeted surveys for the species (NPS unpublished data).

Virginia rail was by far the most commonly detected species at Tavasci Marsh during 2008 to 2017 (Table 64). Data shown in Table 64 represents the number of detections across annual visits and does not necessarily represent the number of individuals. Sora was also common but detected at less than half the rate of Virginia rail. A few detections of least bittern occurred during earlier surveys, and at least one was detected during 2017 (NPS, T. Greenawalt, Chief of Natural Resources, e-mail message, 8 February 2018) (none were detected in 2015-2016). The single American bittern (AZ-PIF species of concern) detection in 2009 was likely a migrant (Supplee 2013). During 2008-2011, Supplee (2013) estimated that there were 10 pairs of Virginia rail and 1 or 2 pairs of least bittern in Tavasci Marsh (Supplee 2013). Common gallinule were also observed 2008-2011 (Supplee 2013).

Two possible detections of Ridgway's rail were heard at Tavasci Marsh in 2008 and 2009; however, confidence in these detections is low; the vocalizations could have been mistaken for least bittern (Supplee 2013). The 2008-2011 surveys suggest that Ridgway's rails do not occur at Tavasci Marsh (Supplee 2013). Thus, call playback surveys for this species were discontinued after 2011. Although this species may not occur in the Tuzigoot NM, it was included in the total number of AZ-PIF species of concern for the monument (i.e., 18) because of earlier reports for this species. Ridgway's rail was listed in Schmidt et al. (2005) as reported by Von Gausig and Radd (2001). Critical habitat for Ridgway's rail has not been identified by the USFWS (2017).

During 2016-2017 hummingbird banding efforts, three of the seven possible hummingbird species (Appendix D) were captured in Montezuma Castle NM (Table 65). Black-chinned hummingbirds (*Archilochus alexandri*) were most common, representing 91% of all birds captured over the two years (excluding recaptured and unbanded birds). Twenty-four of the 195 black-chinned hummingbirds banded were recaptured — an exceptionally high recapture rate of 12%. Recapture data can be used to estimate survival, lifespan, productivity, and population size (Bibby et al. 2000). The only two hummingbird species known to breed in the monument are black-chinned and Anna's hummingbird (*Calypte anna*). Rufous hummingbirds (*Selasphorus rufus*) and the remaining four species are migratory or unconfirmed for the monument (Appendix D). None of the species banded in the monument were listed as AZ-PIF species of concern. Costa's hummingbird, an AZ-PIF species of concern, was not banded but is listed as a rare migrant for both monuments (Table 63).

In summary, considering 42% and 49% of Arizona's species of concern occur in Tuzigoot NM and Montezuma Castle NM, respectively, including two of

Table 65. Summary of hummingbirds banded at Montezuma Castle NM in 2016 and 2017.

Species	2016	2017	Total
Anna's hummingbird	5	1	6
Black-chinned hummingbird	117	78	195
Rufous hummingbird	8	5	13
Total	130	84	214

Note: Data excludes recaptured and unbanded birds.

Source: Data provided by Montezuma Castle NM natural resources staff.

Table 64. Species and number of detections by year at Tavasci Marsh in Tuzigoot NM.

Common Name	2008	2009	2010	2011	2012-2014	2015	2016	2017
American bittern	0	1[2]	0	0	No Surveys	0	0	0
Least bittern	2	0	4	5	No Surveys	0	0	1[3]
Ridgway's rail[1]	1	0	0	1	No Surveys	No Surveys	No Surveys	No Surveys
Sora	9	8	9	11	No Surveys	2	1	0
Virginia Rail	37	42	27	50	No Surveys	35	24	0

[1] Detection possible but uncertain.

[2] Vocalized outside of survey period.

[3] Data provided by Tina Greenawalt, Chief of Natural Resources.

the three threatened and endangered species between the two monuments (and possibly all three), and most of the species that breed (≥75%) in the monuments were observed during relatively recent surveys, the condition for this measure is good. Trend is unknown. Confidence is high because targeted surveys have been recently conducted for the three threatened and endangered species.

Overall Condition, Threats, and Data Gaps

We used one indicator and two measures (summarized in Table 66) to assess the condition of birds in Montezuma Castle NM and Tuzigoot NM. Despite the small size of these monuments, their avifauna is remarkably diverse, native species richness is high, and species composition reflects the vegetative communities that the monuments provide. Measures with high confidence weigh more heavily into the overall condition rating than measures with medium or low confidence. In this assessment, both measures were assigned good condition but the confidence levels differed. The measure of richness and composition was assigned medium confidence because changes over time were difficult to assess with the available data. For example, similar surveys for which to compare with SODN surveys do not exist for Montezuma Castle NM. Instead we relied on a historical assessment of changes, which incorporated a variety of surveys with varying methods and degrees of reliability (Palacios 2013). Although the methods used in Tuzigoot NM's bird inventory (Schmidt et al. 2005) were similar to SODN's methods, the short time period between these surveys limits our ability to assess changes over time. In contrast, the measure of species of concern was assigned high confidence because all three threatened an endangered species have been recently surveyed. We assigned an overall confidence of medium because of some uncertainties with the data. Although these measures suggest relatively unchanging conditions, there were not enough data to assess trends.

A key uncertainty is how abundance for species has changed over time, particularly species of concern and those relying on specific habitat types. Inferences regarding changes in abundance are confounded by potential differences in annual detectability (Beaupré et al. 2013). Without a corresponding detectability analysis, changes in abundance could not be determined. Furthermore, differences in survey protocols between the studies precluded this type of comparison. An additional key uncertainty is that the AZ-PIF Bird Conservation Plan has not been updated

Table 66. Summary of birds indicators, measures, and condition rationale.

Indicators	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Species Occurrence	Richness and Composition	Good condition (green circle), medium confidence	A total of 214 species occur in Montezuma Castle NM and 208 species occur in Tuzigoot NM (including species listed by SODN but not NPSpecies). Native species richness in both monuments is high and species composition reflects the vegetative communities that the monuments provide. Overall and based on available data, there have been few changes to the bird community at either monument, except the introduction of four non-native species over time. For these reasons, this measure is in good condition with medium confidence. There were not enough data to assess trends.
	Presence of Species of Conservation Concern	Good condition (green circle), high confidence	Between the two monuments 24 of the 43 species of conservation concern listed for Arizona State, including two of the three U.S. Fish and Wildlife threatened and endangered species, occur in one or both monuments. Twenty-one of the 43 species occur in Montezuma Castle NM and 18 of the 43 species occur in Tuzigoot NM. Most of the species that breed in the monuments (≥75%) have been observed in recent years. For these reasons, the condition is good. Confidence is high because there have been recent targeted surveys for the three threatened and endangered species. Trend is unknown.
Overall Condition	Summary of All Measures	Good condition (green circle), medium confidence	The two measures used to assess birds indicate that the condition for this resource is good. Both monuments exhibited high species richness and provide habitat for half of the State listed species of concern, including threatened and endangered species. The data used in this assessment also suggest that there have been few changes to the bird community except for the introduction of four non-native species, at least over the years included in the various studies. Data gaps include information on changes in abundance, reproductive success, and current non-breeding season data. Confidence is medium and trends are unknown.

since 1999 and may not reflect the current suite of species of concern for Arizona.

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 2016). 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 ranges (USFWS 2016). Also, across the U.S., free-ranging domestic cats may be responsible for as many as one billion bird deaths each year (Wildlife Society 2011, Loss et al. 2013). Although rare, feral cats are known to occur in Montezuma Castle NM, and domestic cattle and feral dogs sometimes occur in Tuzigoot NM (NPSpecies 2017a,b). However, their effects on native birds, either through the direct effects of predation (e.g., feral cats) or through habitat alteration (i.e., cattle) are unknown.

Small NPS parks are especially vulnerable to factors beyond their borders. Because of the monuments' small size and high amount of edge owing to the combined three disjointed units, edge effects such as increased density of nest predators and non-native species encroachment may be high. Four human-adapted non-native bird species have been observed in both monuments (NPS 2017a,b). While the specific effects of these introduced species on native birds in the monuments is unknown, they likely compete with them for nesting habitat, food, and other resources as they do in other areas (Cabe 1993, Lowther and Cink 2006, Romagosa 2012, Lowther and Johnston 2014).

Although native, brown-headed cowbirds, a brood parasite, can reduce nesting success of other species (Johnson and van Riper 2004). Brood parasites lay their eggs in the nests of other birds, often resulting in loss of the host's eggs and nestlings. During a three-year (1994-1996) study of black-throated sparrows in Montezuma Castle NM, more than half (52%) of all sparrow nests were parasitized by cowbirds (Johnson and van Riper 2004). Removal of sparrow eggs by female cowbirds reduced clutch sizes from 3.4 to 1.9 eggs on average, which significantly lowered sparrow reproductive success (Johnson and van Riper 2004). However, black-throated sparrows were among the top 20 most commonly observed species in both desert scrub and riparian habitat during SODN surveys in Montezuma Castle NM. Bell's vireo, song sparrow, yellow-breasted chat, and yellow warbler, all of which occur in both monuments, are also highly susceptible to cowbird parasitism (Schmidt et al. 2005). Brown-headed cowbirds aren't the only brood parasite. Bronzed cowbirds (*Molothrus aeneus*) breed in both monuments and are known to parasitize 101 species of bird, including many of the monuments' breeding species (Ellison and Lowther 2009).

Riparian habitat represents less than 2% (0.5% in Arizona) of the American southwestern landscape but supports more than 50% of the region's bird species (Kirkpatrick et al. 2009a,b). Despite its importance, riparian habitat in Arizona is one of the most imperilled in the state (Latta et al. 1999), primarily as a result of increasing human pressure on water resources and climate change (Shamir et al. 2007). Just over half (~54%) of all confirmed species in each monument were documented in riparian habitat during SODN surveys.

Historical accounts of the Verde River indicate that in the 1860s the riparian area was much wider than it is today, with a dense forest of trees and shrubs (Stoutamire 2011). A long history of mining, irrigation, grazing, and agriculture have altered the flow and pathways of the river with negative effects on riparian vegetation. An estimated 90% of Arizona's wetland habitat has been altered or destroyed, making wetland and riparian habitat within the monuments increasingly important (Stoutamire 2011).

Tavasci Marsh, acquired by the NPS in 2005, is the largest freshwater wetland not associated with the Colorado River drainage and is the largest remaining wetland in the northern Sonoran Desert (Ryan and Parsons 2009, Stoutamire 2011). Because of the rarity of wetlands in the arid west, it has been subject to human use and alteration for more than a century and by Sinagua occupants before modern American settlement (Ryan and Parsons 2009, Stoutamire 2011). Modern American settlement of the marsh began in the late 1870s with the establishment of the area's first mining claims. Subsequently, the area around the marsh was developed for agriculture and ranching. Alteration of hydrology, loss of native vegetation, and the presence of non-native plants threaten ecosystem structure and function of the marsh (Supplee 2006).

However, despite the marsh's long history of human manipulation, the marsh appears to be "functioning moderately to very well" according to a 2009 NPS Water Resources Division wetlands assessment (Ryan and Parsons 2009). Owing to its high quality in the region, the marsh was designated as an Important Bird Area by BirdLife International and the National Audubon Society (Supplee 2006).

Maintaining high quality riparian and wetland habitat depends on regular and adequate stream flow, the amount and timing of precipitation and spring snowmelt, groundwater discharge, and the rate of evapotranspiration (Gwilliam et al. 2016). Variability in water resources is in part driven by climate change and water diversions for agriculture and other human uses. A climate assessment for the monuments revealed that the climate has become warmer and drier (Monahan and Fisichelli 2014 a,b). These results reflect trends occurring throughout the southwestern U.S. (Prein et al. 2016).

Key data gaps include information on reproductive success for species of concern. While presence/absence and abundance data are valuable, reproductive success can inform whether the protected area of the monuments serve as a source for which to populate other areas outside of their boundaries. Additionally, the majority of surveys have occurred during the breeding season. However, half of all species recorded in the monuments are migratory or resident. The southern location in the U.S. and relatively low elevation of the monuments (Beaupré et al. 2013) suggest that they may also provide important wintering habitat for many species. For example, during 2002 and 2003, 59 species were recorded during winter bird surveys (November-February) at Tuzigoot NM (Schmidt et al. 2005).

Sources of Expertise

This assessment was written by science writer and wildlife biologist, Lisa Baril, Utah State University. Sources of expertise include the reviewers listed in Appendix A.

Wildlife, such as coyotes, need connected tracts of land for their survival needs. They frequent Tuzigoot and Montezuma Castle NMs, with this photo taken at Montezuma Castle NM. Photo Credit: NPS.

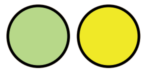
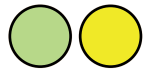
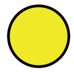
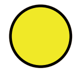
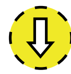
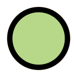
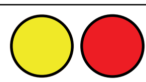
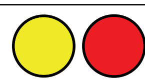
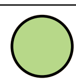
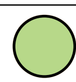
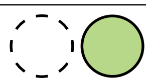
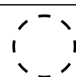
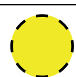
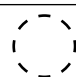
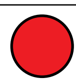
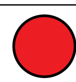
Discussion

The majority of the focal natural resources assessed for Montezuma Castle and Tuzigoot NMs Natural Resource Condition Assessment (NRCA) are in good condition or of moderate concern (Table 87). Exceptions include fish due to the low diversity of species, which is considered to be of significant concern, and aspects of riparian vegetation due to the presence of invasive, non-native plants. Managing the monuments' resources in light of rapidly changing environmental conditions, such as invasive plants and animals, increasing temperatures, decreasing precipitation, and land use change is challenging, but paramount to resource preservation.

Through collaborative partnerships, land managers and scientists are better able to define and work towards resilient landscapes capable of adapting to these ever-changing environmental stressors. Given the fact that the monuments are surrounded by the U.S. Forest Service (USFS) Coconino National Forest (NF), provides opportunities to increase staff's resource-reach. Both monuments' foundation documents (NPS 2016a,b) identify partnerships with the surrounding national forest and tribes as providing opportunities that have the potential to augment resource protection, education, and maintenance needs. Considering management objectives and subsequent actions and goals from a strategic, landscape-scale perspective will more likely maintain or improve resource conditions since most resources rely on factors for their survival needs that transcend political boundaries. In addition, considering conditions between closely related resources or "through the lens of" important topics and issues, may assist managers by providing an integrated and holistic approach to resource stewardship (NPS 2017c).

To support Tuzigoot and Montezuma Castle NMs' efforts in maintaining or improving resource conditions, the USFS' Watershed Condition Framework (WCF) 2011 assessments for the Mescal Gulch – Verde River, Beaver Creek, and Lower Wet

Table 87. Focal natural resource condition summary for Montezuma Castle and Tuzigoot NMs.

Focal Resource	Montezuma Castle Conditions	Tuzigoot Conditions
Landscape Dynamics		
Air Quality		
Hydrology		
Water Quality		
Upland Vegetation		n/a
Riparian Vegetation		
Birds		
Mammals		
Herpetofauna		
Fish		

Beaver Creek (HUC 12 watersheds) (Tables 88, 89, and 90) where Tuzigoot, Montezuma Castle unit, and Montezuma Well unit are located, respectively (Figure 30) are presented in this chapter. The USFS defines the WCF as "a comprehensive approach for proactively implementing integrated restoration on priority watersheds on national forests and grasslands." Twelve indicators serve as proxies representing the "underlying ecological, hydrological, and geomorphic functions and processes that affect watershed condition" (USFS 2011). The WCF is designed to "foster integrated ecosystem-based watershed assessments; target programs of work in watersheds that have been identified for restoration; enhance communication and coordination with external agencies and partners [such as the national monuments]; and improve national-scale reporting and monitoring of program accomplishments. The WCF provides the USFS with an outcome-based performance measure for documenting improvement to watershed condition at forest, regional, and national scales" (USFS 2011).

Given the fact that most park staffs face pressures of limited personnel and funding to fully monitor, take action, and protect resources, establishing partnerships may provide a means of achieving shared conservation goals. For example, a memorandum of understanding with the USFS Coconino NF has established an environmental scenic perimeter contiguous to Montezuma Castle NM on lands within the national forest (NPS 2016a). The memorandum also provides for an annual review of the status of the environmental quality of Montezuma Castle NM and "provides for adjustments in the Backdrop Management Unit as may be necessary... which has proved beneficial in preserving the historic integrity of the lands surrounding the monument (NPS 2016a)."

The primary threats to resource conditions within the monuments and throughout the surrounding area include increasing temperatures, drier conditions due to reduced precipitation, changes in adjacent land use due to increasing developments, and increasing water use. These are landscape-scale drivers that affect resources region-wide and require an integrated systems and landscape-scale way of approaching resource protection.

The full extent of impacts from climate change is unknown, but will likely include range shifts for

Table 88. Watershed summary for Montezuma Castle and Tuzigoot NMs.

National Monument	Watershed	Watershed Area (acres)	Proportion of Watershed Area Owned by USFS	Watershed Framework Condition (2011)
Tuzigoot NM	Mescal-Gulch	28,490.2	54%	Functioning at Risk
Montezuma Castle unit	Beaver Creek	7583.8	78%	Impaired Function
Montezuma Well unit	Wet Beaver Creek	19,060.6	77%	Impaired Function

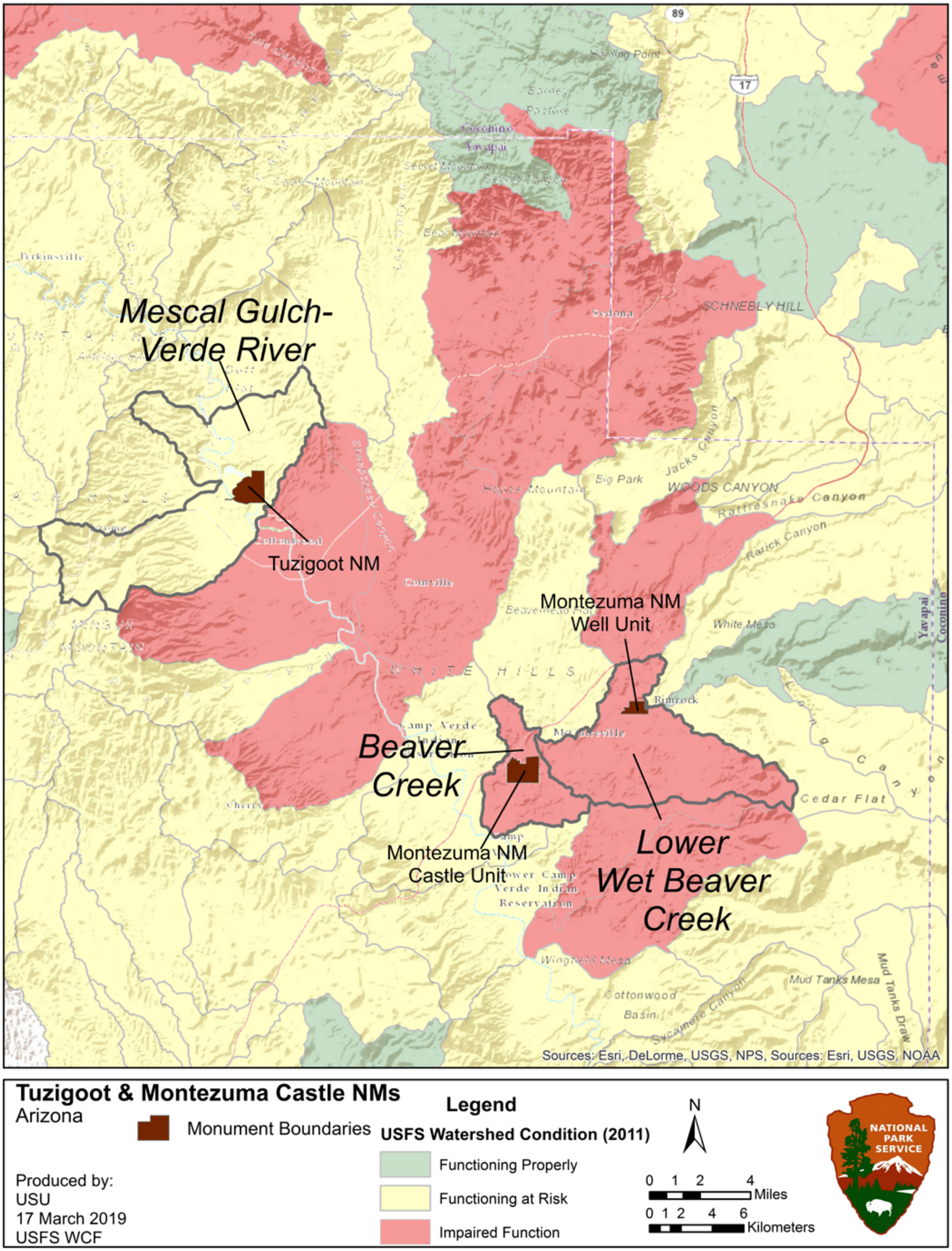


Figure 30. **Tuzigoot NM is situated in the Mescal Gulch-Verde River watershed, which is functioning but at risk. Montezuma Castle and Well units are situated in the Beaver Creek and Lower Beaver Creek watersheds, respectively, which are of impaired function.**

Table 89. USFS Watershed Condition Framework (WCF) (2011) assessment for aquatic systems in Mescal-Gulch Verde River, Beaver Creek, and Lower Beaver Creek watersheds.

WCF Resource Group	WCF Core Indicator	WCF Core Attributes	Mescal-Gulch Watershed (Tuzigoot NM)	Beaver Creek Watershed (Montezuma Castle)	Lower Beaver Creek Watershed (Montezuma Well)
Aquatic Physical	Water Quality	Impaired Waters (503d Listed) Water Quality (Unlisted)	red	green	green
	Water Quantity	Flow Characteristics	red	yellow	green
	Aquatic Habitat	Habitat Fragmentation Large Woody Debris Channel Shape & Function	green	red	red
Aquatic Biological	Aquatic Biota	Life Form Presence Native Species Exotic and/or Invasive Species	red	red	red
	Riparian/ Wetland Vegetation	Vegetation Condition	green	red	red

plants, changes in phenology, such as earlier flower blooms and leaf-out events for riparian plants, which may impact migratory birds and other wildlife, greater risk of fires, spread of non-native species, increased frequency and severity of droughts, decreased stream flows, increases in flooding events, and outbreaks of forest insects. Several of these factors are listed in the three WCFs as core attributes and some are monitored at the monuments by park and NPS Inventory and Monitoring Network staffs, which will inform resource conditions over time.

Over the last few decades, the southwestern U.S. has become more arid and is expected to become even drier as temperatures increase and rainfall decreases, although some computer models predict more extreme precipitation and flooding events. Continuing drought will likely lead to an increase in the abundance of upland desert scrub species and increased fire risk in wooded riparian areas. Warmer temperatures may also promote new non-native plant infestations, providing fuel for fires in desert habitats that are not adapted to burning. These changes directly and indirectly affect wildlife habitats and populations. Competition among native wildlife for reduced availability of habitat, drinking water, and food may increase. Mortality rates may increase as reproductive success decreases. Wildlife populations may be adversely affected by weather changes as the presence of viruses and plague respond to changes in minimum and mean temperatures and the amount and timing of precipitation (Garfin et al. 2014). Recently, Monahan and Fischelli (2014a,b) evaluated which of 289 National Park Service (NPS) parks, including both monuments, have experienced extreme climate change during the last 10-30 years. Twenty-five climate variables (i.e., temperature and precipitation) were evaluated to determine which ones were "extreme" (i.e., either within <5th percentile or >95th percentile relative to the historical range of variability (HRV) from 1901-2012). Results for both monuments (Table 91) are summarized as follows:

- Five and six temperature variables were "extreme warm" for Montezuma and Tuzigoot NMs, respectively.
- No temperature variables were "extreme cold" for either monument.
- One and two precipitation variables were "extreme dry" for Montezuma and Tuzigoot NMs, respectively.
- No precipitation variables were "extreme wet" for either monument.

Table 90. USFS Watershed Condition Framework (WCF) (2011) assessment for terrestrial systems in Mescal-Gulch Verde River, Beaver Creek, and Lower Beaver Creek watersheds.

WCF Resource Group	WCF Core Indicator	WCF Core Attributes	Mescal-Gulch Watershed (Tuzigoot NM)	Beaver Creek Watershed (Montezuma Castle)	Lower Beaver Creek Watershed (Montezuma Well)
Terrestrial Physical	Roads & Trails	Open Road Density Road Maintenance Proximity to Water Mass Wasting	Red	Yellow	Red
	Soils	Soil Productivity Soil Erosion Soil Contamination	Red	Red	Red
	Fire Regime	Fire Condition Class Wildfire Effects	Yellow	Green	Green
Terrestrial Biological	Forest Cover	Loss of Forest Cover	Green	–	Green
	Rangeland Vegetation	Vegetation Condition	Red	Red	Red
	Invasive Species	Extent and Rate of Spread	Green	Green	Red
	Forest Health	Insects and Disease Ozone	Green	Green	Yellow

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 31. 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 have already begun shifting beyond the HRV, with the 2003-2012 decade representing the warmest on record at both monuments (Monahan and Fisichelli 2014a,b).

<u>Adjacent Land Use, Development, and Water Use</u>

Yavapai County, which extends beyond the Upper Verde watershed, was the fastest growing rural county in the United States as of 1999, and its population (132,000 in the year 2000) is expected to more than double over the next 50 years (Smith and Ledbetter 2011). Specifically, the Verde Valley, located in Yavapai County, is one of the fastest growing areas in Arizona (NPS 1994), and the areas near Montezuma Castle and Tuzigoot NMs are experiencing rapid human population growth along with a corresponding increase in the number of housing units (Schmidt et al. 2006) and road densities, which is of concern throughout all three watersheds (USFS 2011). The increased development on lands adjacent to and surrounding the monuments results in direct and indirect impacts, such as the introduction of non-native species (e.g., landscaping plants and free-ranging domestic animals), increased groundwater withdrawal, surface water-quality problems and pollution, and visual intrusions to the natural landscape (NPS 1994a,b, Schmidt et al. 2005, 2006).

Threats related to water quantity include high rates of withdrawal (Schmidt et al. 2006), and the environment in and around Montezuma Well would be affected by a significant reduction in the flow of water from area springs. Groundwater and spring discharges contribute to the perennial flow in the Verde River and some of its tributaries (e.g., Beaver Creek), but adjacent land uses can interrupt the natural regime of surface waters. An increase in the number of water-supply wells drilled due to the rapid urbanization of the area (NPS 1994a) has lowered groundwater levels. The continued depletion of aquifers through groundwater pumping to support this growth, in addition to the drier conditions, could threaten the flow of the Verde River's headwater

Table 91. Results of climate change exposure evaluation.

Climate Variable	Temperature & Precipitation Variables	Montezuma Castle NM	Tuzigoot NM
Temperature	Annual mean temperature	Extreme warm	Extreme warm
	Maximum temperature of warmest month	Extreme warm	Extreme warm
	Minimum temperature of coldest month	Extreme warm	Extreme warm
	Mean temperature of driest quarter	–	Extreme warm
	Mean temperature of warmest quarter	Extreme warm	Extreme warm
	Mean temperature of coldest quarter	Extreme warm	Extreme warm
	Extreme cold	none	none
Precipitation	Precipitation of the driest month	–	Extreme dry
	Precipitation of the driest quarter	Extreme dry	Extreme dry
	Extreme wet	none	none

Source: Monahan and Fisichelli (2014a,b).

springs, and therefore the flow of the upper Verde (Smith and Ledbetter 2011). Part or all of the flow for Beaver Creek is diverted upstream for irrigation during the summer months, which affects the amount of creek water flowing through both the Montezuma Castle and Well units (NPS 1994a). But concerns regarding the protection of spring flow not only relate to discharge, but also to water quality and the maintenance of the Well's natural biological status and adjacent riparian habitats. The

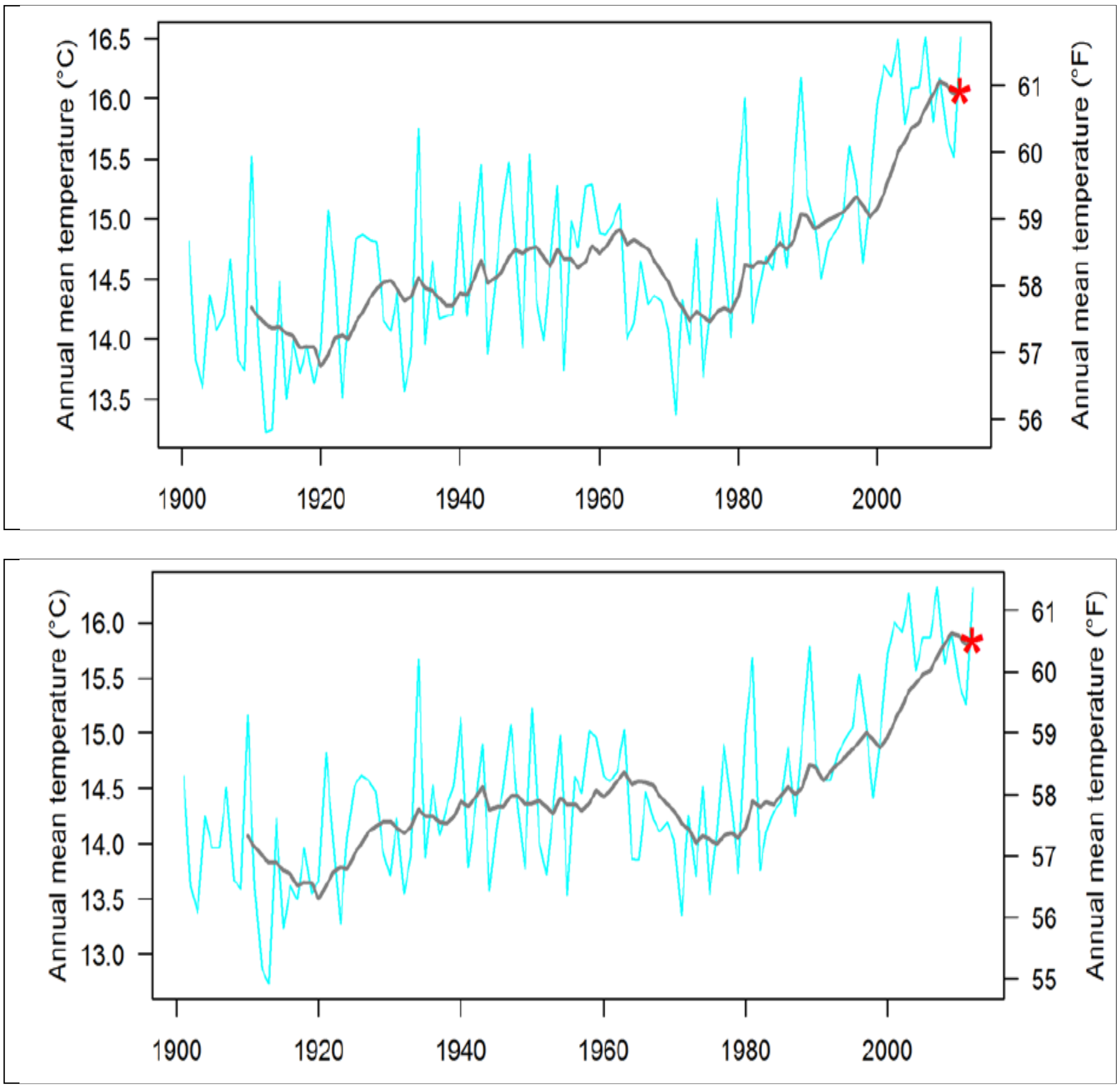


Figure 31. Time series used to characterize the historical range of variability and most recent percentile for annual mean temperature at Montezuma Castle (top) and Tuzigoot (bottom) NMs (including areas within 30-km [18.6-mi] of the monuments' boundaries). Figure Credits: Monahan and Fisichelli (2014a,b).

combination of near constant spring flow and unusual water chemistry creates a unique habitat for several endemic species in Montezuma Well (Konieczki and Leake 1997).

Water Quality

Tuzigoot NM is located down gradient from most potential contaminants, sources of which include non-point source pollution from urban development, agricultural and livestock runoff, industrial discharges from waste water treatment plants, and pollution from mine tailings (Sprouse et al. 2002). Four-million tons of mine tailings to the northwest of Tuzigoot NM are an unwelcome reminder of the historical importance of copper mining to the nearby towns of Jerome and Clarkdale, Arizona and leaching of heavy metals such as arsenic, beryllium, selenium, and zinc into Peck's Lake and Tavasci Marsh is a concern for the monument (Schmidt et al. 2005). The Verde River is one of the few remaining perennial rivers in Arizona, supporting one of the last remaining Freemont cottonwood-Gooding willow (*Populus fremontii-Salix gooddingii*) gallery forests, diverse native wildlife, and abundant recreational opportunities (Pawlowski 2012). Good water quality not only supports the endemic species but also a strong recreational economy.

Water Rights

Water rights to surface water in the Verde River as well as groundwater are currently under adjudication. The NPS claims for Montezuma Castle NM include "all surface and ground water resources including creeks, springs, seeps, and confined and unconfined aquifers within portions of the unit reserved or withdrawn from public domain and continuously administered by Federal agencies. This includes Beaver Creek and its unnamed tributaries." The claim for the reserved rights at Montezuma Castle includes both consumptive and non-consumptive uses of all groundwater wells and surface waters. At Montezuma Well, two groundwater wells, the prehistoric/historic irrigation ditch, and half the discharge from the Well are included in the claim. Water rights here are appropriative and reserved (NPS 1994a). At Tuzigoot NM, water rights to groundwater are also under adjudication. The NPS claims for the monument are for "groundwater resources for both domestic use and fire protection" (NPS 1994b).

Non-native Species

Long-term anthropogenic disturbance in the Verde Valley has contributed to the introduction and spread

Common black hawks depend on riparian vegetation for nesting. Photo Credit: NPS.

of non-native flora and fauna, a significant challenge to natural resource management (Rowlands 1999) for both Montezuma Castle and Tuzigoot NMs. Non-native grasses such as red brome (*Bromus rubens*) and Lehmann lovegrass (*Eragrostis lehmanniana*) are well established within monument boundaries. Saltcedar (*Tamarix* species) is prevalent along the banks of Beaver and Wet Beaver Creeks. Saltcedar and five-stamen-tamarisk are established along the banks of the Verde River outside Tuzigoot (Schmidt et al. 2005, Schmidt et al. 2006). Non-native fauna include free-ranging dogs and cats, cattle, birds, and bullfrogs. Declines in abundance and the extirpation of native fish, amphibians, and some aquatic reptiles throughout the Verde River and in Beaver Creek may be caused by non-native fish, five of which were recorded in Wet Beaver Creek alone (Montgomery et al. 1995).

Inseparable Cultural and Natural Resources

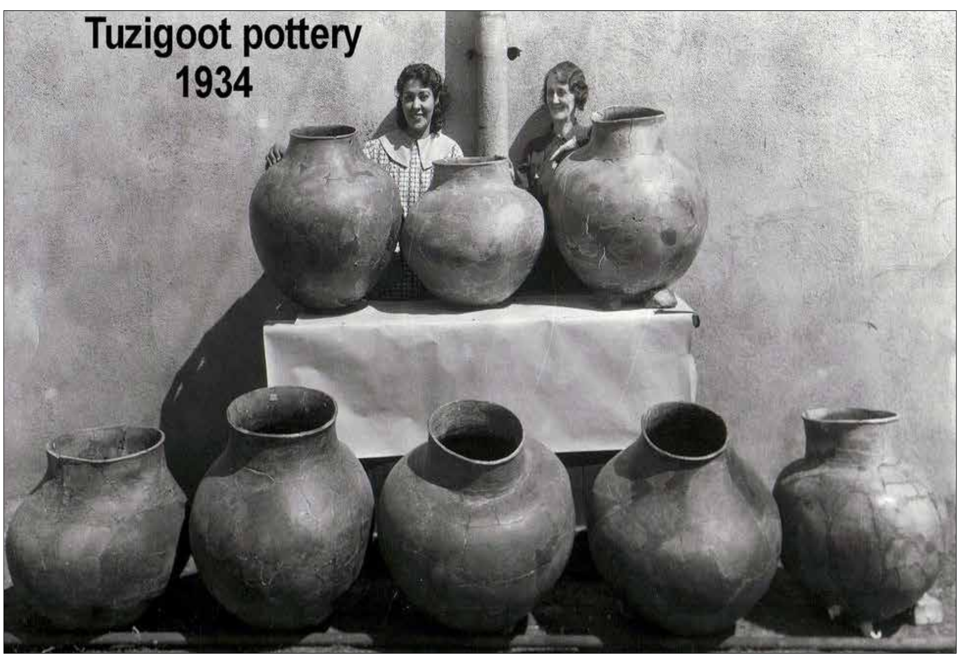
As changes to the area's resources continue, such as those described above, management adaptation will be necessary. Hart's (2014) review of published literature indicates that "the entire Verde Valley of Arizona comprises a cultural landscape of ethnographic resources with traditional significance to the five Native American peoples who are the subject of the [ethnographic overview] report [for the monuments]. Montezuma Castle, Montezuma Well, and Tuzigoot are ethnographic resources within this landscape, and these park units cannot be separated from that landscape."

The aquatic and riparian ecosystems in both monuments supported prehistoric and historic settlement and land uses. Over the years, these highly productive environments, created and sustained by surface and groundwater resources, have become increasingly important in the arid southwest due to the significant alteration and/or widespread destruction. These same resources continue to attract an ever-increasing population throughout the region, both residential and commercial. Excessive groundwater withdrawal, overgrazing, channelization of streambeds, alterations of surface water flow, impoundments, mining, and other developments have all contributed to reductions in the areal extent and complexity of these freshwater systems. These stressors, while most often beyond the management control of monument staff, often conflict with the monument's mandate of cultural and natural resource protection (NPS 1994a,b).

Certain localized activities such as fence maintenance to prevent cattle trespass, eradication of non-native plants, especially within the riparian areas, and control of aggressive predators (e.g., bullfrogs, feral cats, etc.) will likely help to maintain or improve park resource conditions, however, other issues require a much broader, landscape-scale coordinating effort.

Since most resources and stressors transcend political boundaries, developing partnerships with interested agencies and individuals is likely the key to successfully sustaining "systems" that support the region's diversity. Both monuments are adjacent to the Coconino NF's Verde Valley Management Area, which encompasses 130,898 ha (323,455 ac) of "some of the most arid and lowest elevation areas on the Coconino NF (USFS 2018).The Land and Resource Management Plan for the Coconino NF identifies a management approach of "collaborating with the Montezuma Castle NM staff to better meet visitor needs and protect resources in the vicinity of Montezuma Castle and Montezuma Well" (USFS 2018).

But because most watersheds contain many owners, effective stewardship will require involvement from several participants who are affected by the environmental changes. Furniss et al. (2010) identify the need for collaboration, community engagement, linking research to adaptive management, and employing methods for collaborative communication within a given watershed. History shows that environmental change is inevitable, and by working together towards a collective goal, resources can be best managed so that future generations may also enjoy.



Large olla pots excavated from Tuzigoot NM and reconstructed. Photo Credit: NPS.


Olla pot in situ at Tuzigoot NM. They were used to carry water and store food. Photo Credit: NPS.

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Appendix A. Report Reviewers

Table A-1. 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 McGinnity	Managed Business Solutions, a Sealaska Company Contractor to DOI, National Park Service	Washington-level Publishing and 508 Compliance Review
Tina Greenawalt	National Park Service Montezuma Castle National Monument and Tuzigoot National Monument, Chief of Natural Resources	Park Expert Reviewer - All Assessments, Full Report
Andy Hubbard	National Park Service Sonoran Desert Inventory and Monitoring Network, Program Manager	Air Quality and Water Quality Assessments
Kara Raymond	National Park Service Southern Arizona Office, Hydrologist	Hydrology, Herpetofauna, Riparian Vegetation, and Mammals Assessments
Ksienya Taylor	National Park Service Air Resources Division, Natural Resource Specialist	Air Quality Assessment
Salek Shafiqullah	National Park Service Intermountain Region Office, Hydrologist	Hydrology Assessment
Kerensa King	National Park Service Water Resources Division, Contaminants Specialist	Water Quality Assessment
Bryan Hamilton	National Park Service Great Basin National Park, Wildlife Biologist	Herpetofauna Assessment
Elaine F. Leslie	National Park Service Natural Resource Stewardship and Science, Chief Biological Resources	Mammals Assessment
Sallie Hejl	National Park Service Desert Southwest Cooperative Ecosystem Studies Unit, Research Coordinator	Birds Assessment
Melissa Trammel	National Park Service Intermountain Region, Fisheries Biologist	Fish Assessment
Donna Shorrock	U.S. Forest Service, Rocky Mountain Regional Office, Regional Vegetation Ecologist, Research Natural Areas Coordinator	Upland Vegetation Assessment
Sarah Studd	National Park Service Sonoran Desert Inventory and Monitoring Network, Vegetation Ecologist	Riparian & Aquatic Vegetation Assessment
Evan Gwilliam	National Park Service Sonoran Desert Inventory and Monitoring Network, Ecologist	Fish Assessment
Greg Eckert	National Park Service Great Plains Cooperative Ecosystem Studies Unit, Acting Research Coordinator and Restoration Ecologist	Landscape Dynamics Assessment

Appendix B. Native Riparian Species in Tuzigoot and Montezuma Castle National Monuments

Table B-1. Native species richness by zone and year along the Verde River in Tuzigoot NM.

Species	Common Name	Wetland Status[1]	Greenline		Riparian	
			2010	2014	2010	2014
Ambrosia confertiflora	Weakleaf bur ragweed	UPL	–	–	X	–
Ambrosia psilostachya	Cuman ragweed	FACU	–	–	X	–
Aristida purpurea	Purple threeawn	UPL	–	–	–	X
Aristida ternipes	Spidergrass	UPL	–	–	–	X
Baccharis salicifolia	Mule-fat	FAC	–	–	X	X
Baccharis sarothroides	Desertbroom	FACU	–	–	X	–
Bothriochloa barbinodis	Cane bluestem	UPL	–	–	–	X
Brickellia californica	California brickellbush	FACU	–	–	–	X
Brickellia floribunda	Chihuahuan brickellbush	UPL	–	–	X	X
Carex senta	Swamp carex	OBL	X	X	X	–
Chilopsis linearis	Desert willow	FAC	–	–	X	X
Clematis ligusticifolia	Western white clematis	FAC	–	–	X	–
Cleome lutea	Yellow spiderflower	UPL	–	–	X	–
Croton texensis	Texas croton	UPL	–	–	X	–
Cuscuta umbellata	Flatglobe dodder	UPL	X	–	X	–
Datura wrightii	Sacred thorn-apple	UPL	–	–	–	X
Eleocharis parishii	Parish's spikerush	FACW	X	–	–	–
Elymus arizonicus	Arizona wheatgrass	UPL	–	X	–	–
Equisetum arvense	Field horsetail	FAC	–	X	X	–
Equisetum laevigatum	Smooth horsetail	FACW	X	X	X	–
Fraxinus velutina	Velvet ash	FAC	X	–	X	–
Hibiscus biseptus	Arizona rosemallow	UPL	–	–	–	X
Hydrocotyle verticillata	Whorled marshpennywort	OBL	–	X	X	–
Hymenothrix loomisii	Loomis' thimblehead	UPL	–	–	–	X
Juncus saximontanus	Rocky Mountain rush	FACW	–	–	X	–
Machaeranthera asteroides	Fall tansyaster	UPL	–	–	X	–
Muhlenbergia asperifolia	Scratchgrass	FACW	X	–	–	–
Paspalum distichum	Knotgrass	FACW	X	–	–	–
Plantago virginica	Virginia plantain	FACU	X	–	–	–
Populus fremontii[2]	Fremont cottonwood	FACW	X	X	X	X
Prosopis velutina	Velvet mesquite	FACU	–	–	X	X
Salix bonplandiana	Bonpland willow	FACW	–	–	X	–
Salix exigua	Narrowleaf willow	FACW	X	X	X	–
Salix gooddingii	Goodding's willow	FACW	X	X	X	–
Schoenoplectus americanus	Chairmaker's bulrush	OBL	X	X	X	–
Setaria macrostachya	Large-spike bristlegrass	UPL	–	–	–	X
Sporobolus cryptandrus	Sand dropseed	FACU	–	–	X	X

[1] OBL = almost always occurs in wetlands, FACW = usually occurs in wetlands but may occur in non-wetlands, FAC = occurs in wetlands and non-wetlands, FACU = usually occurs in non-wetlands, and UPL = almost never occurs in wetlands.

[2] *Populus fremontii* (Fremont cottonwood) is not listed in Lichter et al. (2016), which indicates it is an upland species. However, this species is strongly associated with riparian areas and wetlands in the southwest (Henson 2002). This species also commonly occurs with *Salix* spp., many of which are considered facultative wetland species. For these reasons, we consider Fremont cottonwood to be an FACW species.

Note: X = species present.

Table B-1 continued. Native species richness by zone and year along the Verde River in Tuzigoot NM.

Species	Common Name	Wetland Status[1]	Greenline		Riparian	
			2010	2014	2010	2014
Typha domingensis	Southern cattail	OBL	X	X	X	–
Xanthium strumarium	Rough cocklebur	FAC	X	–	–	–
Total Richness	N/A	N/A	14	10	25	14

[1] OBL = almost always occurs in wetlands, FACW = usually occurs in wetlands but may occur in non-wetlands, FAC = occurs in wetlands and non-wetlands, FACU = usually occurs in non-wetlands, and UPL = almost never occurs in wetlands.

[2] *Populus fremontii* (Fremont cottonwood) is not listed in Lichter et al. (2016), which indicates it is an upland species. However, this species is strongly associated with riparian areas and wetlands in the southwest (Henson 2002). This species also commonly occurs with *Salix* spp., many of which are considered facultative wetland species. For these reasons, we consider Fremont cottonwood to be an FACW species.

Note: X = species present.

Table B-2. Native species richness by zone and year along Beaver Creek in Montezuma Castle NM.

Species	Common Name	Wetland Status[1]	Greenline		Riparian	
			2009	2014	2009	2014
Acacia constricta	Whitethorn acacia	UPL	–	–	X	–
Acacia greggii	Catclaw acacia	FACU	–	–	X	X
Achnatherum hymenoides	Inidan ricegrass	UPL	–	–	–	X
Allionia incarnata	Trailing windmills	UPL	–	–	–	X
Alnus oblongifolia	Arizona alder	FACW	X	X	–	–
Ambrosia psilostachya	Cuman ragweed	FACU	–	X	–	–
Amorpha fruticosa	False indigo bush	FACW	X	X	X	X
Aristida purpurea	Purple threeawn	UPL	X	X	X	X
Aristida ternipes	Spidergrass	UPL	–	–	X	X
Artemisia dracunculus	Tarragon	UPL	–	–	X	–
Artemisia ludoviciana	White sagebrush	UPL	–	–	X	–
Astragalus allochrous	Halfmoon milvetch	UPL	–	–	X	–
Atriplex canescens	Fourwing saltbush	UPL	–	–	X	–
Baccharis emoryi	Emory's baccharis	UPL	X	–	X	–
Baccharis salicifolia	Mule-fat	FAC	X	–	X	–
Baccharis salicina	Willow baccharis	FACW	–	X	–	X
Baccharis sarothroides	Desertbroom	FACU	X	–	X	X
Berberis haematocarpa	Red barberry	UPL	–	X	X	X
Bidens laevis	Smooth beggartick	OBL	X	–	–	–
Bothriochloa saccharoides	Silver bluestem	UPL	–	X	–	–
Bouteloua curtipendula	Sideouts grama	UPL	X	–	X	X
Bouteloua eriopoda	Black grama	UPL	–	–	X	–
Brickellia floribunda	Chihuahuan brickellbush	UPL	–	–	X	–
Bromus carinatus	California brome	UPL	X	–	X	–
Carex aquatilis	Water sedge	OBL	X	–	X	–
Carex senta	Swamp carex	OBL	–	X	–	–
Celtis ehrenbergiana	Spiny hackberry	UPL	–	–	X	–
Celtis laevigata var. reticulata	Netleaf hackberry	FAC	X	–	X	–

[1] OBL = almost always occurs in wetlands, FACW = usually occurs in wetlands but may occur in non-wetlands, FAC = occurs in wetlands and non-wetlands, FACU = usually occurs in non-wetlands, and UPL = almost never occurs in wetlands.

[2] *Populus fremontii* (Fremont cottonwood) is not listed in Lichter et al. (2016), which indicates it is an upland species. However, this species is strongly associated with riparian areas and wetlands in the southwest (Henson 2002). This species also commonly occurs with *Salix* spp., many of which are considered facultative wetland species. For these reasons, we consider Fremont cottonwood to be an FACW species.

Note: X = species present.

Table B-2 continued. Native species richness by zone and year along Beaver Creek in Montezuma Castle NM.

Species	Common Name	Wetland Status[1]	Greenline		Riparian	
			2009	2014	2009	2014
Celtis reticulata	Netleaf hackberry	FAC	–	X	–	X
Chaetopappa ericoides	Rose heath	UPL	–	–	X	–
Chilopsis linearis	Desert willow	FACU	X	–	X	X
Croton texensis	Texas croton	UPL	X	–	–	–
Datura wrightii	Sacred thorn-apple	UPL	X	–	X	–
Digitaria californica	Arizona cottontop	UPL	–	–	–	X
Eleocharis palustris	Common spikerush	OBL	–	X	–	X
Eleocharis rostellata	Beaked spikerush	UPL	X	–	–	–
Elymus elymoides	Squirreltail	FACU	X	–	–	X
Elymus trachycaulus	Slender wheatgrass	FACU	–	–	X	–
Equisetum arvense	Field horsetail	FAC	–	X	–	–
Equisetum hyemale	Scouringrush horsetail	FACW	X	–	–	–
Equisetum laevigatum	Smooth horsetail	FACW	–	X	–	X
Eriastrum diffusum	Miniature woollystar	UPL	–	–	X	–
Erigeron divergens	Spreading fleabane	UPL	–	–	–	X
Erigeron speciosus	Aspen fleabane	UPL	–	–	X	–
Eriogonum inflatum	Desert trumpet	UPL	–	–	X	–
Fraxinus velutina	Velvet ash	FAC	X	X	X	X
Gutierrezia sarothrae	Broom snakeweed	UPL	X	X	X	X
Hydrocotyle verticillata	Whorled marshpennywort	OBL	X	X	–	–
Hymenoclea monogyra	Singlewhorl burrobrush	UPL	X	X	X	X
Hymenoclea salsola	Burrobrush	UPL	–	–	X	–
Hymenothrix loomisii	Loomis' thimblehead	UPL	–	–	–	X
Juglans major	Arizona walnut	FAC	–	–	–	X
Juncus saximontanus	Rocky mountain rush	FACW	–	X	–	X
Juniperus monosperma	Oneseed juniper	UPL	X	X	X	X
Juniperus osteosperma	Utah juniper	UPL	–	–	X	–
Krameria erecta	Littleleaf ratany	UPL	–	–	X	–
Larrea tridentata	Creosote bush	UPL	–	–	X	–
Leersia oryzoides	Rice cutgrass	OBL	–	X	–	–
Mentha arvensis	Wild mint	FACW	–	X	–	X
Mimosa aculeaticarpa	Catclaw mimosa	UPL	–	–	X	X
Mirabilis multiflora	Colorado four o'clock	UPL	X	–	–	–
Muhlenbergia porteri	Bush muhly	UPL	–	–	X	–
Muhlenbergia rigens	Deergrass	FAC	–	–	X	–
Pascopyrum smithii	Western wheatgrass	FAC	X	–	X	–
Paspalum distichum	Knotgrass	FACW	X	X	–	–
Platanus wrightii	Arizona sycamore	FACW	X	X	X	X
Populus fremontii[2]	Fremont cottonwood	FACW	X	X	–	X

[1] OBL = almost always occurs in wetlands, FACW = usually occurs in wetlands but may occur in non-wetlands, FAC = occurs in wetlands and non-wetlands, FACU = usually occurs in non-wetlands, and UPL = almost never occurs in wetlands.

[2] *Populus fremontii* (Fremont cottonwood) is not listed in Lichter et al. (2016), which indicates it is an upland species. However, this species is strongly associated with riparian areas and wetlands in the southwest (Henson 2002). This species also commonly occurs with *Salix* spp., many of which are considered facultative wetland species. For these reasons, we consider Fremont cottonwood to be an FACW species.

Note: X = species present.

Table B-2 continued. ***Native species richness by zone and year along Beaver Creek in Montezuma Castle NM.***

Species	Common Name	Wetland Status[1]	Greenline		Riparian	
			2009	2014	2009	2014
Proboscidea althaeifolia	Desert unicorn-plant	UPL	–	–	X	–
Prosopis velutina	Velvet mesquite	FACU	X	X	X	X
Rhus trilobata	Skunkbush sumac	UPL	–	–	X	–
Salix exigua	Narrowleaf willow	FACW	–	X	–	–
Salix gooddingii	Gooding’s willow	FACW	X	X	–	X
Sapindus saponaria	Wingleaf soapberry	FACU	X	–	–	–
Schizachyrium cirratum	Texas bluestem	UPL	–	–	X	–
Solanum elaeagnifolium	Silverleaf nightshade	UPL	–	–	X	X
Sporobolus cryptandrus	Sand dropseed	FACU	X	–	X	X
Typha domingensis	Southern cattail	OBL	–	X	–	–
Typha latifolia	Broadleaf cattail	OBL	–	X	–	–
Vitis arizonica	Canyon grape	FACU	X	X	–	–
Xanthium strumarium	Rough cocklebur	FAC	X	–	X	–
Yucca elata	Soaptree yucca	UPL	–	–	X	–
Ziziphus obtusifolia	Lotebush	UPL	–	–	X	–
Total Richness	N/A	N/A	33	29	49	32

[1] OBL = almost always occurs in wetlands, FACW = usually occurs in wetlands but may occur in non-wetlands, FAC = occurs in wetlands and non-wetlands, FACU = usually occurs in non-wetlands, and UPL = almost never occurs in wetlands.

[2] *Populus fremontii* (Fremont cottonwood) is not listed in Lichter et al. (2016), which indicates it is an upland species. However, this species is strongly associated with riparian areas and wetlands in the southwest (Henson 2002). Furthermore, Stromberg (2013) considers Fremont cottonwood a hydromesic species that requires access to shallow groundwater for survival and reproduction. This species also commonly occurs with *Salix* spp., many of which are considered facultative wetland species. For these reasons, we consider Fremont cottonwood to be an FACW species.

Note: X = species present.

Table B–3. Native species by zone and year along Wet Beaver Creek in Montezuma Castle NM.

Species	Common Name	Wetland Status[1]	Greenline		Riparian	
			2010	2014	2010	2014
Acacia greggii	Catclaw acacia	FACU	–	–	X	X
Alnus oblongifolia	Arizona alder	FACW	X	X	X	X
Ambrosia psilostachya	Cuman ragweed	FACU	–	–	–	X
Amorpha fruticosa	False indigo bush	FACW	–	–	X	X
Aristida purpurea	Purple threeawn	UPL	–	–	X	–
Aristida ternipes	Spidergrass	UPL	X	–	–	X
Atriplex canescens	Fourwing saltbush	UPL	–	–	–	X
Baccharis salicifolia	Mule–fat	FAC	X	–	–	–
Baccharis salicina	Willow baccharis	FACW	–	X	–	X
Berberis harrisoniana	Harrison's barberry	UPL	–	–	X	–
Bothriochloa barbinodis	Cane bluestem	UPL	–	–	X	X
Bothriochloa saccharoides	Silver bluestem	UPL	–	–	–	X
Bouteloua curtipendula	Sideoats grama	UPL	–	–	X	X
Brickellia floribunda	Chihuahuan brickellbush	UPL	–	–	X	X
Carex senta	Swamp carex	OBL	–	X	–	–
Celtis ehrenbergiana	Spiny hackberry	UPL	–	–	X	–

[1] OBL = almost always occurs in wetlands, FACW = usually occurs in wetlands but may occur in non-wetlands, FAC = occurs in wetlands and non-wetlands, FACU = usually occurs in non-wetlands, and UPL = almost never occurs in wetlands.

[2] *Populus fremontii* (Fremont cottonwood) is not listed in Lichvar et al. (2016), which indicates it is an upland species. However, this species is strongly associated with riparian areas and wetlands in the southwest (Henson 2002). Furthermore, Stromberg (2013) considers Fremont cottonwood a hydromesic species that requires access to shallow groundwater for survival and reproduction. This species also commonly occurs with *Salix* spp., many of which are considered facultative wetland species. For these reasons, we consider Fremont cottonwood to be an FACW species.

Note: X = species present.

Table B-3 continued. Native species richness by zone and year along Wet Beaver Creek in Montezuma Castle NM.

Species	Common Name	Wetland Status[1]	Greenline		Riparian	
			2010	2014	2010	2014
Celtis reticulata	Netleaf hackberry	FAC	–	–	–	X
Chilopsis linearis	Desert willow	FACU	–	–	X	X
Digitaria californica	Arizona cottontop	UPL	–	–	–	X
Elymus glaucus	Blue wildrye	FACU	–	–	–	X
Elymus trachycaulus	Slender wheatgrass	FACU	–	–	X	–
Ephedra viridis	Mormon tea	UPL	–	–	–	X
Equisetum arvense	Field horsetail	FAC	–	X	–	X
Eriogonum wrightii	Bastardsage	UPL	–	–	X	–
Fraxinus velutina	Velvet ash	FAC	X	X	X	X
Gutierrezia sarothrae	Broom snakeweed	UPL	–	–	X	X
Hymenoclea monogyra	Singlewhorl burrobrush	UPL	–	–	X	X
Juncus saximontanus	Rocky Mountain rush	FACW	–	X	–	–
Juncus torreyi	Torrey's rush	FACW	X	–	–	–
Juncus xiphioides	Irisleaf rush	OBL	–	X	–	X
Juniperus monosperma	Oneseed juniper	UPL	–	–	X	–
Juniperus osteosperma	Utah juniper	UPL	–	–	–	X
Leptochloa dubia	Green sprangletop	UPL	–	–	–	X
Lycium pallidum	Pale desert–thorn	UPL	–	–	X	–
Mentha arvensis	Wild mint	FACW	–	X	–	–
Mimosa aculeaticarpa	Catclaw mimosa	UPL	–	–	X	X
Muhlenbergia asperifolia	Scratchgrass	FACW	–	X	–	–
Muhlenbergia rigida	Purple muhly	UPL	–	X	–	–
Panicum obtusum	Vine mesquite	FACU	–	–	–	X
Pascopyrum smithii	Western wheatgrass	FAC	–	–	X	–
Paspalum distichum	Knotgrass	FACW	X	–	–	–
Penstemon pseudospectabilis	Desert penstemon	UPL	–	–	–	X
Platanus wrightii	Arizona sycamore	FACW	X	X	X	X
Populus fremontii	Fremont cottonwood	UPL	X	–	X	X
Prosopis velutina	Velvet mesquite	FACU	–	–	X	X
Rhus virens	Evergreen sumac	UPL	–	–	X	–
Salix bonplandiana	Bonpland willow	FACW	–	–	X	–
Salix gooddingii	Goodding's willow	FACW	–	X	X	X
Salix laevigata	Red willow	FACW	–	X	–	X
Solanum elaeagnifolium	Silverleaf nightshade	UPL	–	–	–	X
Sporobolus contractus	Spike dropseed	UPL	X	–	–	–
Sporobolus cryptandrus	Sand dropseed	FACU	–	–	X	X
Tridens muticus	Slim tridens	FAC	–	–	–	X
Typha domingensis	Southern cattail	OBL	–	X	–	–
Vitis arizonica	Canyon grape	FACU	X	X	X	X
Xanthium strumarium	Rough cocklebur	FAC	X	–	–	–
Total Richness (56 species)	N/A	N/A	11	15	27	35

[1] OBL = almost always occurs in wetlands, FACW = usually occurs in wetlands but may occur in non-wetlands, FAC = occurs in wetlands and non-wetlands, FACU = usually occurs in non-wetlands, and UPL = almost never occurs in wetlands.

[2] *Populus fremontii* (Fremont cottonwood) is not listed in Lichter et al. (2016), which indicates it is an upland species. However, this species is strongly associated with riparian areas and wetlands in the southwest (Henson 2002). Furthermore, Stromberg (2013) considers Fremont cottonwood a hydromesic species that requires access to shallow groundwater for survival and reproduction. This species also commonly occurs with *Salix* spp., many of which are considered facultative wetland species. For these reasons, we consider Fremont cottonwood to be an FACW species.

Note: X = species present.

Appendix C. Tuzigoot NM Bird List

Listed in the table below are the bird species reported for Tuzigoot National Monument according to NPSpecies (NPS 2017b) and the 2007-2015 Sonoran Desert Network (SODN) annual landbird monitoring surveys (Beaupré et al. 2013). The SODN surveys were conducted using standardized bird sampling methods. For descriptions of the survey effort, see the Data and Methods section of the birds condition assessment. Scientific names and common names were updated to reflect current taxonomy according to the American Ornithological Society (AOS 2017). A total of 263 species are contained in the table, 207 of which are considered present in park according to NPSpecies (NPS 2017b). The remaining 55 species are unconfirmed (54) or were reported by SODN but not listed in NPSpecies (1). Species that have been reported but were listed as not present or false reports were excluded from the table. Several species were only reported by SODN.

C-1. Bird species list for Tuzigoot NM.

Common Name	Scientific Name	Occurrence	Abundance	NPS Tags	SODN Riparian Surveys	SODN Upland Surveys
Abert's towhee	*Melozone aberti*	Present	Common	Breeder	X	X
Acorn woodpecker	*Melanerpes formicivorus*	Unconfirmed	–	–	–	–
Allen's hummingbird	*Selasphorus sasin*	Unconfirmed	–	–	–	–
American avocet	*Recurvirostra americana*	Unconfirmed	–	–	–	–
American bittern	*Botaurus lentiginosus*	Unconfirmed	–	–	–	–
American coot	*Fulica americana*	Present	Common	Breeder	X	X
American crow	*Corvus brachyrhynchos*	Present	Occasional	Migratory	–	–
American goldfinch	*Spinus tristis*	Unconfirmed	–	–	–	–
American kestrel	*Falco sparverius*	Present	Uncommon	Breeder	–	X
American pipet	*Anthus rubescens*	Present	Rare	Migratory	–	–
American redstart	*Setophaga ruticilla*	Present	Occasional	Vagrant	X	–
American robin	*Turdus migratorius*	Present	Uncommon	Migratory	X	–
American white pelican	*Pelecanus erythrorhynchos*	Unconfirmed	–	–	–	–
American wigeon	*Mareca americana*	Present	Uncommon	Migratory	–	–
Anna's hummingbird	*Calypte anna*	Present	Uncommon	Breeder	X	X
Ash-throated flycatcher	*Myiarchus cinerascens*	Present	Common	Breeder	X	X
Bald eagle	*Haliaeetus leucocephalus*	Present	Rare	Migratory	–	–
Baltimore oriole	*Icterus galbula*	Unconfirmed	–	–	–	–
Bank swallow	*Riparia riparia*	Present	Rare	Migratory	X	X
Barn owl	*Tyto alba*	Present	Rare	Resident	X	–
Barn swallow	*Hirundo rustica*	Present	Common	Breeder	–	–
Bell's vireo	*Vireo bellii*	Present	Common	Breeder	X	–
Belted kingfisher	*Megaceryle alcyon*	Present	Uncommon	Breeder	X	–
Bendire's thrasher	*Toxostoma bendirei*	Present	Rare	–	X	–

[1] Non-native species.

[2] Formerly known as the clapper rail (*R. crepitans*). The species was split into three species, which are the clapper rail (*R. crepitans*), mangrove rail (*R. longirostris*), and Ridgway's rail (*R. obsoletus*) (AOS 2017). The latter species may occur in the monument and is considered endangered by the U.S. Fish and Wildlife Service's Endangered Species Program (USFWS 2017).

[3] Southwestern subspecies (*E. t. extimus*) is listed by the U.S. Fish and Wildlife Service's Endangered Species Program as endangered (USFWS 2017). The subspecies occurs near the monument but has not been documented in the monument.

[4] The western distinct population, which includes Arizona, is listed as threatened by the U.S. Fish and Wildlife Service's Endangered Species Program (USFWS 2017).

Note: X = species present.

C-1 continued. Bird species list for Tuzigoot NM.

Common Name	Scientific Name	Occurrence	Abundance	NPS Tags	SODN Riparian Surveys	SODN Upland Surveys
Bewick's wren	*Thryomanes bewickii*	Present	Common	Breeder	X	X
Black-necked stilt	*Himantopus mexicanus*	Unconfirmed	–	–	–	–
Black phoebe	*Sayornis nigricans*	Present	Common	Breeder	X	X
Black tern	*Chlidonias niger*	Present	Rare	Migratory	–	–
Black-capped gnatcatcher	*Polioptila nigriceps*	Unconfirmed	–-	–-	–	–
Black-chinned hummingbird	*Archilochus alexandri*	Present	Common	Breeder	X	X
Black-crowned night-heron	*Nycticorax nycticorax*	Present	Uncommon	Breeder	X	X
Black-headed grosbeak	*Pheucticus melanocephalus*	Present	Uncommon	Migratory	X	X
Black-necked stilt		Unconfirmed	–	–	–	–
Black-tailed gnatcatcher	*Polioptila melanura*	Present	Uncommon	Breeder	–	X
Black-throated blue warbler	*Setophaga caerulescens*	Unconfirmed	–	–	–	–
Black-throated gray warbler	*Setophaga nigrescens*	Present	Uncommon	Migratory	X	X
Black-throated sparrow	*Amphispiza bilineata*	Present	Uncommon	Breeder	X	X
Blue grosbeak	*Passerina caerulea*	Present	Common	Breeder	–	X
Blue-gray gnatcatcher	*Polioptila caerulea*	Present	Uncommon	Breeder	–	X
Blue-headed vireo	*Vireo solitarius*	Unconfirmed	–	–	–	–
Blue-winged teal	*Spatula discors*	Present	Rare	Migratory	–	–
Bonaparte's gull	*Chroicocephalus philadelphia*	Present	Occasional	Migratory	–	–
Brewer's blackbird	*Euphagus cyanocephalus*	Present	Uncommon	Migratory	–	–
Brewer's sparrow	*Spizella breweri*	Present	Uncommon	Migratory	–	X
Bridled titmouse	*Baeolophus wollweberi*	Present	Uncommon	Breeder	X	–
Broad-billed hummingbird	*Cynanthus latirostris*	Present	Rare	Breeder	X	X
Broad-tailed hummingbird	*Selasphorus platycercus*	Present	Uncommon	Migratory	–	–
Bronzed cowbird	*Molothrus aeneus*	Present	Uncommon	Breeder	X	X
Brown creeper	*Certhia americana*	Present	Uncommon	Resident	–	–
Brown-crested flycatcher	*Myiarchus tyrannulus*	Present	Common	Breeder	X	X
Brown-headed cowbird	*Molothrus ater*	Present	Common	Breeder	X	X

[1] Non-native species.

[2] Formerly known as the clapper rail (*R. crepitans*). The species was split into three species, which are the clapper rail (*R. crepitans*), mangrove rail (*R. longirostris*), and Ridgway's rail (*R. obsoletus*) (AOS 2017). The latter species may occur in the monument and is considered endangered by the U.S. Fish and Wildlife Service's Endangered Species Program (USFWS 2017).

[3] Southwestern subspecies (*E. t. extimus*) is listed by the U.S. Fish and Wildlife Service's Endangered Species Program as endangered (USFWS 2017). The subspecies occurs near the monument but has not been documented in the monument.

[4] The western distinct population, which includes Arizona, is listed as threatened by the U.S. Fish and Wildlife Service's Endangered Species Program (USFWS 2017).

Note: X = species present.

C-1 continued. Bird species list for Tuzigoot NM.

Common Name	Scientific Name	Occurrence	Abundance	NPS Tags	SODN Riparian Surveys	SODN Upland Surveys
Bufflehead	*Bucephala albeola*	Present	Rare	Migratory	–	–
Bullock's oriole	*Icterus bullockii*	Present	Uncommon	Breeder	X	X
Bushtit	*Psaltriparus minimus*	Present	Uncommon	Breeder	X	X
Cactus wren	*Campylorhynchus brunneicapillus*	Present	Uncommon	Breeder	–	X
California gull	*Larus californicus*	Present	Occasional	Migratory	–	–
Calliope hummingbird	*Selasphorus calliope*	Present	Rare	Migratory	–	–
Canada goose	*Branta canadensis*	Present	Rare	Migratory	–	–
Canvasback	*Aythya valisineria*	Present	Rare	Migratory	–	–
Canyon towhee	*Melozone fusca*	Present	Uncommon	Breeder	X	X
Canyon wren	*Catherpes mexicanus*	Present	Uncommon	Breeder	X	X
Cassin's finch	*Haemorhous cassinii*	Unconfirmed	–	–	–	–
Cassin's kingbird	*Tyrannus vociferans*	Present	Common	Breeder	X	X
Cattle egret	*Bubulcus ibis*	Present	Occasional	Migratory	–	–
Cedar waxwing	*Bombycilla cedrorum*	Present	Uncommon	Migratory	X	–
Chipping sparrow	*Spizella passerina*	Present	Uncommon	Migratory	X	X
Cinnamon teal	*Spatula cyanoptera*	Present	Rare	Migratory		–
Cliff swallow	*Petrochelidon pyrrhonota*	Present	Uncommon	Breeder	X	–
Common black-hawk	*Buteogallus anthracinus*	Present	Uncommon	Breeder	X	–
Common gallinule	*Gallinula galeata*	Present	Uncommon	Breeder	X	X
Common goldeneye	*Bucephala clangula*	Present	Occasional	Migratory	–	–
Common grackle	*Quiscalus quiscula*	Unconfirmed	–	–	–	–
Common loon	*Gavia immer*	Unconfirmed	–	–	–	–
Common merganser	*Mergus merganser*	Present	Uncommon	Breeder	–	–
Common nighthawk	*Chordeiles minor*	Present	Uncommon	Breeder	–	–
Common poorwill	*Phalaenoptilus nuttallii*	Present	Uncommon	Breeder	–	X
Common raven	*Corvus corax*	Present	Common	Breeder	X	X
Common yellowthroat	*Geothlypis trichas*	Present	Common	Breeder	X	X
Cooper's hawk	*Accipiter cooperii*	Present	Uncommon	Breeder	X	X
Cordilleran flycatcher	*Empidonax occidentalis*	Unconfirmed	–	–	–	–
Costa's hummingbird	*Calypte costae*	Present	Rare	Migratory	–	–
Crested caracara	*Caracara cheriway*	Unconfirmed	–	–	–	–
Crissal thrasher	*Toxostoma crissale*	Present	Uncommon	Breeder	–	X
Dark-eyed junco	*Junco hyemalis*	Present	Uncommon	Resident	–	–

[1] Non-native species.

[2] Formerly known as the clapper rail (*R. crepitans*). The species was split into three species, which are the clapper rail (*R. crepitans*), mangrove rail (*R. longirostris*), and Ridgway's rail (*R. obsoletus*) (AOS 2017). The latter species may occur in the monument and is considered endangered by the U.S. Fish and Wildlife Service's Endangered Species Program (USFWS 2017).

[3] Southwestern subspecies (*E. t. extimus*) is listed by the U.S. Fish and Wildlife Service's Endangered Species Program as endangered (USFWS 2017). The subspecies occurs near the monument but has not been documented in the monument.

[4] The western distinct population, which includes Arizona, is listed as threatened by the U.S. Fish and Wildlife Service's Endangered Species Program (USFWS 2017).

Note: X = species present.

C-1 continued. Bird species list for Tuzigoot NM.

Common Name	Scientific Name	Occurrence	Abundance	NPS Tags	SODN Riparian Surveys	SODN Upland Surveys
Double-crested cormorant	*Phalacrocorax auritus*	Present	Rare	Migratory	X	–
Dusky flycatcher	*Empidonax oberholseri*	Present	Uncommon	Migratory	–	–
Dusky-capped flycatcher	*Myiarchus tuberculifer*	Present	Rare	Breeder	–	–
Eared grebe	*Podiceps nigricollis*	Present	Rare	Migratory	–	–
Eastern meadowlark	*Sturnella magna*	Present	Uncommon	Migratory	–	–
Eastern towhee	*Pipilo erythrophthalmus*	Unconfirmed	–	–	–	–
Elf owl	*Micrathene whitneyi*	Present	Rare	Migratory	–	–
Eurasian collared-dove[1]	Streptopelia decaocto	Present	Uncommon	Resident	X	X
European starling[1]	Sturnus vulgaris	Present	Uncommon	Breeder	X	X
Evening grosbeak	Coccothraustes vespertinus	Unconfirmed	–	–	–	–
Ferruginous hawk	*Buteo regalis*	Unconfirmed	–	–	–	–
Forster's tern	*Sterna forsteri*	Unconfirmed	–	–	–	–
Franklin's gull	*Leucophaeus pipixcan*	Present	Rare	Migratory	–	–
Gadwall	*Mareca strepera*	Present	Rare	Migratory	–	–
Gambel's quail	*Callipepla gambelii*	Present	Common	Breeder	X	X
Gila woodpecker	*Melanerpes uropygialis*	Present	Common	Breeder	X	X
Gilded flicker	*Colaptes chrysoides*	Unconfirmed	–	–	–	–
Golden eagle	*Aquila chrysaetos*	Present	Rare	Migratory	–	–
Gray flycatcher	*Empidonax wrightii*	Present	Uncommon	Migratory	X	–
Gray vireo	*Vireo vicinior*	Present	Uncommon	Migratory	–	–
Great blue heron	*Ardea herodias*	Present	Common	Breeder	X	X
Great egret	*Ardea alba*	Present	Rare	Migratory	–	
Great horned owl	*Bubo virginianus*	Present	Uncommon	Breeder	X	X
Greater roadrunner	*Geococcyx californianus*	Present	Uncommon	Breeder	–	X
Greater white-fronted goose	*Anser albifrons*	Present	Occasional	Migratory	–	–
Greater yellowlegs	*Tringa melanoleuca*	Present	Uncommon	Migratory	–	–
Great-tailed grackle	*Quiscalus mexicanus*	Present	Common	Breeder	X	X
Green heron	*Butorides virescens*	Present	Uncommon	Breeder	X	X
Green-tailed towhee	*Pipilo chlorurus*	Present	Uncommon	Migratory	X	X
Green-winged teal	*Anas crecca*	Present	Rare	Migratory	–	–
Hairy woodpecker	*Picoides villosus*	Unconfirmed	–	–	–	–
Hammond's flycatcher	*Empidonax hammondii*	Present	Uncommon	Migratory	X	–

[1] Non-native species.

[2] Formerly known as the clapper rail (*R. crepitans*). The species was split into three species, which are the clapper rail (*R. crepitans*), mangrove rail (*R. longirostris*), and Ridgway's rail (*R. obsoletus*) (AOS 2017). The latter species may occur in the monument and is considered endangered by the U.S. Fish and Wildlife Service's Endangered Species Program (USFWS 2017).

[3] Southwestern subspecies (*E. t. extimus*) is listed by the U.S. Fish and Wildlife Service's Endangered Species Program as endangered (USFWS 2017). The subspecies occurs near the monument but has not been documented in the monument.

[4] The western distinct population, which includes Arizona, is listed as threatened by the U.S. Fish and Wildlife Service's Endangered Species Program (USFWS 2017).

Note: X = species present.

C-1 continued. Bird species list for Tuzigoot NM.

Common Name	Scientific Name	Occurrence	Abundance	NPS Tags	SODN Riparian Surveys	SODN Upland Surveys
Harris's hawk	*Parabuteo unicinctus*	Unconfirmed	–	–-	–	–
Hermit thrush	*Catharus guttatus*	Present	Uncommon	Migratory	–	–
Hermit warbler	*Setophaga occidentalis*	Unconfirmed	–	–	–	–
Hooded merganser	*Lophodytes cucullatus*	Present	Rare	Migratory	–	–
Hooded oriole	*Icterus cucullatus*	Present	Uncommon	Breeder	X	X
Horned lark	*Eremophila alpestris*	Present	Rare	Migratory	–	–
House finch	*Haemorhous mexicanus*	Present	Common	Breeder	X	X
House sparrow[1]	Passer domesticus	Present	Uncommon	Resident	–	X
House wren	*Troglodytes aedon*	Present	Uncommon	Resident	–	–
Hutton's vireo	*Vireo huttoni*	Present	Rare	Migratory	–	X
Inca dove	*Columbina inca*	Present	Uncommon	Breeder	X	–
Indigo bunting	*Passerina cyanea*	Present	Uncommon	Breeder	X	X
Juniper titmouse	*Baeolophus ridgwayi*	Unconfirmed	–	–	–	–
Killdeer	*Charadrius vociferus*	Present	Uncommon	Breeder	X	X
Ladder-backed woodpecker	*Picoides scalaris*	Present	Common	Breeder	X	X
Lark bunting	*Calamospiza melanocorys*	Present	Rare	Migratory	X	–
Lark sparrow	*Chondestes grammacus*	Present	Uncommon	Breeder	–	X
Lawrence's goldfinch	*Spinus lawrencei*	Unconfirmed	–	–	–	–
Lazuli bunting	*Passerina amoena*	Present	Uncommon	Breeder	–	X
Least bittern	*Ixobrychus exilis*	Present	Uncommon	Breeder	X	–
Least sandpiper	*Calidris minutilla*	Present	Rare	Migratory	–	–
Lesser goldfinch	*Carduelis psaltria*	Present	Common	Breeder	X	X
Lesser nighthawk	*Chordeiles acutipennis*	Present	Uncommon	Breeder	X	X
Lesser scaup	*Aythya affinis*	Present	Rare	Migratory	–	–
Lesser yellowlegs	*Tringa flavipes*	Present	Uncommon	Migratory	–	–
Lewis's woodpecker	*Melanerpes lewis*	Unconfirmed	–	–	–	–
Lincoln's sparrow	*Melospiza lincolnii*	Present	Uncommon	Migratory	–	–
Little blue heron	*Egretta caerulea*	Unconfirmed	–	–	–	–
Loggerhead shrike	*Lanius ludovicianus*	Present	Uncommon	Breeder	X	–
Long-billed curlew	*Numenius americanus*	Unconfirmed	–	–	–	–
Long-billed dowitcher	*Limnodromus scolopaceus*	Unconfirmed	–	–	–	–
Long-eared owl	*Asio otus*	Unconfirmed	–	–	–	–
Lucy's warbler	*Oreothlypis luciae*	Present	Common	Breeder	X	X
MacGillivray's warbler	*Geothlypis tolmiei*	Present	Uncommon	Migratory	X	X
Mallard	*Anas platyrhynchos*	Present	Uncommon	Breeder	X	X

[1] Non-native species.

[2] Formerly known as the clapper rail (*R. crepitans*). The species was split into three species, which are the clapper rail (*R. crepitans*), mangrove rail (*R. longirostris*), and Ridgway's rail (*R. obsoletus*) (AOS 2017). The latter species may occur in the monument and is considered endangered by the U.S. Fish and Wildlife Service's Endangered Species Program (USFWS 2017).

[3] Southwestern subspecies (*E. t. extimus*) is listed by the U.S. Fish and Wildlife Service's Endangered Species Program as endangered (USFWS 2017). The subspecies occurs near the monument but has not been documented in the monument.

[4] The western distinct population, which includes Arizona, is listed as threatened by the U.S. Fish and Wildlife Service's Endangered Species Program (USFWS 2017).

Note: X = species present.

C-1 continued. Bird species list for Tuzigoot NM.

Common Name	Scientific Name	Occurrence	Abundance	NPS Tags	SODN Riparian Surveys	SODN Upland Surveys
Marbled godwit	*Limosa fedoa*	Unconfirmed			–	–
Marsh wren	*Cistothorus palustris*	Present	Uncommon	Breeder	X	X
Merlin	*Falco columbarius*	Present	Rare	Migratory	–	–
Mexican jay	*Aphelocoma ultramarina*	Unconfirmed	–	–	–	–
Mexican whip-poor-will	*Antrostomus arizonae*	Unconfirmed	–	–	–	–
Mountain bluebird	*Sialia currucoides*	Present	Occasional	Migratory	–	–
Mourning dove	*Zenaida macroura*	Present	Common	Breeder	X	X
Nashville warbler	*Oreothlypis ruficapilla*	Present	Uncommon	Migratory	–	–
Northern beardless-tyrannulet	*Camptostoma imberbe*	Present	Uncommon	–	X	–
Northern cardinal	*Cardinalis cardinalis*	Present	Common	Breeder	–	X
Northern flicker	*Colaptes auratus*	Present	Common	Resident	–	X
Northern harrier	*Circus cyaneus*	Present	Rare	Migratory	–	–
Northern mockingbird	*Mimus polyglottos*	Present	Common	Breeder	–	X
Northern pintail	*Anas acuta*	Present	Rare	Migratory	–	–
Northern rough-winged swallow	*Stelgidopteryx serripennis*	Present	Common	Breeder	–	X
Northern saw-whet owl	*Aegolius acadicus*	Unconfirmed	–	–	–	–
Northern shoveler	*Spatula clypeata*	Present	Uncommon	Migratory	–	–
Northern waterthrush	*Parkesia noveboracensis*	Present	Rare	Migratory	–	–
Oak titmouse	*Baeolophus inornatus*	Unconfirmed	–	–	–	–
Olive-sided flycatcher	*Contopus cooperi*	Present	Rare	Migratory	X	–
Orange-crowned warbler	*Oreothlypis celata*	Present	Uncommon	Migratory	–	X
Osprey	*Pandion haliaetus*	Present	Uncommon	Migratory	–	–
Pacific-slope flycatcher	*Empidonax difficilis*	Present	Uncommon	Migratory	–	–
Painted redstart	*Myioborus pictus*	Unconfirmed	–	–	–	–
Peregrine falcon	*Falco peregrinus*	Present	Uncommon	Breeder	X	–
Phainopepla	*Phainopepla nitens*	Present	Common	Breeder	X	X
Pied-billed grebe	*Podilymbus podiceps*	Present	Uncommon	Breeder	X	–
Pine siskin	*Spinus pinus*	Present	Uncommon	Migratory	–	–
Pinyon jay	*Gymnorhinus cyanocephalus*	Unconfirmed	–	–	–	–

[1] Non-native species.

[2] Formerly known as the clapper rail (*R. crepitans*). The species was split into three species, which are the clapper rail (*R. crepitans*), mangrove rail (*R. longirostris*), and Ridgway's rail (*R. obsoletus*) (AOS 2017). The latter species may occur in the monument and is considered endangered by the U.S. Fish and Wildlife Service's Endangered Species Program (USFWS 2017).

[3] Southwestern subspecies (*E. t. extimus*) is listed by the U.S. Fish and Wildlife Service's Endangered Species Program as endangered (USFWS 2017). The subspecies occurs near the monument but has not been documented in the monument.

[4] The western distinct population, which includes Arizona, is listed as threatened by the U.S. Fish and Wildlife Service's Endangered Species Program (USFWS 2017).

Note: X = species present.

C-1 continued. Bird species list for Tuzigoot NM.

Common Name	Scientific Name	Occurrence	Abundance	NPS Tags	SODN Riparian Surveys	SODN Upland Surveys
Plumbeous vireo	*Vireo plumbeus*	Present	Uncommon	Migratory	X	–
Prairie falcon	*Falco mexicanus*	Present	Rare	Migratory	–	–
Purple finch	*Haemorhous purpureus*	Unconfirmed	–	–	–	–
Purple martin	*Progne subis*	Present	Rare	Migratory	–	–
Red crossbill	*Loxia curvirostra*	Present	Rare	Migratory	–	–
Red-faced warbler	*Cardellina rubrifrons*	Unconfirmed	–	–	–	–
Redhead	*Aythya americana*	Present	Rare	Migratory	–	–
Red-naped Sapsucker	*Sphyrapicus nuchalis*	Present	Uncommon	Resident	–	–
Red-necked phalarope	*Phalaropus lobatus*	Unconfirmed	–	–	–	–
Red-tailed hawk	*Buteo jamaicensis*	Present	Common	Breeder	X	X
Red-winged blackbird	*Agelaius phoeniceus*	Present	Common	Breeder	X	X
Ridgway's rail[2]	*Rallus obsoletus*	Present	Occasional	Vagrant	X	–
Ring-billed gull	*Larus delawarensis*	Present	Occasional	Migratory	–	–
Ring-necked duck	*Aythya collaris*	Present	Rare	Migratory	–	–
Rock pigeon[1]	Columba livia	Present	Rare	Resident	–	–
Rock wren	*Salpinctes obsoletus*	Present	Uncommon	Breeder	X	X
Rough-legged hawk	*Buteo lagopus*	Unconfirmed	–	–	–	–
Ruby-crowned kinglet	*Regulus calendula*	Present	Uncommon	Resident	X	–
Ruddy duck	*Oxyura jamaicensis*	Present	Uncommon	Breeder	–	–
Rufous hummingbird	*Selasphorus rufus*	Present	Rare	Migratory	–	–
Rufous-crowned sparrow	*Aimophila ruficeps*	Present	Uncommon	Breeder	–	–
Sabine's gull	*Xema sabini*	Present	Occasional	Migratory	–	–
Sage thrasher	*Oreoscoptes montanus*	Unconfirmed	–	–	–	–
Sagebrush sparrow	*Artemisiospiza nevadensis*	Present	Rare	Migratory	–	–
Sandhill crane	*Antigone canadensis*	Unconfirmed	–	–	–	–
Savannah sparrow	*Passerculus sandwichensis*	Unconfirmed	–	–	–	–
Say's phoebe	*Sayornis saya*	Present	Common	Breeder	X	X
Scott's oriole	*Icterus parisorum*	Present	Uncommon	Breeder	–	X
Sharp-shinned hawk	*Accipiter striatus*	Present	Uncommon	Migratory	X	–
Snow goose	*Anser caerulescens*	Unconfirmed	–	–	–	–
Snowy egret	*Egretta thula*	Present	Rare	Migratory	–	–
Solitary sandpiper	*Tringa solitaria*	Present	Uncommon	Migratory	X	–
Song sparrow	*Melospiza melodia*	Present	Common	Breeder	X	X

[1] Non-native species.

[2] Formerly known as the clapper rail (*R. crepitans*). The species was split into three species, which are the clapper rail (*R. crepitans*), mangrove rail (*R. longirostris*), and Ridgway's rail (*R. obsoletus*) (AOS 2017). The latter species may occur in the monument and is considered endangered by the U.S. Fish and Wildlife Service's Endangered Species Program (USFWS 2017).

[3] Southwestern subspecies (*E. t. extimus*) is listed by the U.S. Fish and Wildlife Service's Endangered Species Program as endangered (USFWS 2017). The subspecies occurs near the monument but has not been documented in the monument.

[4] The western distinct population, which includes Arizona, is listed as threatened by the U.S. Fish and Wildlife Service's Endangered Species Program (USFWS 2017).

Note: X = species present.

C-1 continued. Bird species list for Tuzigoot NM.

Common Name	Scientific Name	Occurrence	Abundance	NPS Tags	SODN Riparian Surveys	SODN Upland Surveys
Sora	*Porzana carolina*	Present	Uncommon	Breeder	X	X
Spotted sandpiper	*Actitis macularius*	Present	Uncommon	Migratory	X	–
Spotted towhee	*Pipilo maculatus*	Present	Rare	Migratory	X	–
Steller's jay	*Cyanocitta stelleri*	Unconfirmed	–	–	–	–
Summer tanager	*Piranga rubra*	Present	Common	Breeder	X	X
Swainson's hawk	*Buteo swainsoni*	Present	Uncommon	Migratory	–	–
Swainson's thrush	*Catharus ustulatus*	Present	Occasional	Migratory	–	–
Swamp sparrow	*Melospiza georgiana*	–	–	–	–	X
Townsend's solitaire	*Myadestes townsendi*	Present	Rare	Migratory	–	–
Townsend's warbler	*Setophaga townsendi*	Present	Uncommon	Migratory	–	–
Tree swallow	*Tachycineta bicolor*	Present	Uncommon	Migratory	X	X
Tundra swan	*Cygnus columbianus*	Unconfirmed	–	–	–	–
Turkey vulture	*Cathartes aura*	Present	Common	Resident	X	X
Vaux's swift	*Chaetura vauxi*	Unconfirmed	–	––	–	–
Verdin	*Auriparus flaviceps*	Present	Common	Breeder	X	X
Vermilion flycatcher	*Pyrocephalus rubinus*	Present	Uncommon	Breeder	X	X
Vesper sparrow	*Pooecetes gramineus*	Present	Rare	Migratory	–	–
Violet-green swallow	*Tachycineta thalassina*	Present	Uncommon	Migratory	X	X
Virginia rail	*Rallus limicola*	Present	Uncommon	Breeder	X	X
Virginia's warbler	*Oreothlypis virginiae*	Present	Uncommon	Migratory	–	X
Warbling vireo	*Vireo gilvus*	Present	Uncommon	Migratory	X	X
Western bluebird	*Sialia mexicana*	Present	Uncommon	Migratory	–	–
Western grebe	*Aechmophorus occidentalis*	Unconfirmed	–	–	–	–
Western kingbird	*Tyrannus verticalis*	Present	Common	Breeder	X	X
Western meadowlark	*Sturnella neglecta*	Present	Uncommon	Migratory	–	X
Western sandpiper	*Calidris mauri*	Present	Rare	Migratory	–	–
Western screech-owl	*Megascops kennicottii*	Present	Uncommon	Breeder	–	–
Western tanager	*Piranga ludoviciana*	Present	Uncommon	Migratory	X	X
Western wood-pewee	*Contopus sordidulus*	Present	Uncommon	Breeder	X	X
White-breasted nuthatch	*Sitta carolinensis*	Present	Uncommon	Breeder	–	–
White-crowned sparrow	*Zonotrichia leucophrys*	Present	Common	Resident	X	X
White-faced ibis	*Plegadis chihi*	Present	Rare	Migratory	X	–
White-throated sparrow	*Zonotrichia albicollis*	Unconfirmed	–	–	–	–

[1] Non-native species.

[2] Formerly known as the clapper rail (*R. crepitans*). The species was split into three species, which are the clapper rail (*R. crepitans*), mangrove rail (*R. longirostris*), and Ridgway's rail (*R. obsoletus*) (AOS 2017). The latter species may occur in the monument and is considered endangered by the U.S. Fish and Wildlife Service's Endangered Species Program (USFWS 2017).

[3] Southwestern subspecies (*E. t. extimus*) is listed by the U.S. Fish and Wildlife Service's Endangered Species Program as endangered (USFWS 2017). The subspecies occurs near the monument but has not been documented in the monument.

[4] The western distinct population, which includes Arizona, is listed as threatened by the U.S. Fish and Wildlife Service's Endangered Species Program (USFWS 2017).

Note: X = species present.

C-1 continued.   Bird species list for Tuzigoot NM.

Common Name	Scientific Name	Occurrence	Abundance	NPS Tags	SODN Riparian Surveys	SODN Upland Surveys
White-throated swift	*Aeronautes saxatalis*	Present	Uncommon	Breeder	–	–
White-winged dove	*Zenaida asiatica*	Present	Uncommon	Breeder	X	X
Willet	*Catoptrophorus semipalmatus*	Unconfirmed	–	–	–	–
Willow flycatcher[3]	*Empidonax traillii*	Present	Rare	Breeder	X	X
Wilson's phalarope	*Phalaropus tricolor*	Present	Uncommon	Migratory	–	–
Wilson's snipe	*Gallinago delicata*	Present	Rare	Migratory	–	–
Wilson's warbler	*Cardellina pusilla*	Present	Uncommon	Migratory	X	X
Winter wren	*Troglodytes troglodytes*	Unconfirmed	–	–	–	–
Wood duck	*Aix sponsa*	Present	Uncommon	Breeder	X	–
Woodhouse's scrub-jay	*Aphelocoma woodhouseii*	Present	Uncommon	Resident	X	–
Yellow warbler	*Setophaga petechia*	Present	Common	Breeder	X	–
Yellow-bellied sapsucker	*Sphyrapicus varius*	Unconfirmed	–	–-	–	–
Yellow-billed cuckoo[4]	*Coccyzus americanus*	Present	Uncommon	Breeder	X	–
Yellow-breasted chat[4]	*Icteria virens*	Present	Common	Breeder	X	X
Yellow-headed blackbird	*Xanthocephalus xanthocephalus*	Present	Uncommon	Migratory	–	–
Yellow-rumped warbler	*Setophaga coronata*	Present	Common	Resident	X	X
Zone-tailed hawk	*Buteo albonotatus*	Present	Uncommon	Breeder	–	–

[1] Non-native species.

[2] Formerly known as the clapper rail (*R. crepitans*). The species was split into three species, which are the clapper rail (*R. crepitans*), mangrove rail (*R. longirostris*), and Ridgway's rail (*R. obsoletus*) (AOS 2017). The latter species may occur in the monument and is considered endangered by the U.S. Fish and Wildlife Service's Endangered Species Program (USFWS 2017).

[3] Southwestern subspecies (*E. t. extimus*) is listed by the U.S. Fish and Wildlife Service's Endangered Species Program as endangered (USFWS 2017). The subspecies occurs near the monument but has not been documented in the monument.

[4] The western distinct population, which includes Arizona, is listed as threatened by the U.S. Fish and Wildlife Service's Endangered Species Program (USFWS 2017).

Note: X = species present.

Appendix D. Montezuma Castle NM Bird List

Listed in the table below are the bird species reported for Montezuma Castle National Monument according to NPSpecies (NPS 2017a) and the 2007-2015 Sonoran Desert Network (SODN) annual landbird monitoring surveys (Beaupré et al. 2013). The SODN surveys were conducted using standardized bird sampling methods. For descriptions of the survey effort, see the Data and Methods section of the birds condition assessment. Scientific names and common names were updated to reflect current taxonomy according to the American Ornithological Society (AOS 2017). A total of 287 species are contained in the table, 212 of which are considered present in park according to NPSpecies (NPS 2017a). The remaining 75 species are unconfirmed (68), probably present (3), were reported by SODN but not listed in NPSpecies (2), or may occur in the park due to changes in taxonomy (2). Species that have been reported but were listed as not present or false reports were excluded from the table. Species in bold are non-native.

D-1. Bird species list for Montezuma Castle NM.

Common Name	Scientific Name	Occurrence	Abundance	NPS Tags	SODN Riparian Surveys	SODN Upland Surveys
Abert's towhee	*Melozone aberti*	Present	Uncommon	Breeder	X	X
Acorn woodpecker	*Melanerpes formicivorus*	Unconfirmed	–	–	–	–
American avocet	*Recurvirostra americana*	Unconfirmed	–	–	–	–
American bittern	*Botaurus lentiginosus*	Unconfirmed	–	–	–	–
American coot	*Fulica americana*	Present	Occasional	Migratory	–	–
American crow	*Corvus brachyrhynchos*	Unconfirmed	–	–	–	–
American goldfinch	*Spinus tristis*	Present	Rare	Migratory	–	–
American kestrel	*Falco sparverius*	Present	Uncommon	Breeder	–	X
American pipet	*Anthus rubescens*	Present	Rare	Migratory	–	–
American robin	*Turdus migratorius*	Present	Uncommon	Migratory	X	X
American tree sparrow	*Spizelloides arborea*	Unconfirmed	–-	–	–	–
American white pelican	*Pelecanus erythrorhynchos*	Unconfirmed	–	–	–	–
American wigeon	*Mareca americana*	Present	Occasional	Migratory	–	–
Anna's hummingbird	*Calypte anna*	Present	Uncommon	Breeder	X	X
Ash-throated flycatcher	*Myiarchus cinerascens*	Present	Common	Breeder	X	X
Baird's sandpiper	*Calidris bairdii*	Present	Occasional	Migratory	–	–
Bald eagle	*Haliaeetus leucocephalus*	Unconfirmed	–	–	–	–
Bank swallow	*Riparia riparia*	Present	Uncommon	Migratory	–	–

[1] The solitary vireo (formerly *Vireo solitarius*) was split into three species as follows: Cassins' vireo (*V. cassinii*), plumbeous vireo (*V. plumbeus*), and blue-headed vireo (*V. solitarius*). Based on range maps, Cassin's vireo and plumbeous vireo may both occur in the monument, while the blue-headed vireo is unlikely to occur in the monument (Gouguen and Curson 2002, Gouguen and Curson 2012, Morton et al. 2014). NPSpecies and SODN both list both solitary vireo and plumbeous vireo. The solitary vireo listed in NPSpecies and by SODN may be either plumbeous or Cassin's vireo. Thus, Cassin's vireo was included in this table. Solitary vireo, which is no longer a recognized species, was not included.

[2] NPSpecies lists western flycatcher, but the species was split into pacific-slope flycatcher and cordilleran flycatcher, both of which possibly occur in the monument during migration (pacific-slope flycatcher) or breeding and migration (cordilleran flycatcher) (Lowther et al. 2016a,b). Thus, both species were included in this table and western flycatcher was excluded since it is no longer a recognized species.

[3] Non-native species.

[4] Southwestern subspecies (*E. t. extimus*) is listed by the U.S. Fish and Wildlife Service's Endangered Species Program as endangered (USFWS 2017).[5] The western distinct population, which includes Arizona, is listed as Threatened by the U.S. Fish and Wildlife Service's Endangered Species Program (USFWS 2017).

[5] The western distinct population, which includes Arizona, is listed as Threatened by the U.S. Fish and Wildlife Service's Endangered Species Program (USFWS 2017).

Note: X = species present.

D-1 continued. Bird species list for Montezuma Castle NM.

Common Name	Scientific Name	Occurrence	Abundance	NPS Tags	SODN Riparian Surveys	SODN Upland Surveys
Barn owl	*Tyto alba*	Present	Rare	Migratory	–	–
Barn swallow	*Hirundo rustica*	Present	Uncommon	Migratory	X	X
Bell's vireo	*Vireo bellii*	Present	Uncommon	Breeder	X	X
Belted kingfisher	*Megaceryle alcyon*	Present	Occasional	Migratory	X	X
Bendire's thrasher	*Toxostoma bendirei*	Unconfirmed	–	–	–	–
Bewick's wren	*Thryomanes bewickii*	Present	Common	Breeder	X	X
Black phoebe	*Sayornis nigricans*	Present	Uncommon	Breeder	X	X
Black tern	*Chlidonias niger*	Unconfirmed	–	–	–	–
Black vulture	*Coragyps atratus*	Unconfirmed	–	–	–	–
Black-bellied plover	*Pluvialis squatarola*	Unconfirmed	–	–	–	–
Black-chinned hummingbird	*Archilochus alexandri*	Present	Common	Breeder	X	X
Black-chinned sparrow	*Spizella atrogularis*	Present	Uncommon	Breeder	–	X
Black-crowned night-heron	*Nycticorax nycticorax*	Present	Rare	Migratory	–	---
Black-headed grosbeak	*Pheucticus melanocephalus*	Present	Uncommon	Migratory	X	X
Black-necked stilt	*Himantopus mexicanus*	Unconfirmed	–	–	–	---
Black-tailed gnatcatcher	*Polioptila melanura*	Present	Rare	Migratory	–	X
Black-throated blue warbler	*Setophaga caerulescens*	Unconfirmed	–	–	–	–
Black-throated gray warbler	*Setophaga nigrescens*	Present	Uncommon	Migratory	X	X
Black-throated sparrow	*Amphispiza bilineata*	Present	Uncommon	Breeder	X	X
Blue grosbeak	*Passerina caerulea*	Present	Uncommon	Breeder	X	X
Blue-gray gnatcatcher	*Polioptila caerulea*	Present	Common	Breeder	X	X
Blue-throated hummingbird	*Lampornis clemenciae*	Unconfirmed	–	–	–	–
Blue-winged teal	*Spatula discors*	Present	Rare	Migratory	–	–
Bonaparte's gull	*Chroicocephalus philadelphia*	Unconfirmed	–	–	–	–

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D-1 continued. Bird species list for Montezuma Castle NM.

Common Name	Scientific Name	Occurrence	Abundance	NPS Tags	SODN Riparian Surveys	SODN Upland Surveys
Brewer's blackbird	*Euphagus cyanocephalus*	Present	Uncommon	Migratory	–	–
Brewer's sparrow	*Spizella breweri*	Present	Common	Resident	X	X
Bridled titmouse	*Baeolophus wollweberi*	Present	Uncommon	Breeder	X	X
Broad-billed hummingbird	*Cynanthus latirostris*	Present	Common	Migratory	–	–
Broad-tailed hummingbird	*Selasphorus platycercus*	–	–	–	X	–
Bronzed cowbird	*Molothrus aeneus*	Present	Uncommon	Breeder	–	X
Brown creeper	*Certhia americana*	Present	Uncommon	Resident	–	–
Brown thrasher	*Toxostoma rufum*	Unconfirmed	–	–	–	
Brown-crested flycatcher	*Myiarchus tyrannulus*	Present	Common	Breeder	X	X
Brown-headed cowbird	*Molothrus ater*	Present	Common	Breeder	X	X
Bufflehead	*Bucephala albeola*	Present	Occasional	Migratory	–	–
Bullock's oriole	*Icterus bullockii*	Present	Common	Breeder	X	X
Bushtit	*Psaltriparus minimus*	Present	Uncommon	Breeder	X	X
Cactus wren	*Campylorhynchus brunneicapillus*	Present	Uncommon	Breeder	X	X
California gull	*Larus californicus*	Unconfirmed	–	–	–	–
Calliope hummingbird	*Selasphorus calliope*	Present	Rare	Migratory	–	–
Canada goose	*Branta canadensis*	Present	Occasional	Migratory	X	X
Canvasback	*Aythya valisineria*	Present	Occasional	Migratory	–	–
Canyon towhee	*Melozone fusca*	Present	Uncommon	Breeder	---	–
Canyon wren	*Catherpes mexicanus*	Present	Common	Breeder	X	X
Cassin's finch	*Haemorhous cassinii*	Present	Uncommon	Migratory	–	–
Cassin's kingbird	*Tyrannus vociferans*	Present	Uncommon	Breeder	X	X
Cassin's vireo[1]	*Vireo cassinii*	–	–	–	–	–-
Cattle egret	*Bubulcus ibis*	Present	Occasional	Migratory	–	–
Cedar waxwing	*Bombycilla cedrorum*	Present	Uncommon	Migratory	X	X
Chestnut-collared longspur	*Calcarius ornatus*	Unconfirmed	–	–	–	–
Chipping sparrow	*Spizella passerina*	Present	Common	Breeder	X	X

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Common Name	Scientific Name	Occurrence	Abundance	NPS Tags	SODN Riparian Surveys	SODN Upland Surveys
Cinnamon teal	*Spatula cyanoptera*	Present	Occasional	Migratory	–	–
Cliff swallow	*Petrochelidon pyrrhonota*	Present	Common	Breeder	X	X
Common black-hawk	*Buteogallus anthracinus*	Present	Uncommon	Breeder	X	–
Common gallinule	*Gallinula galeata*	Unconfirmed	–	–	–	–
Common goldeneye	*Bucephala clangula*	Probably Present	–	–	–	–
Common grackle	*Quiscalus quiscula*	Unconfirmed	–	–	–	–
Common ground-dove	*Columbina passerina*	Unconfirmed	–	–	–-	–
Common loon	*Gavia immer*	Present	Occasional	Migratory	–	–
Common merganser	*Mergus merganser*	Present	Uncommon	Breeder	X	X
Common nighthawk	*Chordeiles minor*	Present	Uncommon	Breeder	–	–
Common poorwill	*Phalaenoptilus nuttallii*	Present	Uncommon	Breeder	X	X
Common raven	*Corvus corax*	Present	Common	Breeder	X	X
Common yellowthroat	*Geothlypis trichas*	Present	Rare	Migratory	X	X
Cooper's hawk	*Accipiter cooperii*	Present	Uncommon	Breeder	X	X
Cordilleran flycatcher[2]	*Empidonax occidentalis*	–	–	–	–	–
Costa's hummingbird	*Calypte costae*	Present	Rare	Migratory	–	–
Crested caracara	*Caracara cheriway*	Unconfirmed	–	–	–	–
Crissal thrasher	*Toxostoma crissale*	Present	Uncommon	Breeder	–	X
Curve-billed thrasher	*Toxostoma curvirostre*	Present	Uncommon	Breeder	X	X
Dark-eyed junco	*Junco hyemalis*	Present	Common	Resident	–	–
Double-crested cormorant	*Phalacrocorax auritus*	Unconfirmed	–	–	–	–
Downy woodpecker	*Picoides pubescens*	Unconfirmed	–	–	–	–
Dusky flycatcher	*Empidonax oberholseri*	Present	Uncommon	Migratory	–	–
Dusky-capped flycatcher	*Myiarchus tuberculifer*	Present	Rare	Breeder	X	–
Eared grebe	*Podiceps nigricollis*	Unconfirmed	–	–	–	–
Eastern meadowlark	*Sturnella magna*	Present	Rare	Migratory	–	–
Eastern towhee	*Pipilo erythrophthalmus*	Unconfirmed	–	–	–	–

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D-1 continued. Bird species list for Montezuma Castle NM.

Common Name	Scientific Name	Occurrence	Abundance	NPS Tags	SODN Riparian Surveys	SODN Upland Surveys
Elegant trogon	*Trogon elegans*	Present	Occasional	Vagrant	X	–
Elf owl	*Micrathene whitneyi*	Present	Uncommon	Breeder	–	–
Eurasian collared-dove[3]	Streptopelia decaocto	Present	Uncommon	Resident	X	X
Eurasian wigeon[3]	Anas penelope	Unconfirmed	–	–	–	–
European starling[3]	Sturnus vulgaris	Present	Uncommon	Breeder	X	X
Evening grosbeak	Coccothraustes vespertinus	Present	Occasional	Migratory	–	–
Ferruginous hawk	*Buteo regalis*	Present	Occasional	Migratory	–	–
Forster's tern	*Sterna forsteri*	Unconfirmed	–	–		
Fox sparrow	*Passerella iliaca*	Unconfirmed	–	–	–	–
Franklin's gull	*Leucophaeus pipixcan*	Unconfirmed	–	–	–	–
Gadwall	*Mareca strepera*	Present	Occasional	Migratory	–	–
Gambel's quail	*Callipepla gambelii*	Present	Uncommon	Breeder	X	X
Gila woodpecker	*Melanerpes uropygialis*	Present	Common	Breeder	X	X
Golden eagle	*Aquila chrysaetos*	Present	Rare	Migratory	–	–
Golden-crowned kinglet	*Regulus satrapa*	Unconfirmed	–	–	–	–
Golden-winged warbler	*Vermivora chrysoptera*	Unconfirmed	–	–	–	–
Grace's warbler	*Setophaga graciae*	Unconfirmed	–	–	–	–
Gray flycatcher	*Empidonax wrightii*	Present	Uncommon	Migratory	X	X
Gray vireo	*Vireo vicinior*	Present	Uncommon	Breeder	X	X
Great blue heron	*Ardea herodias*	Present	Uncommon	Breeder	X	X
Great egret	*Ardea alba*	Present	Rare	Migratory	X	–
Great horned owl	*Bubo virginianus*	Present	Uncommon	Breeder	X	X
Greater roadrunner	*Geococcyx californianus*	Present	Uncommon	Breeder	–	X
Greater white-fronted goose	*Anser albifrons*	Present	Occasional	Migratory	–	–
Greater yellowlegs	*Tringa melanoleuca*	Present	Rare	Migratory	–	–
Great-tailed grackle	*Quiscalus mexicanus*	Present	Uncommon	Migratory	X	---
Green heron	*Butorides virescens*	Present	Rare	Migratory	X	–
Green-tailed towhee	*Pipilo chlorurus*	Present	Uncommon	Migratory	–	X
Green-winged teal	*Anas crecca*	Present	Occasional	Migratory	–	–

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D-1 continued. Bird species list for Montezuma Castle NM.

Common Name	Scientific Name	Occurrence	Abundance	NPS Tags	SODN Riparian Surveys	SODN Upland Surveys
Groove-billed ani	*Crotophaga sulcirostris*	Unconfirmed	–	–	–	–
Hairy woodpecker	*Picoides villosus*	Unconfirmed	–	–	–	–
Hammond's flycatcher	*Empidonax hammondii*	Present	Uncommon	Migratory	X	X
Harris's hawk	*Parabuteo unicinctus*	Unconfirmed	–	–	X	X
Hepatic tanager	*Piranga flava*	Present	Uncommon	Migratory	X	–
Hermit thrush	*Catharus guttatus*	Present	Uncommon	Resident	–	X
Hermit warbler	*Setophaga occidentalis*	Present	Rare	Migratory	X	–
Hooded merganser	*Lophodytes cucullatus*	Present	Occasional	Migratory	–	–
Hooded oriole	*Icterus cucullatus*	Present	Common	Breeder	X	X
Hooded warbler	*Setophaga citrina*	Unconfirmed	–	–	–	---
Horned lark	*Eremophila alpestris*	Present	Rare	Migratory	–	–
House finch	*Haemorhous mexicanus*	Present	Common	Breeder	X	X
House sparrow[3]	Passer domesticus	Present	Uncommon	Resident	–	X
House wren	*Troglodytes aedon*	Present	Uncommon	Resident	X	X
Hutton's vireo	*Vireo huttoni*	Present	Uncommon	Migratory	X	---
Inca dove	*Columbina inca*	Present	Rare	Breeder	–	–
Indigo bunting	*Passerina cyanea*	Present	Rare	Breeder	X	X
Juniper titmouse	*Baeolophus ridgwayi*	Present	Uncommon	Breeder	–	X
Killdeer	*Charadrius vociferus*	Present	Uncommon	Migratory	X	X
Ladder-backed woodpecker	*Picoides scalaris*	Present	Common	Breeder	X	X
Lark bunting	*Calamospiza melanocorys*	Present	Uncommon	Migratory	–	–
Lark sparrow	*Chondestes grammacus*	Present	Uncommon	Breeder	X	X
Lawrence's goldfinch	*Spinus lawrencei*	Probably Present	–	–	–	–
Lazuli bunting	*Passerina amoena*	Present	Uncommon	Breeder	X	X
LeConte's thrasher	*Toxostoma lecontei*	Unconfirmed	–	–	–	–
Least bittern	*Ixobrychus exilis*	Unconfirmed	–	–	–	–
Least sandpiper	*Calidris minutilla*	Present	Rare	Migratory	–	–
Lesser goldfinch	*Carduelis psaltria*	Present	Common	Breeder	X	X
Lesser nighthawk	*Chordeiles acutipennis*	Present	Uncommon	Breeder	–	–
Lesser scaup	*Aythya affinis*	Present	Occasional	Migratory	–	–
Lesser yellowlegs	*Tringa flavipes*	Present	Rare	Migratory	–	–

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D-1 continued. Bird species list for Montezuma Castle NM.

Common Name	Scientific Name	Occurrence	Abundance	NPS Tags	SODN Riparian Surveys	SODN Upland Surveys
Lewis's woodpecker	*Melanerpes lewis*	Present	Occasional	Migratory	–	–
Lincoln's sparrow	*Melospiza lincolnii*	Present	Uncommon	Migratory	X	–
Little blue heron	*Egretta caerulea*	Unconfirmed			–	–
Loggerhead shrike	*Lanius ludovicianus*	Present	Uncommon	Breeder	–	–
Long-billed curlew	*Numenius americanus*	Unconfirmed	–	–	–	–
Long-billed dowitcher	*Limnodromus scolopaceus*	Unconfirmed	–	–	–	–
Long-eared owl	*Asio otus*	Unconfirmed	–	–	–	–
Lucy's warbler	*Oreothlypis luciae*	Present	Uncommon	Breeder	X	X
MacGillivray's warbler	*Geothlypis tolmiei*	Present	Uncommon	Migratory	X	X
Mallard	*Anas platyrhynchos*	Present	Uncommon	Breeder	X	X
Marbled godwit	*Limosa fedoa*	Unconfirmed			–	–
Marsh wren	*Cistothorus palustris*	Present	Occasional	Migratory	–	–
Merlin	*Falco columbarius*	Present	Uncommon	Migratory	–	–
Mexican jay	*Aphelocoma ultramarina*	Present	Occasional	Vagrant	–	–
Mexican spotted owl	*Strix occidentalis*	Unconfirmed	–	–	–	–
Mountain bluebird	*Sialia currucoides*	Present	Occasional	Migratory	–	–
Mountain chickadee	*Poecile gambeli*	Unconfirmed	–	–	–	–
Mountain plover	*Charadrius montanus*	Unconfirmed	–	–	–	–
Mourning dove	*Zenaida macroura*	Present	Common	Breeder	X	X
Nashville warbler	*Oreothlypis ruficapilla*	Present	Common	Migratory	–	–
Northern beardless-tyrannulet	*Camptostoma imberbe*	Present	Rare	Breeder	X	–
Northern cardinal	*Cardinalis cardinalis*	Present	Common	Breeder	X	X
Northern flicker	*Colaptes auratus*	Present	Uncommon	Resident	X	X
Northern goshawk	*Accipiter gentilis*	Present	Occasional	Migratory	–	–
Northern harrier	*Circus cyaneus*	Present	Uncommon	Migratory	–	–
Northern mockingbird	*Mimus polyglottos*	Present	Common	Breeder	X	X
Northern pintail	*Anas acuta*	Present	Occasional	Migratory	–	–
Northern pygmy-owl	*Glaucidium gnoma*	Present	Rare	Migratory	–	–
Northern rough-winged swallow	*Stelgidopteryx serripennis*	Present	Common	Breeder	X	X

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D-1 continued. Bird species list for Montezuma Castle NM.

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Northern saw-whet owl	*Aegolius acadicus*	Present	Occasional	Migratory	–	–
Northern shoveler	*Spatula clypeata*	Present	Occasional	Migratory	–	–
Northern waterthrush	*Parkesia noveboracensis*	Present	Rare	Migratory	–	–
Oak titmouse	*Baeolophus inornatus*	Unconfirmed	–	–	–	–
Olive-sided flycatcher	*Contopus cooperi*	Present	Rare	Migratory	X	–
Orange-crowned warbler	*Oreothlypis celata*	Present	Uncommon	Migratory	X	X
Osprey	*Pandion haliaetus*	Present	Rare	Migratory	–	–
Pacific-slope flycatcher[2]	*Empidonax difficilis*	–	–	–	X	–
Painted redstart	*Myioborus pictus*	Present	Rare	Migratory	–	–
Peregrine falcon	*Falco peregrinus*	Present	Uncommon	Breeder	X	X
Phainopepla	*Phainopepla nitens*	Present	Common	Breeder	X	X
Pied-billed grebe	*Podilymbus podiceps*	Present	Rare	Migratory	–	–
Pine siskin	*Spinus pinus*	Present	Uncommon	Migratory	X	X
Pinyon jay	*Gymnorhinus cyanocephalus*	Present	Occasional	Migratory	–	–
Plumbeous vireo[1]	*Vireo plumbeus*	Present	Uncommon	Migratory	X	X
Prairie falcon	*Falco mexicanus*	Present	Rare	Migratory	–	–
Purple finch	*Haemorhous purpureus*	Unconfirmed	–	–	–	–
Purple martin	*Progne subis*	Present	Uncommon	Migratory	–	–
Pygmy nuthatch	*Sitta pygmaea*	Unconfirmed	–	–	–	–
Red crossbill	*Loxia curvirostra*	Present	Rare	Migratory	X	–
Red-breasted merganser	*Mergus serrator*	Unconfirmed	–	–	–	–
Red-breasted nuthatch	*Sitta canadensis*	Present	Occasional	Migratory	–	–
Red-faced warbler	*Cardellina rubrifrons*	Unconfirmed	–	–	–	–
Redhead	*Aythya americana*	Present	Occasional	Migratory	–	–
Red-headed woodpecker	*Melanerpes erythrocephalus*	Unconfirmed	–	–	–	–

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[2] NPSpecies lists western flycatcher, but the species was split into pacific-slope flycatcher and cordilleran flycatcher, both of which possibly occur in the monument during migration (pacific-slope flycatcher) or breeding and migration (cordilleran flycatcher) (Lowther et al. 2016a,b). Thus, both species were included in this table and western flycatcher was excluded since it is no longer a recognized species.

[3] Non-native species.

[4] Southwestern subspecies (*E. t. extimus*) is listed by the U.S. Fish and Wildlife Service's Endangered Species Program as endangered (USFWS 2017).[5] The western distinct population, which includes Arizona, is listed as Threatened by the U.S. Fish and Wildlife Service's Endangered Species Program (USFWS 2017).

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Note: X = species present.

D-1 continued. Bird species list for Montezuma Castle NM.

Common Name	Scientific Name	Occurrence	Abundance	NPS Tags	SODN Riparian Surveys	SODN Upland Surveys
Red-naped Sapsucker	*Sphyrapicus nuchalis*	Present	Uncommon	Resident	–	–
Red-necked phalarope	*Phalaropus lobatus*	Unconfirmed	–	–	–	–
Red-tailed hawk	*Buteo jamaicensis*	Present	Common	Breeder	X	X
Red-winged blackbird	*Agelaius phoeniceus*	Present	Uncommon	Migratory	X	X
Ring-billed gull	*Larus delawarensis*	Unconfirmed	–	–	–	–
Ring-necked duck	*Aythya collaris*	Present	Occasional	Migratory	–	–
Ring-necked pheasant[3]	Phasianus colchicus	Unconfirmed	–	–	–	–
Rock pigeon[3]	Columba livia	Present	Rare	Resident	–	–
Rock wren	*Salpinctes obsoletus*	Present	Uncommon	Breeder	X	X
Rough-legged hawk	*Buteo lagopus*	Unconfirmed	–	–	–	–
Ruby-crowned kinglet	*Regulus calendula*	Present	Common	Resident	X	–
Ruddy duck	*Oxyura jamaicensis*	Present	Rare	Migratory	–	–
Rufous hummingbird	*Selasphorus rufus*	Present	Uncommon	Migratory	–	–
Rufous-crowned sparrow	*Aimophila ruficeps*	Present	Common	Breeder	X	X
Sabine's gull	*Xema sabini*	Unconfirmed	–	–	–	–
Sage thrasher	*Oreoscoptes montanus*	Present	Rare	Resident	–	–
Sagebrush sparrow	*Artemisiospiza nevadensis*	Present	Uncommon	Migratory	–	–
Savannah sparrow	*Passerculus sandwichensis*	Unconfirmed	–	–	–	–
Say's phoebe	*Sayornis saya*	Present	Uncommon	Breeder	X	X
Scott's oriole	*Icterus parisorum*	Present	Uncommon	Breeder	X	X
Sharp-shinned hawk	*Accipiter striatus*	Present	Uncommon	Migratory	X	–
Short-eared owl	*Asio flammeus*	Present	Occasional	Vagrant	–	
Snow goose	*Anser caerulescens*	Present	Occasional	Migratory	–	–
Snowy egret	*Egretta thula*	Present	Occasional	Migratory	–	–
Solitary sandpiper	*Tringa solitaria*	Present	Rare	Migratory	–	–
Song sparrow	*Melospiza melodia*	Present	Uncommon	Breeder	X	X
Sora	*Porzana carolina*	Unconfirmed	–	–	–	–
Spotted sandpiper	*Actitis macularius*	Present	Uncommon	Breeder	X	–

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D-1 continued. Bird species list for Montezuma Castle NM.

Common Name	Scientific Name	Occurrence	Abundance	NPS Tags	SODN Riparian Surveys	SODN Upland Surveys
Spotted towhee	*Pipilo maculatus*	Present	Uncommon	Resident	X	X
Steller's jay	*Cyanocitta stelleri*	Unconfirmed	–	–	–	–
Summer tanager	*Piranga rubra*	Present	Common	Breeder	X	X
Swainson's hawk	*Buteo swainsoni*	Present	Uncommon	Migratory	–	–
Swainson's thrush	*Catharus ustulatus*	Present	Rare	Migratory	–	–
Townsend's solitaire	*Myadestes townsendi*	Present	Rare	Resident	–	–
Townsend's warbler	*Setophaga townsendi*	Present	Rare	Migratory	X	–
Tree swallow	*Tachycineta bicolor*	Present	Uncommon	Migratory	–	–
Tundra swan	*Cygnus columbianus*	Unconfirmed	–	–	–	–
Turkey vulture	*Cathartes aura*	Present	Common	Breeder	X	X
Vaux's swift	*Chaetura vauxi*	Present	Rare	Migratory	–	–
Verdin	*Auriparus flaviceps*	Present	Common	Breeder	X	X
Vermilion flycatcher	*Pyrocephalus rubinus*	Present	Uncommon	Breeder	X	X
Vesper sparrow	*Pooecetes gramineus*	Present	Uncommon	Breeder	–	X
Violet-green swallow	*Tachycineta thalassina*	Present	Uncommon	Migratory	X	X
Virginia rail	*Rallus limicola*	Unconfirmed	–	–	–	–
Virginia's warbler	*Oreothlypis virginiae*	Present	Uncommon	Migratory	X	–
Warbling vireo	*Vireo gilvus*	Present	Uncommon	Migratory	X	X
Western bluebird	*Sialia mexicana*	Present	Rare	Migratory	X	–
Western grebe	*Aechmophorus occidentalis*	Unconfirmed	–	–	–	–
Western kingbird	*Tyrannus verticalis*	Present	Uncommon	Breeder	X	X
Western meadowlark	*Sturnella neglecta*	Present	Uncommon	Migratory	–	X
Western sandpiper	*Calidris mauri*	Present	Rare	Migratory	–	–
Western screech-owl	*Megascops kennicottii*	Present	Uncommon	Breeder	–	–
Western tanager	*Piranga ludoviciana*	Present	Uncommon	Migratory	X	X
Western wood-pewee	*Contopus sordidulus*	Present	Common	Breeder	X	X
White-breasted nuthatch	*Sitta carolinensis*	Present	Uncommon	Breeder	X	–
White-crowned sparrow	*Zonotrichia leucophrys*	Present	Common	Resident	X	X

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D-1 continued. Bird species list for Montezuma Castle NM.

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White-faced ibis	*Plegadis chihi*	Unconfirmed	–	–	–	–
White-throated sparrow	*Zonotrichia albicollis*	Probably Present	–	–	–	–
White-throated swift	*Aeronautes saxatalis*	Present	Common	Breeder	X	X
White-winged dove	*Zenaida asiatica*	Present	Uncommon	Breeder	X	X
Willet	*Catoptrophorus semipalmatus*	Present	Occasional	Migratory	–	–
Williamson's sapsucker	*Sphyrapicus thyroideus*	Present	Rare	Migratory	–	–
Willow flycatcher[4]	*Empidonax traillii*	Unconfirmed	–	–	–	–
Wilson's phalarope	*Phalaropus tricolor*	Present	Uncommon	Migratory	–	–
Wilson's snipe	*Gallinago delicata*	Present	Occasional	Migratory	–	–
Wilson's warbler	*Cardellina pusilla*	Present	Uncommon	Migratory	X	X
Winter wren	*Troglodytes troglodytes*	Unconfirmed			–	–
Wood duck	*Aix sponsa*	Present	Uncommon	Breeder	X	X
Woodhouse's scrub-jay	*Aphelocoma woodhouseii*	Present	Uncommon	Breeder	X	–
Yellow warbler	*Setophaga petechia*	Present	Common	Breeder	X	X
Yellow-bellied sapsucker	*Sphyrapicus varius*	Unconfirmed	–	–	–	–
Yellow-billed cuckoo[5]	*Coccyzus americanus*	Present	Uncommon	Breeder	X	X
Yellow-breasted chat	*Icteria virens*	Present	Uncommon	Breeder	X	X
Yellow-headed blackbird	*Xanthocephalus xanthocephalus*	Present	Rare	Migratory	–	–
Yellow-rumped warbler	*Setophaga coronata*	Present	Common	Resident	X	X
Yellow-throated vireo	*Vireo flavifrons*	Present	Rare	Migratory	X	–
Zone-tailed hawk	*Buteo albonotatus*	Present	Uncommon	Breeder	–	–

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U.S. Department of the Interior

Natural Resource Stewardship and Science
1201 Oak Ridge Drive, Suite 150
Fort Collins, Colorado 80525

www.nature.nps.gov

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