National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Gila Cliff Dwellings National Monument

Natural Resource Condition Assessment

Natural Resource Report NPS/SODN/NRR—2019/1961

ON THE COVER

Morning View of Gila Cliff Dwellings National Monument on Solstice 2015. Photo Credit: NPS/Janice Wei.

Gila Cliff Dwellings National Monument

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Natural Resource Report NPS/SODN/NRR—2019/1961

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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 Gila Cliff Dwellings National Monument (NM) began with an initial project scoping in 2010 as a collaborative effort between the national monument staff, the NPS Sonoran Desert Inventory and Monitoring Network (SODN) staff, NPS Intermountain Region, and the Sonoran Institute. Nine focal resources were selected for condition assessment reporting, and in 2017, Utah State University was added as a partner to complete the monument's NRCA report.

Gila Cliff Dwellings was established as a national monument in 1907 because of the cliff dwellings ". . . exceptional scientific and educational interest, and being the best representative of the Cliff-Dwellers' remains of that region." In addition to the cultural resources, the monument's natural resources, including a portion of the Gila River, and diverse assemblages of vegetation, mammals, birds, amphibians, and reptiles, offer outstanding opportunities for scientific inquiry and interpreting the relationship between the long history of human habitation and the area's environment.

The monument's nine natural resources evaluated for current conditions were grouped into three broad categories: landscapes (i.e., 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 except for air quality, herpetofauna, and fish, which were evaluated as of moderate concern.

Like many national parks throughout the United States, the resource conditions at Gila Cliff Dwellings are vulnerable to stressors far beyond its borders, such as warming temperatures and variable and intense precipitation events. But overall, the monument's natural resources are well protected due to its isolation and proximity to the U.S. Forest Service's Gila National Forest. The forest surrounds the monument and offers outstanding partnership opportunities for managing resources in ways that can help achieve shared conservation goals.

Acknowledgements

We thank Gila Cliff Dwellings NM former Chief of Interpretation, Rita Garcia, for her helpful information and thorough reviews. We also are indebted to the NPS Sonoran Desert Inventory and Monitoring Network (SODN) staff, Andy Hubbard, Kristen Bonebrake, Sarah Studd, Evan Gwilliam, and Alice Wondrak Biel, and former staff, 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 expert reviews and information for most assessment topics.

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

And finally, to all of the additional reviewers and contributors, who are listed in Appendix A, we thank you. Your contributions have increased the value of Gila Cliff Dwellings NM's NRCA report.

Little Bear Canyon. Photo Credit: NPS.

NRCA Background Information

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

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

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

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

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

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

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

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

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

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

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

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

Gila spotted whiptail. 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.

Looking toward Gila Cliff Dwellings NM Administration buildings. Photo Credit: NPS/B. Fields.

Introduction and Resource Setting

Introduction

Enabling Legislation/Executive Orders

The area in which Gila Cliff Dwellings National Monument (NM) is located has a long record of occupation by prehistoric peoples from several thousand years BC to historical times (Nichols 1988). The Mogollon culture evolved from the Cochise hunter-gatherer culture circa 200-300 BC as an agriculturally based society that settled in open areas with reliable water sources and level land suitable for irrigation. In southwestern New Mexico, the early Mogollon lived in aggregations of pit houses, but by AD 900 they began to inhabit villages of aboveground masonry buildings in open areas and natural caves (Nichols 1988, Parent 1992, NPS 2003). To preserve the collection of prehistoric ruins in this area of the U.S. Forest Service (USFS) Gila National Forest, two sites were set aside as a national monument.

On November 16, 1907, Presidential Proclamation No. 781 (35 Stat. 2162) set aside a group of cliff dwellings because of their ". . . exceptional scientific and educational interest, being the best representative of the Cliff-Dwellers' remains of that region" as Gila Cliff Dwellings NM along "with as much land as may be necessary for the proper protection thereof." The monument was not intended to interfere with the operation of the Gila National Forest, but if uses did come into conflict, the monument would be the dominant reservation.

On July 23, 1908, Executive Order 919 withdrew approximately 225 ha (557 ac) from the Gila National Forest for military purposes, specifically to protect the water supply of Fort Bayard, located to the south of the monument. In this case, the War Department reservation had precedence over that of the USFS if uses should come into conflict.

On April 9, 1962, Public Land Order 2655 (27 FR 3609) withdrew 43 ha (107 ac) for use as a joint USFS/National Park Service (NPS) administrative site and recreation area.

On April 17, 1962, Presidential Proclamation No. 3467 added approximately 152 ha (375 ac) that contained additional cliff dwellings and pit-house sites "needed to round out the interpretive story" for the monument. Just over 21 ha (53 ac) of this addition became the separate TJ Unit, which encompasses pit houses dating from approximately AD 100-400 and a large unexcavated pueblo site (Casey 1976).

Administration of Gila Cliff Dwellings NM has shifted several times between the NPS and the USFS over the monument's more than 100-year history. The USFS managed the monument from 1907 until 1933, when the NPS assumed management responsibilities. In 1975, management was returned to the USFS, but since 2003, an NPS superintendent has overseen the monument, working in close cooperation with the USFS (Powell et al. 2006, NPS 2007).

According to the monument's Foundation for Planning and Management (NPS 2007), Gila Cliff Dwellings NM encompasses a total of 45 prehistoric sites, most not open to the public, on 215 ha (533 ac). The archeological sites as a whole "represent at least 2,000 years of human occupation of the Gila River headwaters area." These sites include rock shelters from the Archaic period, structures from the Early and Late Pithouse and Classic Mimbres Pueblo period, cliff dwellings, the foundations of Salado buildings, and a possible Apache grave. The monument is the only unit in the NPS that represents the Mogollon Culture, one of the three major prehistoric cultures of the southwestern United States.

The monument is comprised of two sites – the Cliff Dwellings unit and the TJ unit. The Cliff Dwellings unit covers 194 ha (480 ac ; NPS 2012a) and contains the namesake cliff dwellings built by the Tularosa phase Mogollon between AD 1270 and 1290 (Parent 1992) and occupied from roughly AD 1275-1300 (NPS 2007), as well as a visitor contact station. Cliff dwellings were not commonly used as residences by the Mogollon, and the Gila cliff dwellings are among the last built by them before they were assimilated with other cultures in the region (Parent 1992). The TJ unit covers just over 21 ha (53 ac; NPS 2012a) that are adjacent to the joint NPS/USFS visitor center. Surface studies suggest that the TJ site was used from approximately AD 400-1400. This unit protects the "last known intact Mogollon pueblo of its size from the Classic Mimbres phase" (NPS 2007).

The importance of natural resources to interpreting the relationship between the long history of human habitation and the area's environment is expressed in the monument's Foundation Document (NPS 2016). Significance statement #3 states:

> The combination of springs, rivers, narrow canyons, and unique caves, and the resulting biodiversity in and around Gila Cliff Dwellings National Monument, enticed and sustained human cultures for thousands of years. The cultural resources of the monument are preserved within their natural setting due to their remoteness and location within the Gila Wilderness—the world's first designated wilderness area.

Additionally, one of the monument's fundamental resources and values statement (NPS 2016) further elaborates on the significance of its natural resources:

> Scientific Value. The pristine, multicomponent TJ unit and the remarkably intact cliff dwellings offer outstanding opportunities for ongoing and future scientific inquiry including comparison with other Tularosa and Mimbres Mogollon sites as well as other major southwestern precontact cultures. The monument's cultural resources exhibit a continuum of human use for anthropologic and ethnographic study. Research of the ongoing erosional processes that created the unique complex of caves and narrow Cliff Dweller Canyon could provide insight into the timing of major geologic events that helped shape the region. Comparisons of natural resources in the area today with similar resources within the archeological record may provide opportunities for ethnobiological studies and can also be used to gauge the impact of climate change over time. The park is surrounded by more than 558,000 acres of wilderness with minimal historic impacts from humans. These ecosystems are a unique living laboratory of near-pristine conditions, providing an important reference site for more impacted areas within the region.

Geographic Setting

The monument is in a sparsely inhabited area in southwestern New Mexico's Catron County at the end of a minor highway that connects it to the nearest incorporated town of Silver City, approximately 75 km (46 mi) to the southeast, and the town of Mimbres (Powell et al. 2006), both in neighboring Grant County. The two units of Gila Cliff Dwellings NM are located slightly less than 3.2 km (2 mi) apart (Casey 1976) along the Gila River (Figure 1). The total area of the two units is 216 ha (just over 533 ac; NPS 2012a),

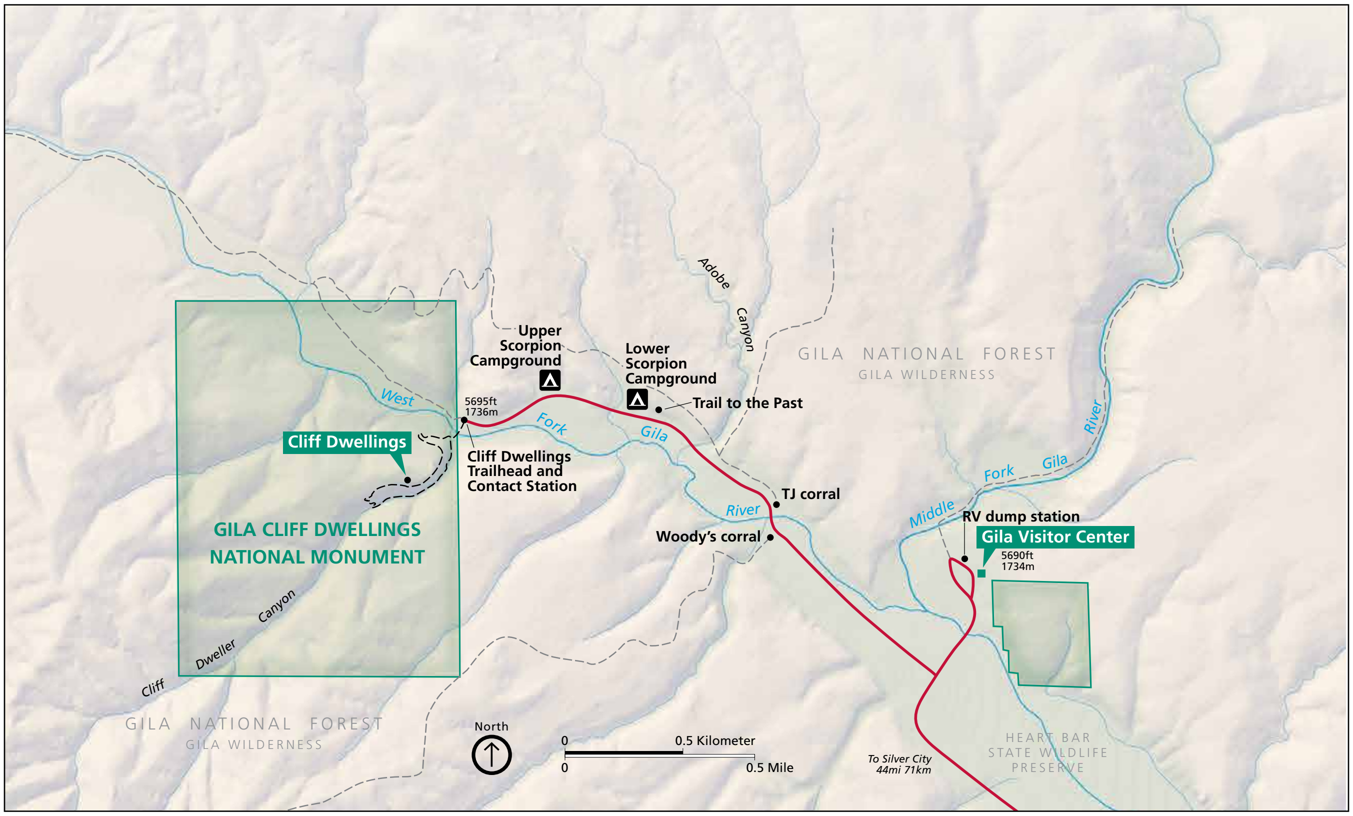


Figure 1. **Gila Cliff Dwellings NM is located along a winding, mountainous road, approximately 71 km (44 mi) northwest of Silver City, New Mexico.**

and both units are surrounded by the 1.3 million ha (3.3 million ac) of the Gila National Forest and the 202,343-ha (500,000-ac) Gila Wilderness (NPS 2007).

Gila Cliff Dwellings NM is located at approximately 1,800 m (6,000 ft) in rugged terrain typical of the Arizona-New Mexico Mountains ecoregion (Bell et al. 1999) and the Basin and Range topography of the intermountain west (Scarborough 2000 as cited in Gwilliam et al. 2012). The monument sits in a valley, about 0.31 km (0.5 mi) across at its widest reach, bordered by the Mogollon Range to the west, the Black Range to the east, and the Pinos Altos Range to the south (Russell 1992). The Cliff Dwellings unit is characterized by two high mesas overlooking Cliff Dweller Canyon, a deep cleft in which the dwellings were built. Cliff Dweller Canyon Spring flows perennially through the canyon, which opens onto the West Fork of the Gila River. The West Fork trends to the southeast at the mouth of the canyon toward its confluence with the Middle Fork. A few miles downstream, the combined forks are joined by the East Fork near the unincorporated town of Gila Hot Springs (Mau-Crimmins 2005). The TJ unit lies atop a mesa that overlooks the confluence of the West and Middle Forks (Russell 1992).

Gila Cliff Dwellings NM is located in Catron County, New Mexico, just north of its border with Grant County. Silver City, NM, the Grant County seat, is the largest town in the vicinity of the monument with a population of 9,647 (U.S. Census Bureau 2018). The only other community closer to the monument is Gila Hot Springs, about 3.2 km (2 mi) to the southeast. Both towns benefit from tourism to the monument and to the surrounding Gila National Forest and Wilderness, especially in the summer months. Catron County is the largest county by area in southwestern New Mexico. According to the U.S. Census Bureau (2018), in July 2016, the population in Catron County was 3,508, representing a -5.9% population decrease since 2010. Grant County had a population of 9,298 in July 2017, representing a growth of 1.3% since 2010 (U.S. Census Bureau 2018).

The Southwestern or Arizona climate pattern, 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, is predominant in southwestern New Mexico. However, the mountains in the area influence this pattern by concentrating precipitation at the higher elevations and channeling that moisture down to the valley bottoms through perennial streams such as the three forks of the Gila River (Powell et al. 2006).

The NPS' Sonoran Desert Inventory and Monitoring Network (SODN) (2018) reports the following precipitation results for Gila Cliff Dwellings NM:

> In WY2016, overall annual precipitation was 113% of normal for Gila Cliff Dwellings National Monument (18.35" vs. 16.26"). Overall precipitation was essentially normal (104% or +0.29") for the fall and winter of WY2016—but rainfall in February and April represented less than 20% of normal. November was dramatically wetter than normal—288% of normal. Overall precipitation was above average (119%, 1.80") for the spring and summer months. Again, though, monthly variation was extensive. April and September were 200% wetter than normal. June rainfall was only 36% of normal. Drought indicators show that the last two "wet" years have not been enough to eliminate the multi-year precipitation deficit.

There is a considerable range in daily and seasonal air temperatures (Bell et al. 1999), and the average annual temperature in the region is 10.5°C (51°F; Mau-Crimmins et al. 2005). April-October is the hot season when temperatures often exceed 30°C (86°F; Gwilliam et al. 2012), and July is the warmest month (Mau-Crimmins et al. 2005). January is the coldest month, and winter temperatures can fall to -9°C (15°F) when snow is common (Mau-Crimmins et al. 2005).

Visitation Statistics
Located at the end of a twisting, winding road after a 2-hour drive from Silver City, Gila Cliff Dwellings NM is one of the lesser visited units in the National Park System. Annual visitation at the monument was fewer than 1,000 visitors between 1934 and 1955, with zero visitors recorded from 1942-1947 (Figure 2). Visitation gradually increased between 1956 and 1963, and then experienced a sharp rise to 24,000 visitors in 1964 (NPS Public Use Statistics Office 2019), following the completion of the first paved road to the forks of the Gila River and the appointment of a full-time NPS ranger to manage the monument (Russell 1992). Subsequently, the number of visitors generally increased until 1978, dropped by about 10,000 in 1979, then increased to a peak of 62,292 in 1995. Since then, visitation has generally declined, reaching a low of 25,317 in 2011, then sharply increasing to the highest number of visitors ever recorded, 78,872, in 2017 (NPS Public Use Statistics Office 2019). Note that 2018 visitation data were not available as of February 2019.

Natural Resources
Ecological Units and Watersheds
Gila Cliff Dwellings NM is situated at the intersection of three major ecological provinces – the Rocky Mountains, the Chihuahuan Desert, and the Sierra Madre Mountains (or Madrean; NPS 2007). According to Bell et al. (1999), the monument is within the Arizona-New Mexico Mountains Ecoregion, as defined by The Nature Conservancy, which covers nearly 12.1 million ha (30 million ac) of highlands in western and central New Mexico, eastern Arizona, and east-central Texas. Characterized by plateaus and mountain ranges amid desert plains, it is an extremely diverse physiographic region with elevations ranging from approximately 1,371.6 to 3,048 m (4,500 to 10,000 ft). The region is ". . .based upon the oldest mountains in the Southwest, containing Precambrian igneous rocks as old as 1.5 billion years. . . overlain with more recent sediments (including important fossil deposits from the Jurassic and Triassic) and volcanics (including volcanic flows and calderas from as recently as 600 years ago" (New Mexico Department of Game and Fish [NMDGF] 2006) The headwaters of the Gila, Little Colorado, San Francisco, Mimbres, and Verde rivers originate in these mountains (NMDGF 2006). The Mogollon Rim is a prominent feature that defines the southern edge of much of the region (Bell et al. 1999).

Terrestrial habitats common at higher elevations are Madrean pine-oak, conifer-oak forests and woodlands, Rocky Mountain forests and woodlands, and Rocky Mountain montane mixed conifer. Piñon-juniper/juniper savanna, steppe and grasslands, Chihuahuan semi-desert grasslands, and Western Great Plains shortgrass prairie are prevalent at lower elevations. Riparian forests are found throughout the ecoregion (NMDGF 2006). The Arizona-New Mexico Mountains contain more bird and mammal species than any other ecoregion in the Southwest, including more than 200 rare plants and animals.

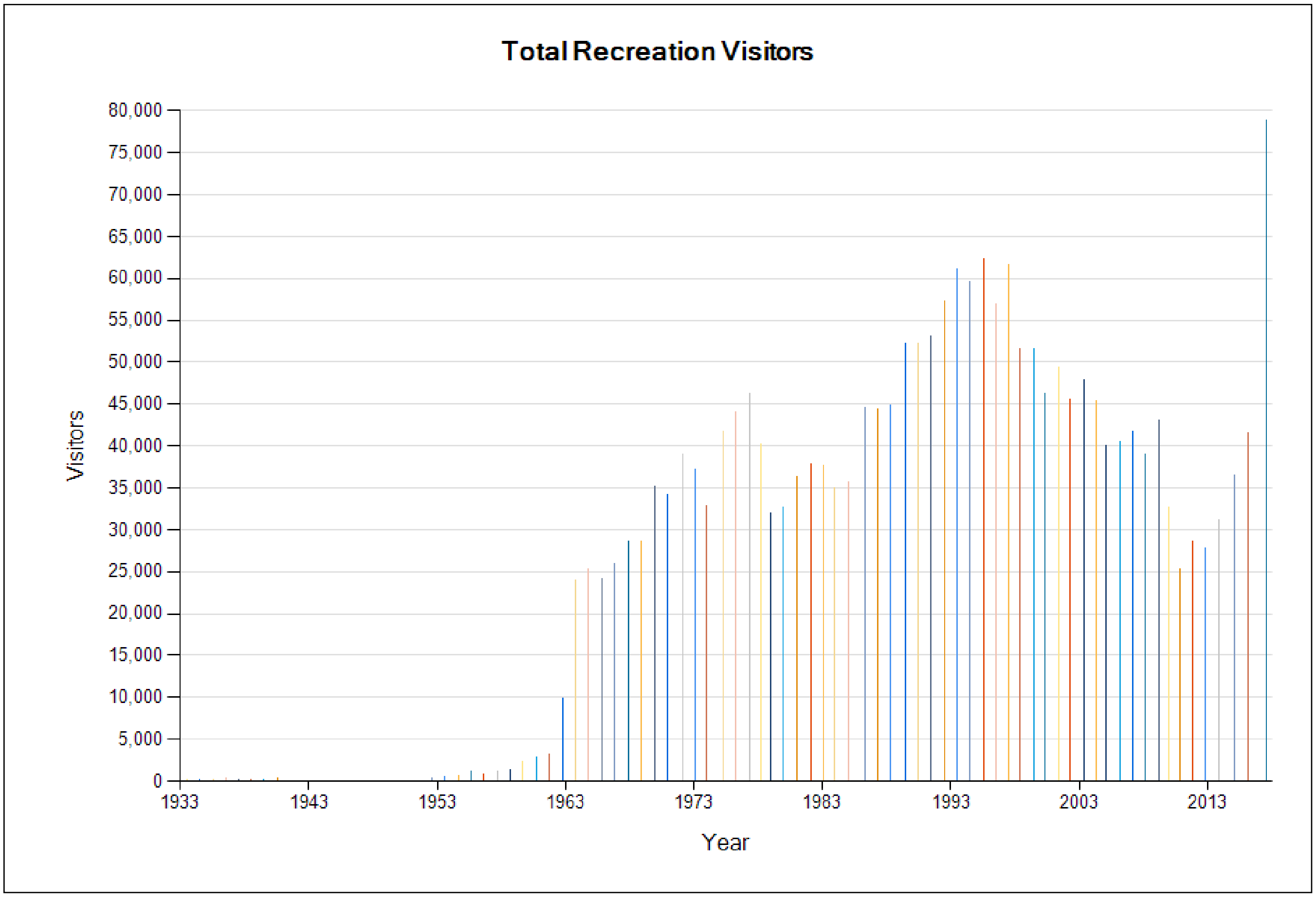


Figure 2. Total number of annual visitors to Gila Cliff Dwellings NM from 1934-2017. Figure Credit: NPS Public Use Statistics Office 2019.

Gila Cliff Dwellings NM lies within the upper Gila River watershed, which drains nearly 33,670 km^2 (13,000 mi^2) of rugged mountains, broad intermountain plains, and flat, gentle valleys in southwestern New Mexico and southeastern Arizona; elevations range from 793 to 3,355 m (2,600 to 11,000 ft; Steiner et al. 2000). According to the NMDGF (2006), the Gila's West, Middle, and East Forks are formed by the joining of headwaters streams originating in the Mogollon Mountains. The Middle Fork flows into the West Fork about 0.8 km (½-mi) downstream from Cliff Dweller Canyon (Sprouse et al. 2002), and the East Fork joins the West Fork approximately another 6.4 km (4 mi) to the southeast (Figure 3). The Gila is the only remaining undammed major river in New Mexico (Gila Conservation Coalition 2019). The watershed contains several small lakes, including Snow, Roberts, Wall, and Bill Evans. Snow and Roberts Lakes are on USFS land, Bill Evans Lake is owned by the NMDGF, and Wall Lake is privately owned. Non-native fish predominate in the lakes; any native fish are incidental.

Resource Descriptions

Gila Cliff Dwellings NM and the Gila Wilderness lie within the Gila Cliff Dwellings caldera in the Mogollon-Datil volcanic field (NMBGMR 2012) in the southern Rocky Mountains volcanic province, which extends from Colorado's southern Rocky Mountains to Mexico's Sierra Madre Occidental. The region's geology was shaped by alternating periods of volcanic eruptions, faulting, and erosion over millions of years (GNF 2003). The area is characterized by plateaus consisting of rhyolite, andesite, basalt, and welded tuffs interbedded with Gila Conglomerate rock, while the valleys are characterized by shallow alluvial floodplain deposits (Powell et al. 2006). Block faulting created both the valley through which the Gila River flows today as well as the rolling mesas between the three forks of the river (Russell 1992). Evidence of past and continuing volcanism in this area is revealed by the presence of geothermal springs along the river (Russell 1992), with temperatures ranging between 32° and 65°C (90° and 150°F) (Sprouse et al. 2002).

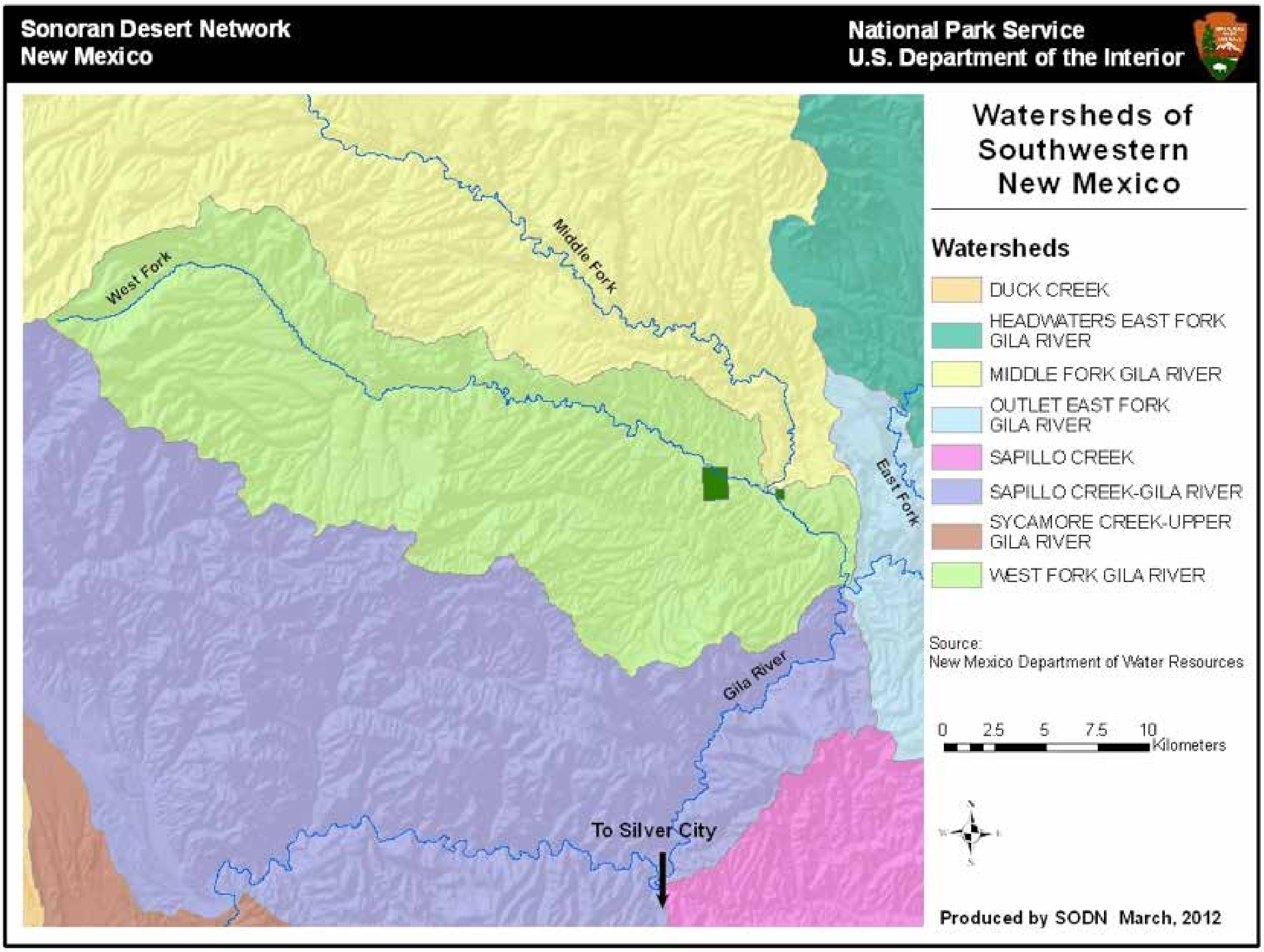


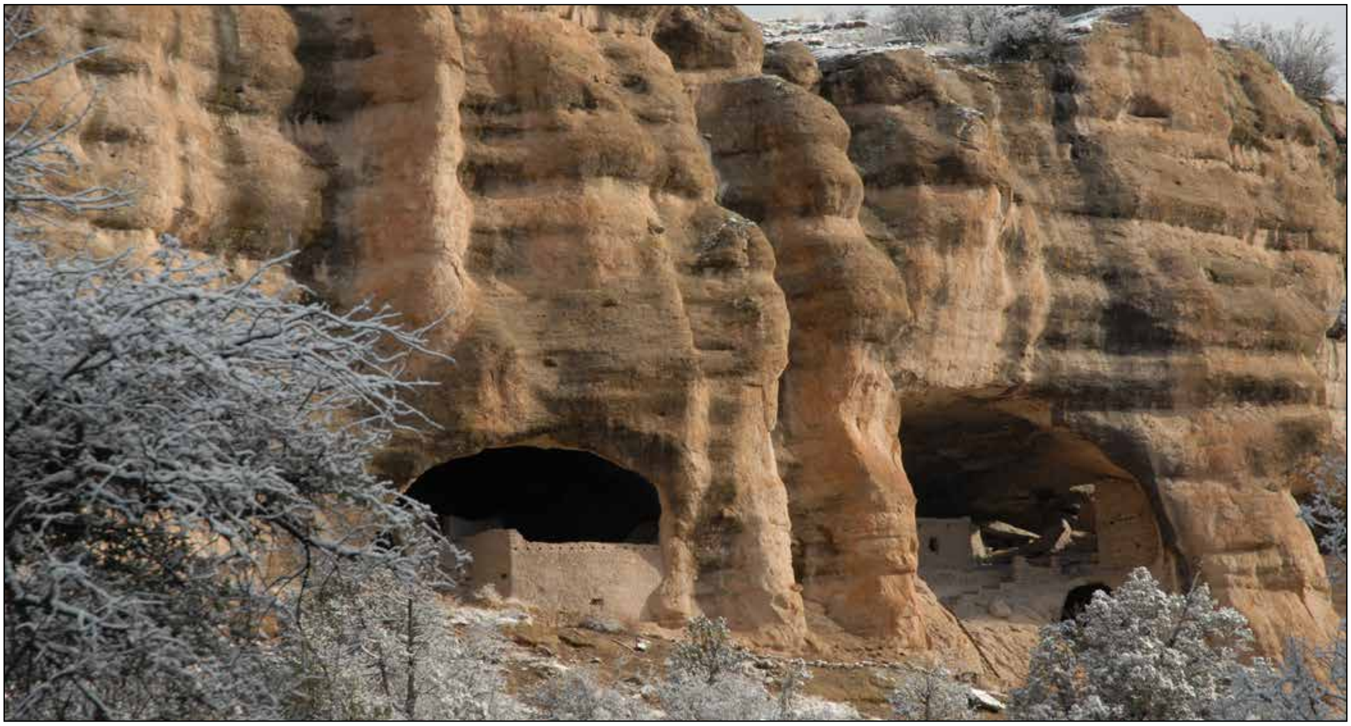
Figure 3. Watersheds of southwestern New Mexico, surrounding Gila Cliff Dwellings NM. Figure Credit: NPS SODN 2012.

The cliff dwellings were built in caves, formed in Gila Conglomerate rock at its interface with harder lava flows below, by erosion from Cliff Dweller Creek, spring sapping, and exfoliation (NPS 2007).

Soils are derived from Tertiary volcanics in the area (Powell et al. 2006). Nauman (2011) found that rock surface cover and soil aggregate stability influence soil texture and chemistry, and surface soils in the uplands are sandy loams and sandy clay loams with a wide variety of pH, solute, and organic carbon levels. Hubbard and Studd (2010) found that upland soils are very well armored with <5% bare mineral soil; however, most of the resistant soil cover is composed of vegetation, leaf litter, and duff, which are quickly eliminated by wildfire or extended droughts. The inherent instability of sites due to low surface soil aggregate stability could result in significant soil erosion if soil cover is lost.

Gila Cliff Dwellings NM is designated as a Class II airshed. In 1980, the NPS recommended an upgrade to Class I, likely due to its location in the heart of the Gila Wilderness, which is automatically designated as Class I (Russell 1992). There are few point sources of air pollution in the immediate vicinity of the monument, and no new sources or developments are expected in the near future (NPS 2003). Visibility trend data were collected at the IMPROVE monitoring station GICL1, NM, which is located just outside the monument in the Gila Wilderness (see the air quality assessment for further details).

The major hydrologic feature in the Gila Cliff Dwellings NM area is the Gila River: New Mexico's last free-flowing river and the longest undammed stretch of river in the contiguous 48 states. Listed on the Nationwide Rivers Inventory, it may be eligible for designation as a national Wild and Scenic River (NPS 2007). The West and Middle Forks of the Gila drain



Gila Cliff Dwellings in winter. Photo Credit: NPS/B. Fields.

approximately 4,200 km^2 (1,620 mi^2; Powell et al. 2006) of the southern Rocky Mountains at an average rate of discharge of 5 m^3/s (177 cfs; Trauger 1963 as cited in Russell 1992). Cliff Canyon Spring, one of several natural springs in the area, feeds Cliff Dweller Creek, which flows perennially through Cliff Dweller Canyon (NPS 2007). Upstream weather events influence stream flow, resulting in high variability (Gwilliam et al. 2012). Recharge of major streams and tributaries is directly dependent upon precipitation within the drainage area (Mau-Crimmins 2005), and heavy storm events, particularly after spring snowmelt, typically cause flash flooding that can result in major erosion events (Powell et al. 2006; NPS 2007). Flows during spring run-off in March and April can reach 10 and 11 m^3/s (354 and 386 cfs), respectively (Russell 1992). Except where exposed in perennial streams, depth to groundwater is over 152.4 m (500 ft). The primary aquifer in the region is Gila Conglomerate, which generally yields 1-500 gallons per minute, depending upon the extent of rock consolidation (Bradford 1992).

While water quality monitoring at the West Fork of the Gila River index site indicates good conditions, there are some exceedences. Most, however, appear to be the result of natural disturbances. Even though two large fires, Miller Fire of 2011, which passed through the monument and the Whitewater-Baldy Complex of 2012, which covered a large part of the watershed directly above the park have occurred, due to a history of fire suppression, the area's hydrologic regime has been affected by an increase in woody plants. These plants include piñon/juniper (*Pinus edulis*/*Juniperus* spp.), which can lower the water table, affect rates of infiltration and evapotranspiration, water runoff, and stream flow. In turn, changes in these processes, as well as the effects from the wildfires, may affect the distribution and abundance of plants and animals, increase drought severity and/or flash flood events, such as the massive floods of 2013, adversely affecting water quality (NPS 2007).

For such a small park at its geographic location and elevation, Gila Cliff Dwellings NM has high plant species richness due to the diversity of soil conditions, microsites, and water availability (Powell et al. 2006). Madrean evergreen woodland, with oaks (*Quercus* spp.), piñon, and juniper, are found on the mesa above the cliff dwellings and on south-facing slopes of the TJ unit. North-facing slopes and Cliff Dweller Canyon are dominated by coniferous forests of ponderosa pine (*Pinus ponderosa*) and Douglas fir (*Pseudotsuga menziesii*). Deciduous riparian vegetation consisting of narrowleaf cottonwood (*Populus angustifolia*), ash (*Fraxinus velutina*), and walnut (*Juglans* spp.) are found in canyon bottoms and the floodplain of the West Fork of the Gila River. The surrounding Gila National Forest, in fact, "contains some of the most extensive stands of virgin ponderosa pine remaining anywhere in the widespread range of this species" (NPS 2003).

A comprehensive biological inventory between 2001 and 2003 (Powell et al. 2006) recorded 388 plant species at the monument, of which 37 were non-natives. Based on this survey and one conducted by Sherman Lambert in the mid-1970s, 471 species have been documented within monument boundaries and on surrounding lands. Even so, there are likely other plant species that they did not find. For example, they did not find four rare or endangered plants—Hess' fleabane (*Erigeron hessii*), Chenopod brickellbush (*Brickellia chenopodina*), Gila manroot (*Marah gilensis*), and Maguire's Penstemon (*Penstemon linaroides* ssp. *maguirei*)—that may occur in the area (based on Sivinski and Lightfoot 1992).

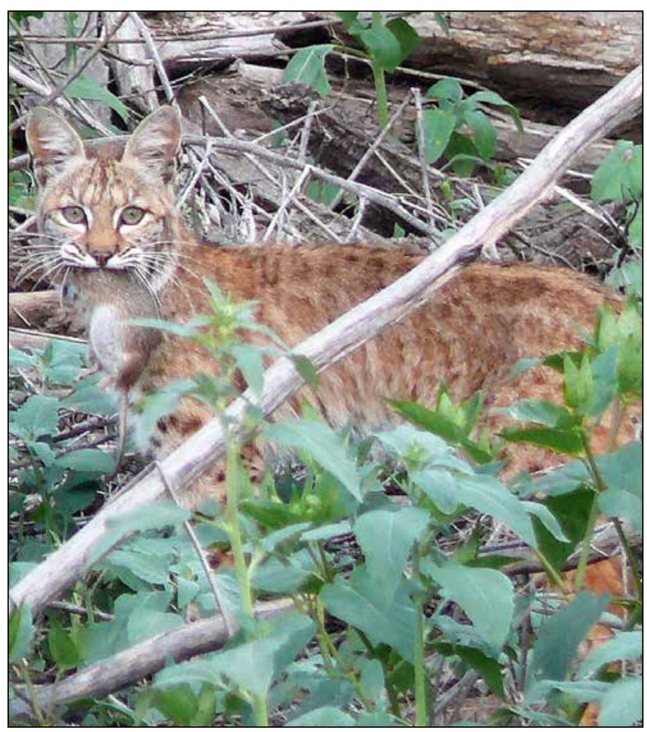
Hubbard and Studd (2010) detected 11 plant species that were previously unknown at the monument, including a new non-native, silversheath knotweed (*Polygonum argyrocoleon*). They also observed one other non-native, common mullein (*Verbascum thapsus*).

The diversity of aquatic and terrestrial habitats in Gila Cliff Dwellings NM supports a wide variety of wildlife. Terrestrial species include birds, large and small mammals, and reptiles. Aquatic species include fish, amphibians, and insects.

There are 158 confirmed bird species for the monument, but there may be as many as 202 if confirmed. During the monument's 2001 and 2002 baseline inventory, primarily during breeding season, at the Cliff Dwellings unit only, Powell et al. (2006) recorded 107 native bird species. All but three were inside the monument boundary. Powell et al. (2006) characterized the bird community as moderately diverse for the size of the monument and the moderate search effort. SODN conducts repeat surveys along two transects. One is located in the riparian habitat and was surveyed from 2009-2010 and from 2012-2015. The upland transect was surveyed in 2010 and 2012-2015 (Beaupré et al. 2013). Currently, the monument's bird survey data suggest that there have been few changes to the bird community except for the relatively recent introduction of the non-native Eurasian collared-dove (*Streptopelia decaocto*).

A total of 57 mammal species have been documented either as present in the monument or within the adjacent area during surveys conducted by Hayward and Hunt (1972) or Powell et al. (2006). Powell et al. (2006) documented the majority of species during their comprehensive biological inventory in 2001 and 2002 using six survey methods. Both surveys occurred prior to the Miller and the Whitewater-Baldy Complex Fires, which resulted in massive flooding in 2013 dramatically altering the landscapes of the Forks of the Gila. Mammal populations likely changed as a result of the fires affecting the habitats throughout the region.

Twenty-five herpetofauna species have been observed during at least one of the four surveys within or around Gila Cliff Dwellings NM (regional surveys conducted by Hayward and Hunt (1972), Painter (1985), and Jennings et al. (2010). Powell et al. (2006) conducted the monument's baseline survey and recorded 16 reptiles and three amphibians at Gila Cliff Dwellings NM and an additional two reptiles within 5 km (3.1 mi) of the monument. While they believe they found all of the common and most of the expected species, they did not find five that are considered likely to occur. Overall, the herpetofauna community is relatively diverse and reflects the wide variety of environmental



Bobcat with rodent. Photo Credit: © Dave Velk.

conditions at the monument. The American bullfrog (*Lithobates catesbeiana*), the only non-native species recorded during the baseline inventory, had the highest relative abundance of any herpetofauna species found.

The NMDGF has conducted an active fish monitoring program on the West and Middle Forks of the Gila River since 1988 (reviewed in Propst 2000 as cited in Powell et al. 2006). There are an estimated 10-12 species of native fish in the Gila River Basin (Propst 1999), seven of which have been documented in the West Fork above and below the monument in recent years. Spikedace (*Meda fulgida*) and loach minnow (*Tiaroga cobitis*) are both endemic to the Gila drainage, and Sonora sucker (*Catostomus insignis*) and desert sucker (*Catostomus clarkii*) are near-endemics (Propst 1999). It is not clear whether the three to five remaining species listed by Propst (1999) historically occurred along the West Fork in and around the monument, but none of them were listed in the monument's NPSpecies list (NPS 2018a).

Resource Issues Overview

While changes in adjacent land uses, such as residential and commercial development, and other human activities threaten natural resources in most of SODN's park units, Gila Cliff Dwellings NM likely has the fewest human-encroachment-related threats of any national park in the Southwest due to its remote location in the Gila National Forest and Wilderness (NPS 2007). Nevertheless, managers are concerned with impacts from visitor use, non-native species, forest fires, degraded air quality, and aircraft noise (Steve Riley, pers. comm. as cited in Powell et al. 2006). In addition, climate change, whether due to natural or human causes, will likely impact resources in the future.

The full extent of impacts from climate change is unknown, but they likely include range shifts for plants; changes in plant cover and the composition of vegetation communities; increased erosion and transport of sediment to streams; greater risk of fires along with increased frequencies, size, and duration; spread of non-native species, increased frequency and severity of droughts; more severe precipitation and flooding events; increased tree mortality due to the interaction between drought stress and outbreaks of forest insects; and a greater likelihood of extinctions of plant and animal species (Loehman 2010). These conditions could alter the natural setting of Gila Cliff Dwellings NM, one that has changed little since prehistoric times (NPS 2007).

According to Enquist and Gori (2008), scientists believe that high-elevation areas in New Mexico may be particularly vulnerable to climate changes, partly due to the prevalence of species sensitive to drought. The majority of forests and woodlands at mid to high elevations in the state "have experienced consistently warmer and drier conditions or greater variability in temperature and precipitation from 1991 to 2005." Holden et al. (2007) found that fires are more likely to burn as high-severity crown fires as the length of rain-free periods increases, based on an analysis of satellite imagery over a 20-year time series for the Gila National Forest.

Effects on wildlife populations are also likely to occur. Cavity-nesting birds in New Mexico, such as the violet-green swallow (*Tachycineta thalassina*), western bluebird (*Sialia mexicana*), and ash-throated flycatcher (*Myiarchus cinerascens*), all observed at Gila Cliff Dwellings, are susceptible to drought-related stress; and researchers have observed impaired immune function, decreased clutch size, nestling body mass, and adult weight, as well as lower overall survival rates (Fair and Whitaker 2008 as cited in Loehman 2010). Disease in the monument's wildlife populations may escalate as the presence of West Nile virus, plague, and hantavirus increases in response to changes in minimum and mean temperatures and the amount and timing of precipitation (Patz et al. 2000, Epstein 2001,

Narrow-headed gartersnake. Photo Credit: NPS.

Field et al. 2007, all as cited in Loehman 2010). Even cultural resources may be at risk. According to the "Vanishing Treasures" program (NPS 1998), Gila Cliff Dwellings NM is a cultural resource in "immediate, imminent danger from natural erosive factors," and the potential increases if wildfires and flooding result in even greater rates of erosion.

Recently, Monahan and Fischelli (2014) evaluated which of 240 NPS parks have experienced extreme climate changes during the last 10-30 years, including Gila Cliff Dwellings NM. 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 Gila Cliff Dwellings NM were reported as follows:

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

Results for the temperature of each year between 1901-2012, the averaged temperatures over progressive 10-year intervals, and the average temperature of 2003-2012 (the most recent interval) are shown in Figure 4. The blue line shows temperature for each year, the gray line shows temperature averaged over progressive 10-year intervals (10-year moving windows), and the red asterisk shows the average temperature of the most recent 10-year moving window (2003–2012). The most recent percentile is calculated as the percentage of values on the gray line that fall below the red asterisk. The results indicate that recent climate conditions have already begun shifting beyond the HRV, with the 2003-2012 decade representing the warmest on record for the monument (Monahan and Fisichelli 2014).

Visitor use has impacted resources in a number of ways over the monument's history. According to Russell (1992), pothunting, burning at the cliff site, and other types of vandalism, common in the 1800s, declined following the designation of the site as a national monument in 1907. He noted, however, that the growing number of visitors to the monument may threaten resources. He observed that climbing on, leaning on, or touching the walls of the dwellings may directly impact these resources and vibrations generated by walking can indirectly cause damage—all of which are still a significant concern today (Steve Riley, pers. comm. as cited in Powell et al. 2006). Although a study of the monument's visitor carrying capacity has been requested by staff (Nichols 1988); to date no study has been funded (Powell et al. 2006).

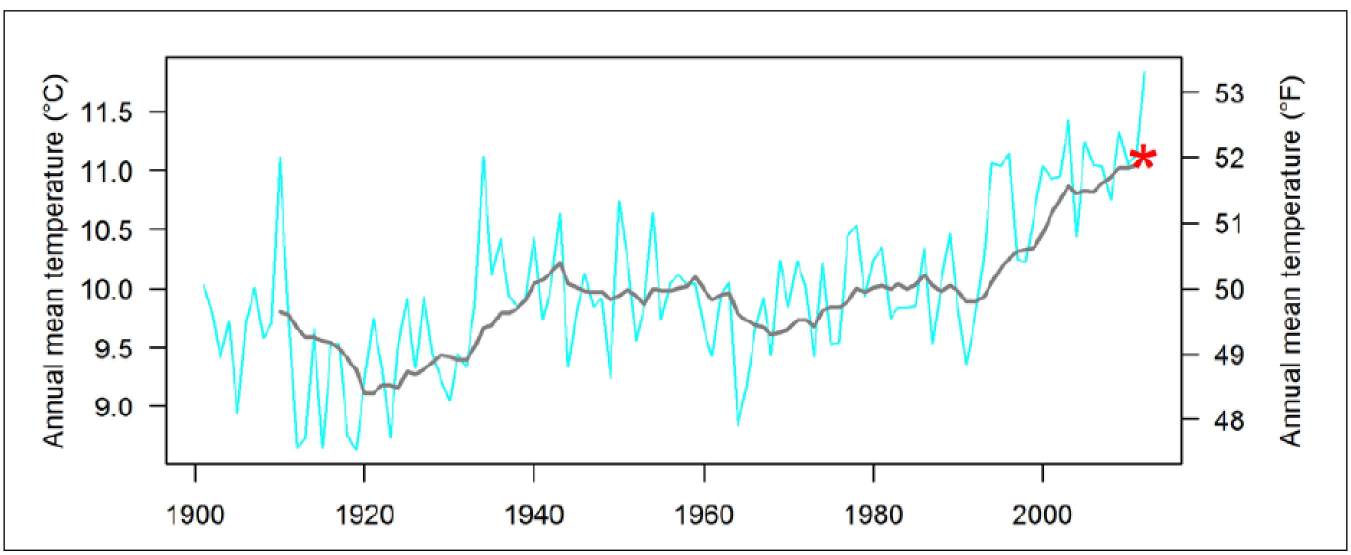


Figure 4. Time series used to characterize the historical range of variability and most recent percentile for annual mean temperature at Gila Cliff Dwellings NM (including areas within 30-km [18.6-mi] of the park's boundary). Figure Credit: Monahan and Fisichelli 2014.

Off-trail hiking and trampling can degrade soil stability and vegetation structure, evidenced by erosion on steep slopes along the trail to the cliff dwellings (Nichols 1988). Powell et al. (2006) identified several other potential impacts. Seed detached from visitors' clothing or automobiles may introduce non-native plants into the monument environment, and disturbed soils and precipitation runoff along the main access road facilitate seed germination and establishment. Human activities can affect animal movement patterns, particularly the activity patterns of medium- and large-sized mammals. Monument staff and volunteers have long been concerned for the protection of black-tailed rattlesnakes (*Crotalus molossus*) along the trail to the cliff dwellings. Some birds may alter their nesting activities (e.g., nest abandonment and failure to defend nests against predation) and feeding patterns due to continual disturbances, such as recreational hiking nearby (Hockin et al. 1992, Theobald et al. 1997, Swarthout and Steidl 2003, all as cited in Powell et al. 2006). Mortality of terrestrial species may also increase as visitors and traffic increase (Powell et al. 2006).

While Hubbard and Studd (2010) concluded that vegetation as of 2009 in Gila Cliff Dwellings NM was within the range of natural variability, there have been two major fires in and around the monument that have caused significant changes to soil stability, water quality, and vegetation (NPS 2016). Some of these changes were temporary, such as high aluminum concentrations in the West Fork of the Gila River (Gwilliam et al. 2018a). Other consequences may be more long-term, such as changes to the structure and composition of vegetation.

Common mullein was the only non-native species encountered in one upland stratum in 2009. The data indicated that common mullein cover was sparse and probably would not influence native vegetation to a measurable degree (Hubbard and Studd 2010). However, since then, wildfire coupled with climate change could alter non-native plant distribution. In addition to mullein, NPSpecies lists 37 confirmed non-native species in Gila Cliff Dwellings NM (NPS 2018a). Annual surveys by the Gila National Forest for saltcedar or tamarisk (*Tamarix* species), a common invasive in riparian areas, include portions of the Middle Fork of the Gila River (Steve Riley, pers. comm. as cited in Hubbard and Studd 2010). It has not yet been detected within the monument, but changing biotic and abiotic conditions (e.g., those due to climate change, fires, etc.) may promote the dispersal of some of these non-natives in the future.

Non-native animals, on the other hand, have had a dramatic negative effect on native species. The alarming increase in non-native aquatic species is strongly believed to have contributed to the decline, even extirpation, of many native aquatic species (Powell et al. 2006). The American bullfrog, a voracious predator and competitor, is believed to have contributed to the decline of native amphibians (Hayes and Jennings 1986, Lawler et al. 1999, both as cited in Powell et al. 2006), reptiles (Schwalbe and Rosen 1988 as cited in Powell et al. 2006), and fish (Minckley and Deacon 1991 as cited in Powell et al. 2006). Non-native fish often outcompete native fish for food and space, and they have been implicated in the decline of many native species (e.g., Propst and Bestgen 1991 as cited in Powell et al. 2006) and native amphibians, such as the Chiricahua leopard frog (*Lithobates chiricahuensis*) Non-native crayfish (*Orconectes* spp.) have been reported in the Middle, but not the West, Fork of the Gila River (David Propst, pers. comm., as cited in Powell et al. 2006). Fernandez and Rosen (1996), as cited in Powell et al. 2006, believe that predation by crayfish is a major factor in the decline of the narrow-headed gartersnake (*Thamnophis rufipunctatus*), a species highly associated with aquatic habitats.

According to the NPS (2003), the area surrounding Gila Cliff Dwellings NM and the Gila Wilderness is a low fire occurrence area. Two recorded fires, one caused by lightning and one by humans, burned between 1993 and 2003 prior to the more recent fires. The landscape is broken, with changes in aspect, slope, fuel type, and fuel moisture that interrupt the progress of large fires. However, fuels built up over the past century of fire suppression increases the risk of an extreme burn. Forest fires burning with enough heat have the potential to damage or destroy cultural resources at the TJ unit (NPS 2007). Fires also impact air quality, plants, and wildlife, and can lead to soil erosion (NPS 2003, Mau-Crimmins 2005). For example, increased sediment flows can result in fish mortality (Rieman and Clayton 1997 as cited in Powell et al. 2006). However, preventive measures taken by monument staff to reduce fuel loadings around archeological sites and trails decreased damage from the Miller Fire in 2011, which burned 88,835 acres in the Gila National Forest, including both units of the monument and the administrative area. Even so, the fire burned through Cliff Dweller Canyon, and the lower section of the trail to the cliff dwellings was severely damaged (NPS 2012b).

In addition to damaging cultural and natural resources, forest fires produce smoke, which adversely affects air quality (Russell 1992). According to the NPS (2003), smoke produces particulates, CO, and other gases that may be detrimental to human health, resulting in short-term exceedances of standards. It also contributes to haze, which reduces visibility and the ability of visitors to enjoy scenic views. Degraded air quality can affect plant communities by altering regeneration, species composition, and productivity (Roundtable on Sustainable Forests 2000 as cited in Coulston et al. 2004). Several vascular plant species at Gila Cliff Dwellings NM are sensitive to high levels of ozone (Bell, In Review).

The vibrations and noise from occasional flights by low-flying aircraft over the monument may damage the walls of the cliff dwellings (Russell 1992, NPS 1994 as cited in Powell et al. 2006) and disrupt the physiology and behavior of local wildlife (NPS 1994; Luz and Smith 1976; Weisenberger et al. 1996, all as cited in Powell et al. 2006). In addition, aircraft noise can alter wilderness values, such as solitude and the natural quiet (soundscape; Russell 1992, NPS 1994, as cited in Powell et al. 2006).

Additional details pertaining to a variety of 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 the monument's purpose, significance, and fundamental resources and values, and other potential resources/ecological drivers of interest, the NPS Washington (WASO) level programs guided the selection of key natural resources for this condition assessment. This included 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. Gila Cliff Dwellings NM is part of the SODN, which includes 10 additional parks. Through a rigorous multi-year, interdisciplinary scoping process, SODN selected a number of important physical, chemical, and/or biological elements and processes for long-term monitoring. These ecosystem elements and processes are referred to as 'vital signs', and their respective monitoring programs are intended to provide high-quality, long-term information on the status and trends of those resources. Air quality, climate, groundwater, invasive exotic plants, landbirds, streams, and upland vegetation and soils were selected for monitoring at Gila Cliff Dwellings NM by SODN and monument staff (NPS SODN 2017).

The structural framework for NRCAs is based upon, but not restricted to, the fundamental and other important values identified in a park's Foundation Document or General Management Plan. NRCAs are designed to deliver current science-based information translated into resource condition findings for a subset of a park's natural resources. The NPS 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 (Figure 5).

Foundation documents describe a park's purpose and significance and identify fundamental and other important park resources and values. A foundation document was completed for Gila Cliff Dwellings NM in 2015 (NPS 2016) and was used to identify some of the primary natural features throughout the monument for the development of the NRCA.

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 monument.

Status of Supporting Science

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

SODN staff located important sources of information that were archived at the Western Archeological and Conservation Center, the monument's physical reference files, SODN's reference libraries, and numerous online databases and collections.

Figure 5. **The relationship of NRCAs to other National Park Service planning reports.**

Prior to SODN's biological inventory and vital signs monitoring projects, information on natural resources at Gila Cliff Dwellings NM was scarce, possibly due to its remote location, small size, changing administration, and focus on cultural resources (Hubbard and Studd 2010). However, a few sources provided insight into the plants and animals at the monument.

The University of Texas at El Paso (UTEP) herbarium holds a collection of 204 plant specimens made in the mid-1970s by Sherman Lambert, a UTEP graduate student, but no study documentation remains (Powell et al. 2006). The Gila National Forest conducts annual surveys for tamarisk that include portions of the West and Middle Forks of the Gila River. The NMDGF has monitored fish on the West and Middle Forks in the vicinity of the monument annually since 1988 (reviewed by Propst 2000, as cited in Powell et al. 2006). Hayward and Hunt (1972) surveyed the Wilderness Ranger District for vertebrates (mammals, birds, reptiles, and amphibians) and submitted an unpublished report to the Gila National Forest (Powell et al. 2006). They noted that Hayward trapped mammals to create a species list, and Ronnie Sidner (pers. comm. 2001, as cited in Powell et al. 2006) indicated that Hayward netted bats in 1965, but the only products were species lists. During spring, summer, and fall of 1995, Williams (1995) (as cited in Powell et al. 2006) trapped small mammals approximately 15 km (9 mi)west of the monument. Painter (1985, as cited in Powell et al. 2006) collected reptiles and amphibians from January to December 1984 in the Gila and San Francisco river drainages, summarized their distribution, and compiled museum records from three New Mexico universities. And finally, Zimmerman (1995) created a checklist of birds for the monument.

Sonoran Desert Inventory and Monitoring Network data collection at Gila Cliff Dwellings NM. Photo Credit: NPS.

Study Scoping and Design

Gila Cliff Dwellings National Monument's (NM) 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) staff, NPS Intermountain Region, and the Sonoran Institute. An on-site scoping meeting was held 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 was added as a partner to complete the monument's NRCA through a Colorado Plateau Cooperative Ecosystem Studies Unit task agreement, P17AC00953. 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 Gila Cliff Dwellings NM was held at the Gila Visitor Center on October 27, 2010. Attendees included staff members from SODN, the national monument, Chamizal National Memorial, and the Gila National Forest Wilderness Ranger District (a list of participants is included in Appendix A).

An overview of the NRCA project was presented by the SODN program manager, followed by a discussion of the management reporting areas for the monument. Meeting participants identified and outlined management reporting areas on base maps and identified the primary management and/or interpretive themes 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, we modified a framework developed by the H. John Heinz III Center for Science, Economics and the Environment (The Heinz Center 2008), which fits well with the resources at the monument.

Scoping meeting participants identified fundamental and important resources at the monument that were included in its NRCA. Where applicable, resource topics were incorporated from monument planning documents, however, topic inclusion was not limited to resources directly identified in those documents. Resources identified during the scoping process were 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 the resource was not considered a priority at the monument. In total, nine focal natural resources were selected for resource condition assessment reporting.

Within each resource category, indicators and measures were identified and are listed in Tables 1, 2, and 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

Table 1. Gila Cliff Dwellings NM natural resource condition assessment framework based on H. John Heinz III Center for Science, Economics and the Environment for landscapes.

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

Table 2. Gila Cliff Dwellings NM natural resource condition assessment framework based on H. John Heinz III Center for Science, Economics and the Environment for supporting environment.

Resource	Indicators	Measures
Hydrology	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	Temperature (°C)
	Core Water Quality	Specific Conductivity (µS/cm)
	Core Water Quality	pH (SU)
	Core Water Quality	Dissolved Oxygen (mg/L)
	Core Water Quality	Turbidity (NTU)
	Metals and Metalloids	Lead, Selenium, Copper, Magnesium, Iron, Aluminum, and Others
	Nutrients	Phosphorus, Potassium, and Others
	Nutrients	Nitrogen (Nitrate, Nitrate + Nitrite)
	Microbiological Organisms	*E. coli* (cfu/100 ml)
	Cyanide	Cyanide
	Alkalinity as $CaCO_3$Total Hardness, and Anion/Cation Balance, and Others	Alkalinity as $CaCO_3$Total Hardness, and Anion/Cation Balance, and Others
	Benthic Macroinvertebrates	New Mexico Stream Condition Index
	Benthic Macroinvertebrates	USEPA Multi-metric Index

Table 3. Gila Cliff Dwellings NM 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 (Class)
	Erosion Hazard	Annual Grass and Forb Cover (%)
	Erosion Features	Extent of Affected Area by Feature Type (%)
	Site Stability	Foliar Cover of Dead Trees (%)
	Site Stability	Foliar Cover of Dead Shrubs
	Fire Hazard	Litter and Duff Cover (%)
	Non-native Plants	Extent
	Non-native Plants	Cover
Riparian and Aquatic 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
Fish	Species Occurrence	Richness and Composition
Birds	Species Occurrence	Richness and Composition
	Species Occurrence	Presence of Species of Conservation Concern
Mammals	Species Occurrence	Richness
	Species Occurrence	Species of Conservation Concern
Herpetofauna	Species Occurrence	Species Presence / Absence
	Species Occurrence	Species Nativity
	Species Occurrence	Presence of Species of Conservation Concern

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 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
Because Gila Cliff Dwellings NM is a relatively small park within the Upper Gila River Watershed, we used the watershed as the ecological foundation for landscape indicators, if necessary. We used broad habitat types (upland vegetation vs. aquatic/riparian vegetation) 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 NRCAs, management reporting areas are defined as specific areas in each monument that differ 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 the NRCA.

Three management areas were identified for the Cliff Dwellings unit and two for the TJ unit. The primary management themes and character-defining features for each management area are shown and listed in Figures 6 and 7 and Tables 4 and 5.

General Approach and Methods
Each natural resource condition assessment relied on existing data and literature to evaluate the selected indicators. Additional data analysis was performed as needed. Where possible, data for each measure was compared to a reference condition and a condition, trend, and confidence level status was reported.

The NRCA information manager for Southern Intermountain Region Parks led the literature search and data-mining effort. A copy of the online NatureBib database containing 70 records for Gila Cliff Dwellings NM was downloaded, and the desktop version of NatureBib was used to manage the literature. Holdings information from individual records was used to locate copies of relevant documents. The information manager coordinated with the park superintendent to search park libraries and files for NPS reports, other governmental reports, and research documents. In addition, the information manager searched online data and literature sources, the Sonoran Desert Network library holdings, and the Western Archeological and Conservation Center.

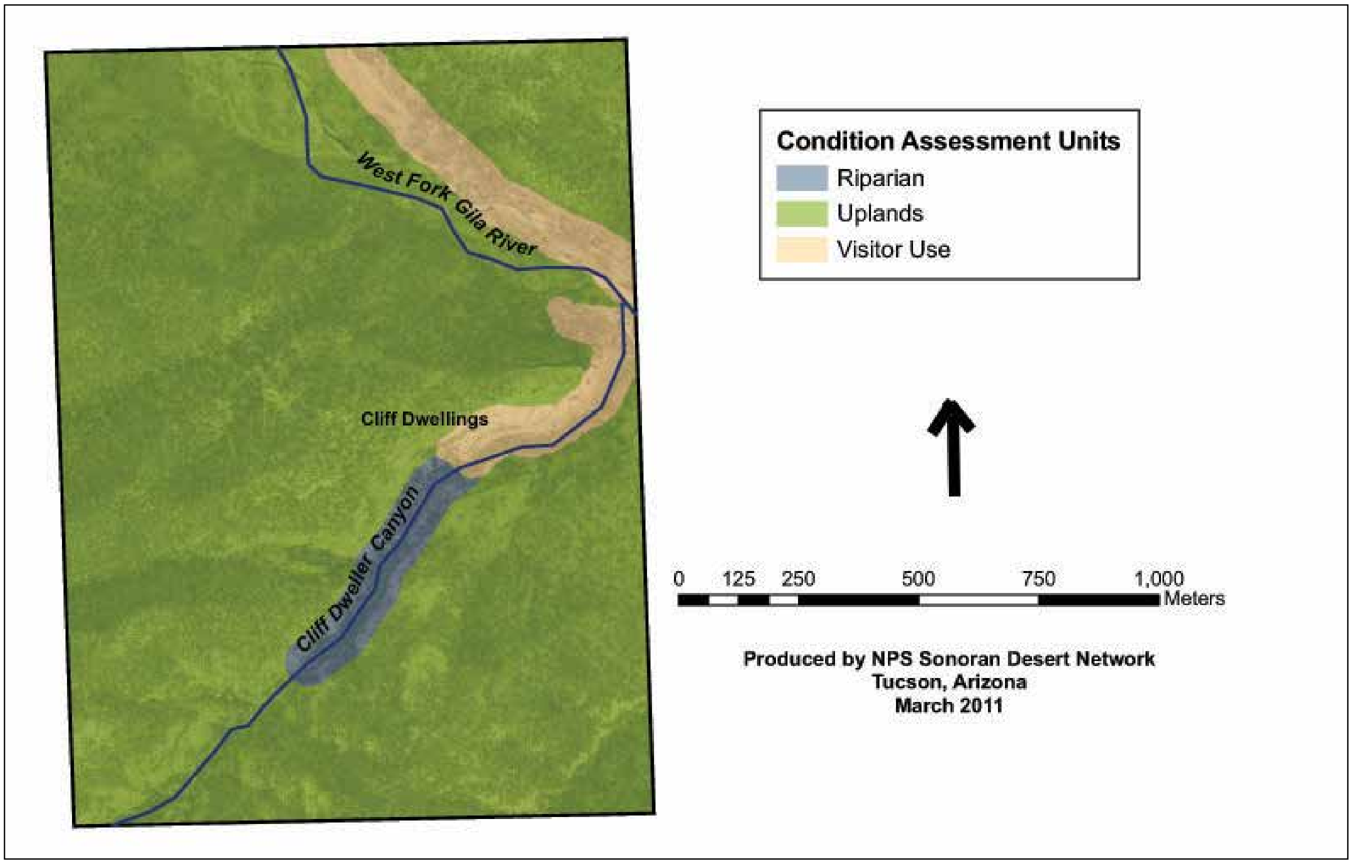


Figure 6. **Management reporting areas for the Cliff Dwellings unit of Gila Cliff Dwellings NM. Figure Credit: NPS/SODN.**

Table 4. **Natural resources for each management reporting area in the Cliff Dwellings unit of Gila Cliff Dwellings NM.**

Resource	Management Reporting Area		
	Riparian	Uplands	Visitor Use
Character-defining features	Includes riparian areas along Cliff Dweller Canyon south of the visitor use area	Primarily forested lands that are not included in the visitor use or riparian management areas	Includes the trail network and cliff dwellings
Management focus	Manage fire hazard fuels (e.g., removal of ladder fuels) around specific cultural resources, and maintain the natural riparian area appearance and continuity of the vegetation within riparian areas in the surrounding Gila National Forest so that native systems are consistent with the cliff dweller era 700 years ago.	Active fuels management to protect the cultural resources, and maintain the natural backcountry appearance and continuity of vegetation with the surrounding Gila National Forest so that native systems are consistent with the cliff dweller era.	Active fuels management to protect the cultural resources and maintain the visitor experience

During the literature-search process, the information manager identified information that was important but outside the scope of this 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 100 records.

Data were found in numerous formats, including spatial, tabular, and prose. Data analysis was specific to each indicator/measure and is described in each Chapter 4 assessment. Tabular data were managed in

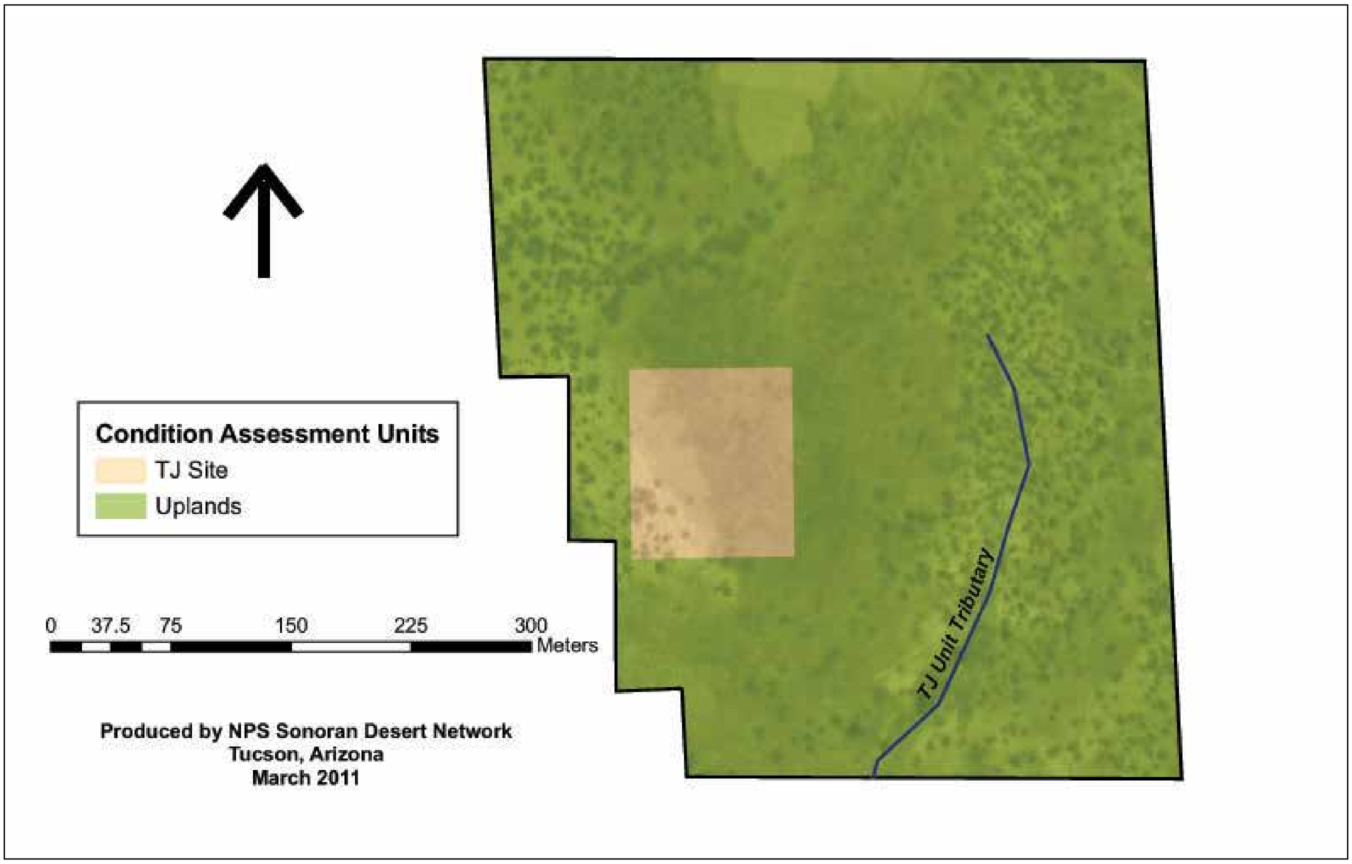


Figure 7. Management reporting areas for the TJ unit of Gila Cliff Dwellings NM. Figure Credit: NPS/SODN.

Table 5. Natural resources for each management reporting area in the TJ unit of Gila Cliff Dwellings NM.

Resource	Management Reporting Area	
	TJ Site	Uplands
Character-defining features	Includes remains of pit houses and a large unexcavated pueblo site	Primarily forested lands that not included in the TJ site management area
Management focus	Active fuels management for the protection of cultural resources.	Active fuels management to protect the cultural resources, and maintain the natural backcountry appearance and continuity of vegetation with the surrounding Gila National Forest so that native systems are consistent with the cliff dweller era.

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 weblinks for original data sources were shared.

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

1. The background and importance section of each condition assessment provides information regarding the relevance of the resource to the park.
2. The data and methods section describes the existing datasets and methodologies used for data collection, which are the indicators and measures used to evaluate current resource conditions.
3. The reference conditions section describes the good, moderate concern, and significant concern thresholds used to evaluate the condition of each measure evaluated.
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 2012c) and serve as visual representations of condition/trend/level of confidence for each measure. Table 6 shows the condition/trend/confidence level scorecard used for each assessment. Table 7 provides examples of conditions, trends, and confidence levels and associated interpretations. The level of confidence in the assessment ranges from high to low and is symbolized by the border thickness around the condition circle. 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 the resource is in good condition. A circle without any color, which is often associated with the low confidence symbol-dashed line, signifies that there is insufficient information to make a statement about condition; therefore, condition is unknown.

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

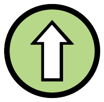
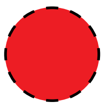
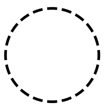
5. The sources of expertise section includes the individuals or programs that were consulted. Assessment author(s) are also listed for each condition assessment.

After the report is published, a disk containing a digital copy of the final report, copies of the literature cited (with exceptions listed in a READ ME document), reviewer comments and writer responses if comments weren't incorporated into the assessment, and any unique GIS datasets created for the purposes of the NRCA was sent to Glia Cliff Dwellings NM staff and the NPS IMR NRCA Coordinator per agreement stipulations.

Table 6. 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 7. Example indicator symbols and descriptions of how to interpret them.

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


Bobcat kitten at Gila Cliff Dwellings NM. Photo Credit: NPS.

Natural Resource Conditions

Chapter 4 delivers current condition reporting for the nine important natural resources and indicators selected for Gila Cliff Dwellings NM NRCA report. The resource topics are presented following the H. John Heinz III Center for Science, Economics and the Environment (The Heinz Center 2008) framework that is presented in Chapter 3.

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). At 245 ha (605 ac) Gila Cliff Dwellings National Monument (NM) is designated as a Class II airshed (NPS 2016). 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 standards establishing limits to protect public welfare

A view of a cloudy day near the confluence of West and Middle Forks Gila River. Photo Credit: NPS/Bruce Fields.

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 Gila Cliff Dwellings NM.

Mercury and other toxic pollutants (e.g., pesticides, dioxins, PCBs) accumulate in the food chain and can affect both wildlife and human health. Elevated levels of mercury and other airborne toxic pollutants like pesticides in aquatic and terrestrial food webs can act as neurotoxins in biota that accumulate fat and/or muscle-loving contaminants. Sources of atmospheric mercury include by-products of coal-fire combustion, municipal and medical incineration, mining operations, volcanoes, and geothermal vents.

High mercury concentrations in birds, mammals, amphibians, and fish can result in reduced foraging efficiency, survival, and reproductive success (NPS ARD 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 Gila Cliff Dwellings NM's airshed was developed by the NPS ARD for use in Natural Resource Condition Assessments (NPS ARD 2018). The indicators are visibility (one measure), level of ozone (two measures), and wet deposition (three measures) (Table 8). For conditions, 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. Trends were computed from data collected over a 10-year period at on-site or nearby representative monitors. Trends were calculated for sites that have at least six years of annual data and an annual value for the end year of the reporting period.

The haze index is the single measure of the visibility indicator used by NPS ARD. Visibility is monitored through the Interagency Monitoring of Protected Visual Environments (IMPROVE) Program (NPS ARD 2010) and annual average measurements for Group 50 visibility 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.

Table 8. 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 maximum value within Gila Cliff Dwellings NM's boundaries is reported as the visibility condition from this national analysis.

Visibility trends are computed from the Haze Index values on the 20% haziest days and the 20% clearest days, consistent with visibility goals in the CAA and Regional Haze Rule, which include improving visibility on the haziest days and allowing no deterioration on the clearest days. Although this legislation provides special protection for NPS areas designated as Class I, the NPS applies these standard visibility metrics to all units of the NPS. If the Haze Index trend on the 20% clearest days is deteriorating, the overall visibility trend is reported as deteriorating. Otherwise, the Haze Index trend on the 20% haziest days is reported as the overall visibility trend. Visibility trend data were collected at the IMPROVE monitoring station GICL1, NM, which is located just outside the monument in the Gila Wilderness.

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 are 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 trend data were not available because monitoring stations were farther than 10 km (7 mi), which is beyond the distance at which NPS ARD considers representative for calculating trends.

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. The 2008 NAAQS for ozone was a 4th-highest daily maximum 8-hour ozone concentration of 75 parts per billion (ppb). On 1 October 2015, the USEPA strengthened the national ozone standard by setting the new level at 70 ppb (USEPA 2017a). The NPS ARD assesses the status for human health risk from ozone using the 4th-highest daily maximum 8-hour ozone concentration in ppb. 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 monument was the maximum estimated value within monument boundaries derived from this national analysis. There were no on-site or nearby representative monitors to assess human health ozone 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 is reported in "parts per million-hours" (ppm-hrs), and is used for vegetation health risk from ozone condition assessments. Annual maximum 3-month 12-hour W126 values are averaged over a 5-year period at all monitoring sites with at least three years of complete annual data. Five-year averages are 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 monument is the maximum value within monument boundaries derived from this national analysis. There were no on-site or nearby representative monitors to assess vegetation health ozone 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 is used as a surrogate for total deposition (wet plus dry), because wet deposition is 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 are 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 is averaged over a 5-year period at monitoring sites with at least three years of annual data. Five-year averages are 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 are reported from this national analysis. To maintain the highest level of protection in the monument, the maximum value is assigned a condition status. Data to determine nitrogen and sulfur conditions were derived by interpolating measured values from multiple monitoring stations farther than 16 km (10 mi).

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 are averaged over a 3-year period at all NADP-MDN monitoring sites with at least three years of annual data. Three-year averages are 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.

Conditions of predicted methylmercury concentration in surface water are 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 is 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).

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).

Reference Conditions

The reference conditions against which current air quality parameters are assessed are identified by Taylor (2017) for NRCAs and listed in Table 9

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

The human health ozone condition thresholds are 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 is less than or equal to 54 ppb, which is in line with the updated Air Quality Index breakpoints; "moderate concern" if the ozone concentration is between 55 and 70 ppb; and of "significant concern" if the concentration is 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).

The NPS ARD selected an N and S wet deposition threshold of 1.0 kg/ha/yr as the level below which natural ecosystems are likely protected from harm. This is 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 10 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 9. 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/m^2/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.

Table 10. 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 11.

The estimated 5-year (2011-2015) haze index measure of visibility for Gila Cliff Dwellings NM (3.5 dv) fell within the moderate concern condition rating, which indicates visibility is degraded from the good reference condition of <2 dv above the natural condition (Taylor 2017). However, the trend has improved. During 2006 to 2015, the trend in visibility at Gila Cliff Dwellings NM improved on both the 20% clearest days and on the 20% haziest days (Figure 8) (IMPROVE Monitor ID: GICL1, NM). Confidence in this measure is high because there was nearby visibility monitor. Visibility impairment primarily results from small particles in the atmosphere that include natural particles from dust and wildfires and anthropogenic sources from organic compounds, NOx and SO_2. The contributions made by different classes of particles to haze on the clearest days and on the haziest days are shown in Figures 9 and 10, respectively, using data collected at the IMPROVE monitoring location, GICL1, NM.

The top three visibility-impairing pollutants on the clearest days from 2006-2015 were ammonium sulfates, organic carbon, and coarse mass, respectively. On the haziest days, the top three pollutants were organic carbon, ammonium sulfates, and coarse mass, respectively (NPS ARD 2016). 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. In 2015, the clearest days occurred during January (Figure 11), while the haziest days occurred during August (Figure 12).

Data for the human health measure of ozone were derived from estimated five-year (2011-2015) values of 66.1 parts per billion for the 4th highest 8-hour

Table 11. Condition and trend results for air quality indicators at Gila Cliff Dwellings NM.

Data Span	Visibility (dv)	Ozone: Human Health (ppb)	Ozone: Vegetation Health (ppm-hrs)	N (kg/ha/yr)	S (kg/ha/yr)	Wet Mercury (μg/m²/yr)	Predicted Methylmercury (ng/L)
Condition	Moderate Concern (3.5) 2011-2015	Moderate Concern (66.1) 2011-2015	Moderate Concern (10.2) 2011-2015	Significant Concern (2.1*) 2011-2015	Good (0.9) 2011-2015	Moderate Concern (6.4) 2013-2015	Unknown
Trend: 2006-2015	The trend in visibility improved on the 20% clearest days and improved on the 20% haziest days (IMPROVE Monitor ID: GICL1, NM).						

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

Source: NPS ARD (2016).

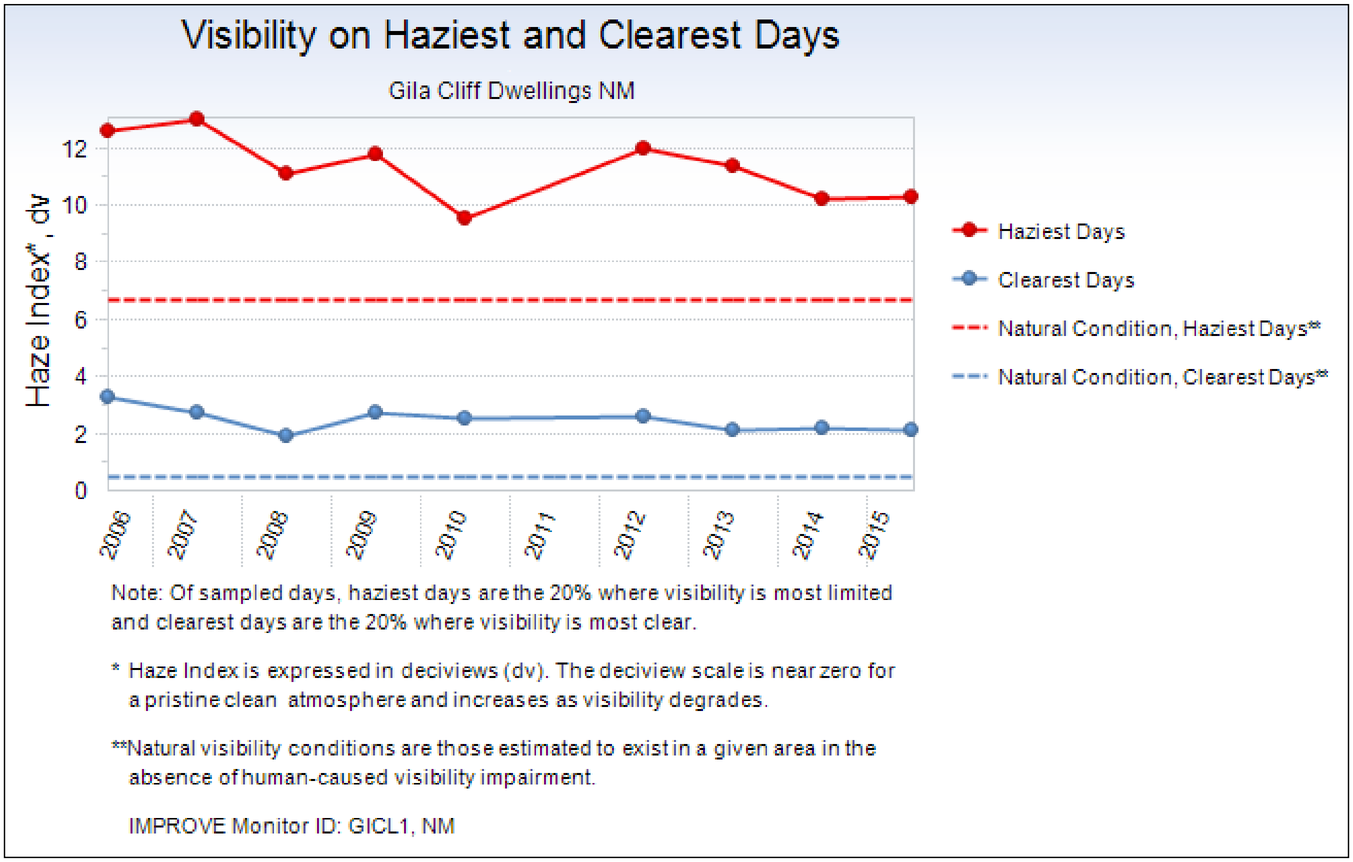


Figure 8. **Trend in visibility at Gila Cliff Dwellings NM during 2006 to 2015. Figure Credit: NPS ARD 2016.**

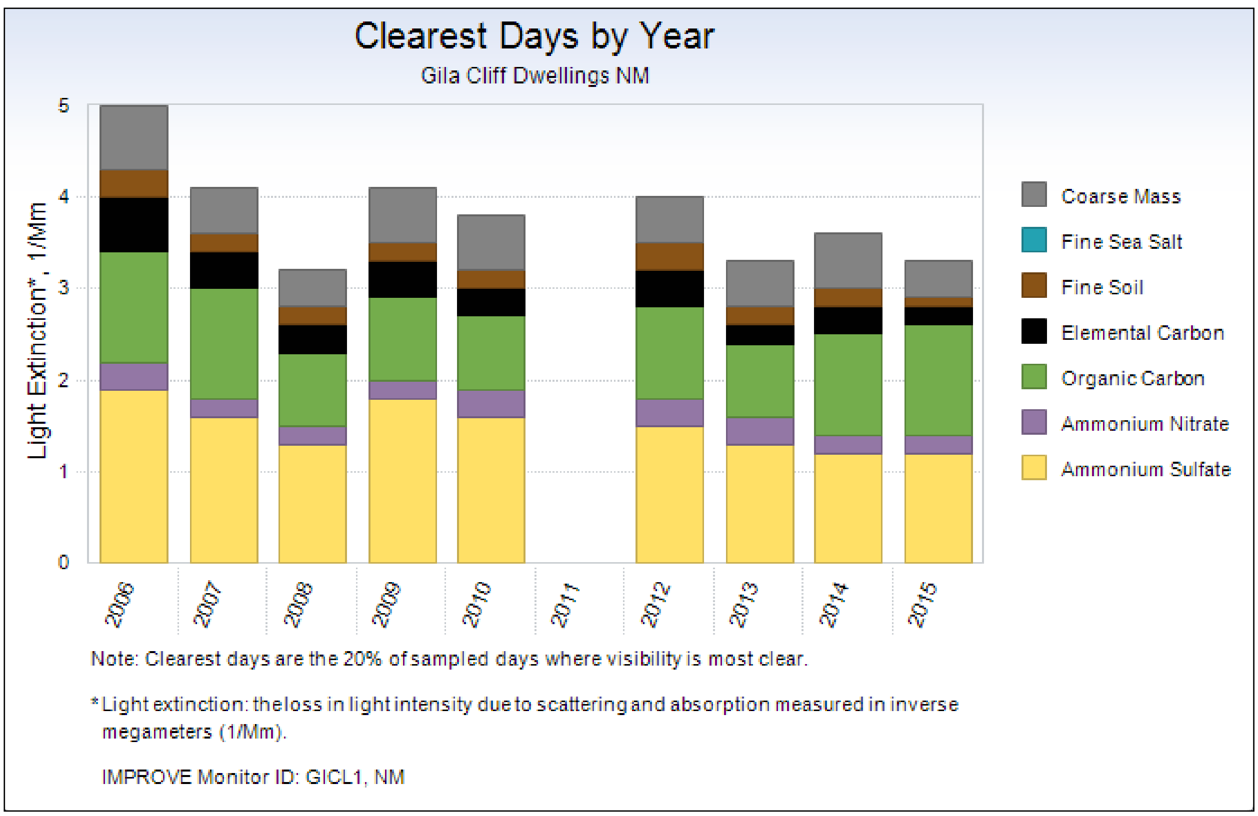


Figure 9. **Visibility data collected at GICL1, NM IMPROVE station showing the composition of particle sources contributing to haze during the clearest days by year (2006-2015). Figure Credit: NPS ARD 2016.**

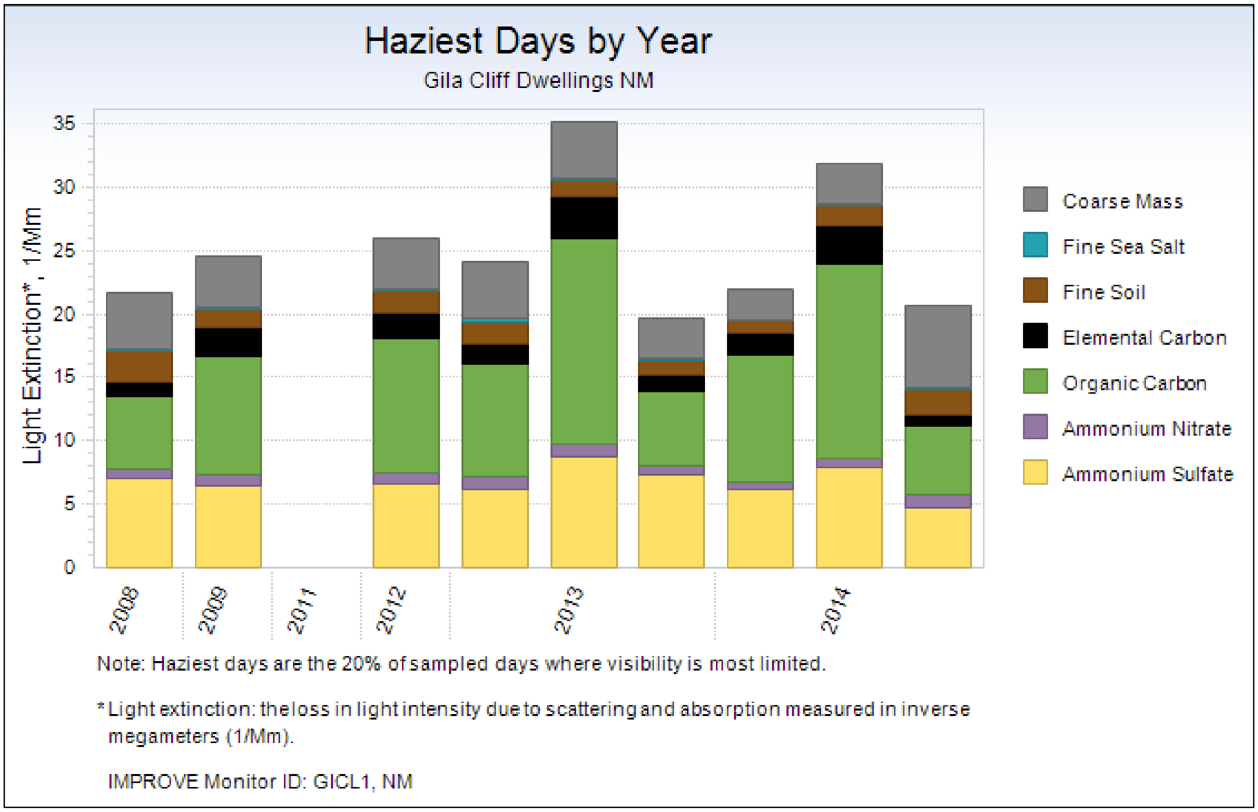


Figure 10. **Visibility data collected at GICL1, NM IMPROVE station showing the composition of particle sources contributing to haze during the haziest days by year (2006-2015). Figure Credit: NPS ARD 2016.**

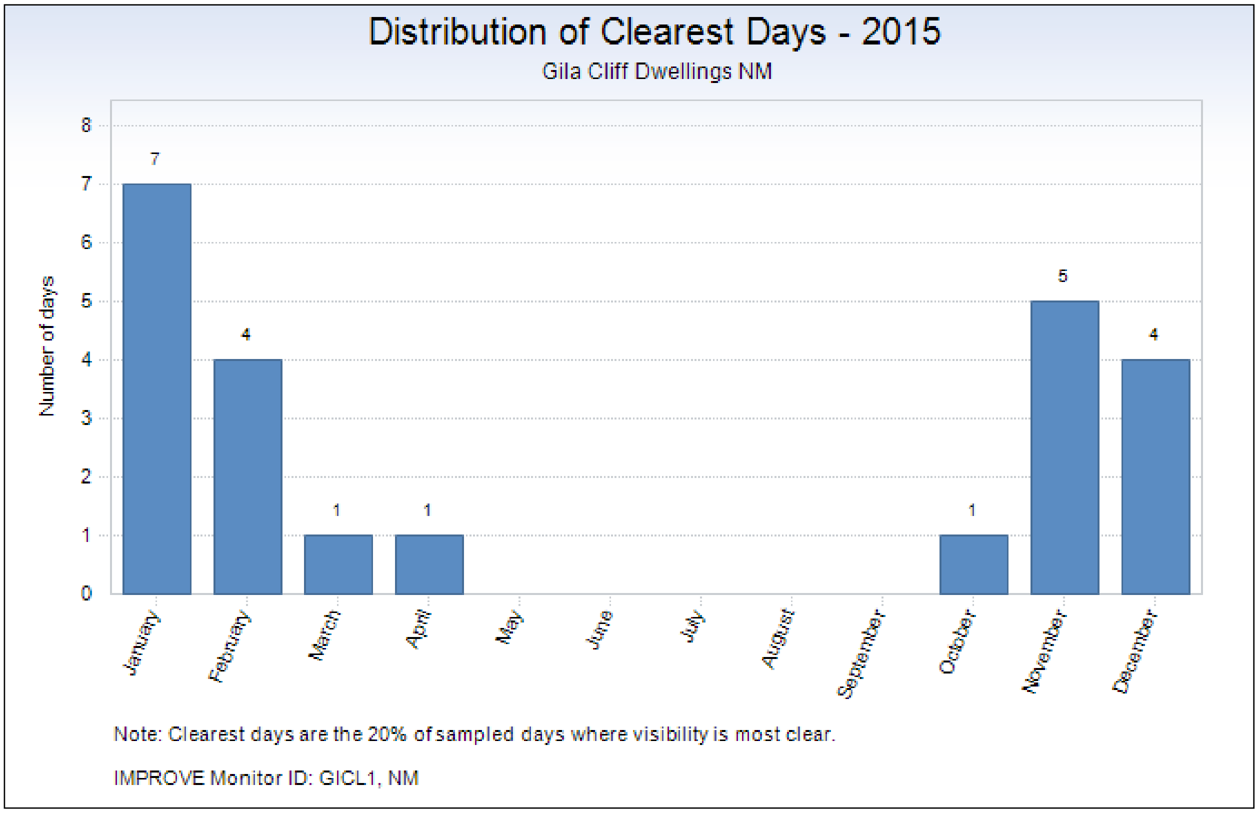


Figure 11. **Visibility data collected at GICL1, NM IMPROVE station showing the distribution of clearest days by month for 2015. Figure Credit: NPS ARD 2016.**

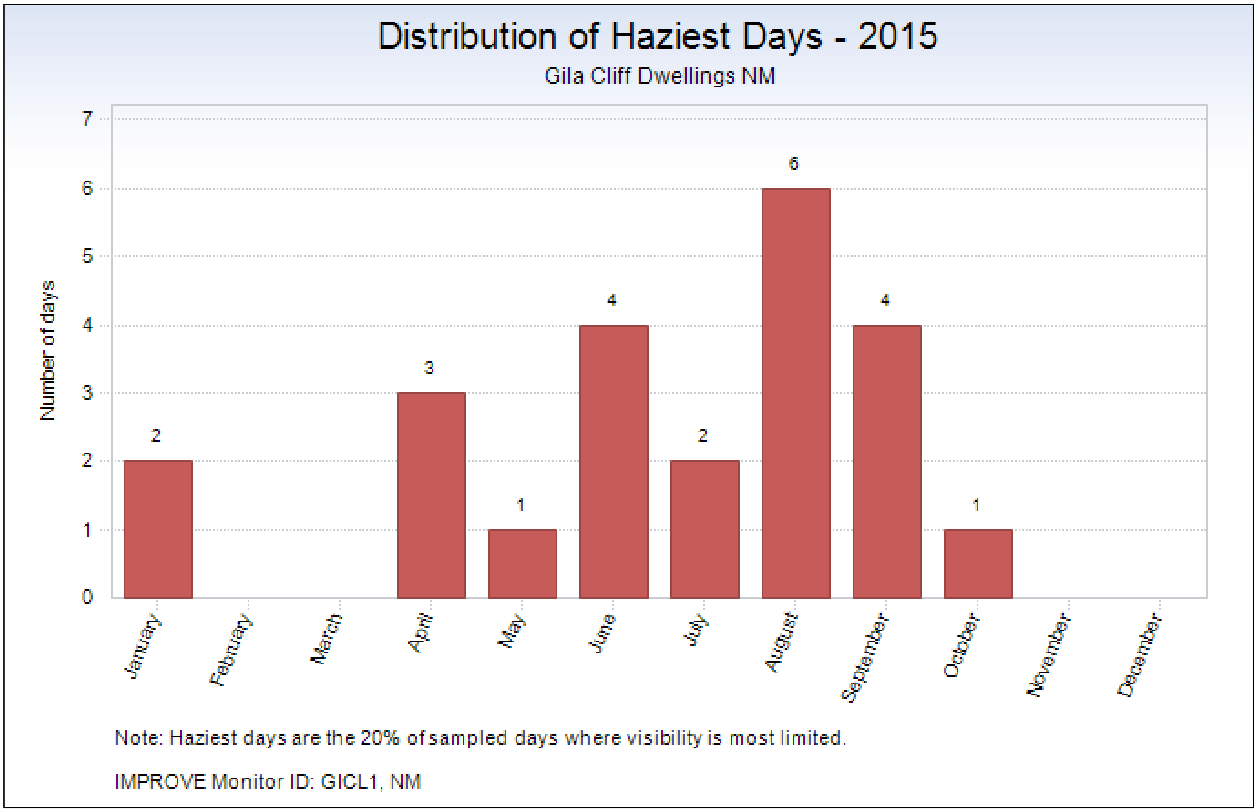


Figure 12. Visibility data collected at GICL1, NM IMPROVE station showing the distribution of haziest days by month for 2015. Figure Credit: NPS ARD 2016.

concentration, which resulted in a condition rating warranting moderate 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 10.2 parts per million-hours (ppm-hrs). Using these numbers, vegetation health risk from ground-level ozone warrants moderate concern at Gila Cliff Dwellings NM (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 13 species of ozone sensitive plants in Gila Cliff Dwellings NM (Table 12). Of these 13 species, nine are considered bioindicators, or species that can reveal ozone stress in ecosystems by producing distinct visible and identifiable injuries to plant leaves (Bell, In Review).

Table 12. Ozone sensitive plants in Gila Cliff Dwellings NM.

Scientific Name	Common Name	Bioindicator
Acer negundo	Ashleaf maple, boxelder	Yes
Achillea millefolium	Bloodwort, common yarrow	No
Apocynum cannabinum	Common dogbane	No
Artemisia ludoviciana	Cudweed sagewort, white sagebrush	Yes
Humulus lupulus	Common hop	Yes
Mentzelia albicaulis	Small-flowered blazing star	Yes
Oenothera elata	Hooker's evening primrose	Yes
Parthenocissus quinquefolia	American ivy, Virginia creeper	No
Pinus ponderosa	Blackjack pine, western yellow pine	Yes
Prunus serotina	Black cherry, black chokecherry	Yes
Rhus aromatica	Fragrant sumac	Yes
Rudbeckia laciniata	Cutleaf coneflower	Yes
Salix exigua	Coyote willow, sandbar willow	No

Wet N deposition data used for the condition assessment were derived from estimated five-year average values (2011-2015) of 2.1 kg/ha/yr. This value falls within the moderate concern condition rating, but because ecosystems at the monument may be particularly sensitive to nitrogen-enrichment effects, the condition status was elevated to significant concern (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 N deposition, see the section entitled "Additional Information for Nitrogen and Sulfur" below.

Wet S deposition data used for the condition assessment were derived from estimated five-year average values (2011-2015) of 0.9 kg/ha/yr, which resulted in a good condition rating for Gila Cliff Dwellings NM (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 Gila Cliff Dwellings 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 very low for estimated acid pollutant exposure and moderate for ecosystem sensitivity to acidification (Sullivan 2016). 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 very low for nutrient N pollutant exposure and moderate for ecosystem sensitivity to nutrient N enrichment at the monument. 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 (NLDC), nitrogen-sensitive vegetation for the monument was identified (E&S Environmental Chemistry, Inc. 2009). LANDFIRE and NWI both mapped nitrogen-sensitive communities in Gila Cliff Dwellings NM (Figure 13). NWI mapped 5 ha (12 ac) of wetlands and LANDFIRE mapped 181 ha (447 ac) of arid and semi-arid communities and 4 ha (10 ac) of grassland and meadow communities.

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 across the SODN (Sullivan 2016). Dry S and N deposition is more common in arid ecosystems but difficult to quantify because many factors influence deposition, including

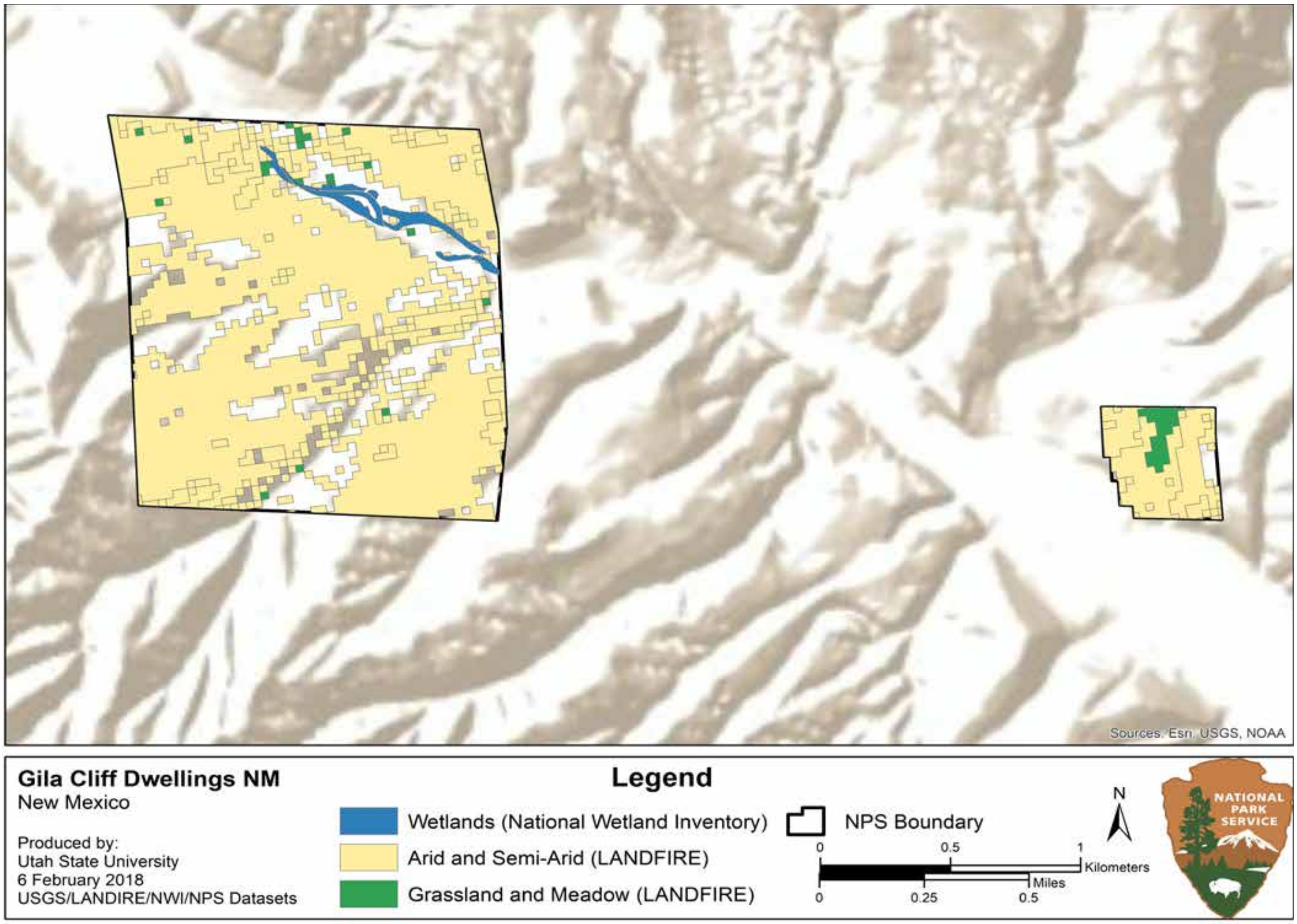


Figure 13. Nitrogen-sensitive plant communities mapped by LANDFIRE and the National Wetlands Inventory at Gila Cliff Dwellings NM.

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

Finally, the 2013–2015 estimated wet mercury deposition was moderate (6.4 μ/m^2/yr) at the national monument (NPS ARD 2017). However, the predicted methylmercury concentration could not be determined due to lack of a surface waters risk assessment and park-specific studies examining contaminant levels in taxa from park ecosystems. 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. However, water quality data collected by SODN in Gila Cliff Dwellings NM show very low mercury concentrations in water samples with no New Mexico State standard exceedences. Water quality was addressed in a separate assessment.

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 13. Based on these indicators and measures, the overall condition of air quality at Gila Cliff Dwellings NM is of moderate concern. The overall confidence is medium since the values for most measures were collected from more distant monitors and may not necessarily represent conditions with the monument. A key uncertainty of the air quality assessment is knowing the effect(s) of air pollution, especially of nitrogen deposition, on ecosystems at the national monument.

Clean air is fundamental to protecting human health, the health of wildlife and plants within parks, and for protecting the aesthetic value of lands managed by

Table 13. 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 (3.5 dv). The trend improved on both the 20% of clearest days and on the 20% of haziest days. Visibility may be impacted by local and regional cities which include Tucson, Arizona; Phoenix, Arizona; and Los Angeles, California. Hazy days reduce a visitor's ability to distinguish color, form, and texture. Clear skies are important to visitor enjoyment, especially where the monument includes scenic vistas. Dark night skies may 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 moderate concern. At this level (66.1 ppb), 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 (10.2 ppm-hrs) as it relates to plant health also warrants moderate 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		Although the five-year (2011-2015) wet deposition of nitrogen value (2.1 kg/ha/yr) fell within moderate concern condition, the potentially high sensitivity of the monument's plant communities to excess nitrogen elevated the condition status to significant concern. 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 (0.9 kg/ha/yr) indicated good condition. 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/m^2/yr)		The overall mercury/toxics deposition condition could not be evaluated due to lack of data regarding predicted methylmercury concentration. The 2013–2015 wet mercury deposition (6.4 micrograms per square meter per year), however, warrants moderate concern at the monument.
	Predicted Methylmercury Concentration (ng/L)		The overall mercury/toxics deposition condition could not be evaluated due to lack of data regarding predicted methylmercury concentration. There has not been a surface waters risk assessment or park-specific studies examining contaminant levels in taxa from park ecosystems.
Overall Condition	Summary of All Measures		Air quality data indicate that most measures are degraded from good condition, but trends in visibility have improved. A key data gap is that most measures were interpolated from distant monitors and may not accurately reflect conditions within the monument. For this reason, confidence in the overall condition rating is medium. Because data were collected from distant monitors, trends in all but visibility are unknown. While protecting air quality is fundamental to ecosystem health within the monument, the majority of threats originate from outside the monument.

the NPS (NPS 2006). The majority of threats to air quality within Gila Cliff Dwellings NM originate from outside the national monument 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).

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 Gila Cliff Dwellings NM, the annual average temperature has significantly increased, but there were no apparent changes in precipitation (Monahan and Fisichelli 2014). 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.

Hydrology

Background and Importance

Gila Cliff Dwellings National Monument (NM) lies at the confluence of the West and Middle Forks of the Gila River—New Mexico's last free flowing river (NPS 2016). A short 1.0 km (0.6 mi) stretch of the West Fork flows through the monument's main unit (NPS 2016). This short stretch was designated as critical habitat for the spikedace (*Meda fulgida*) and loach minnow (*Tiaroga cobitis*), both of which are listed as endangered by the U.S. Fish and Wildlife Service's Endangered Species Program (USFWS 2017). The West Fork is a high quality mountainous stream within a small 311 km^2 (120 mi^2) watershed located entirely within the Gila Wilderness (Gwilliam et al. 2018a, NPS 2016).

Despite this wilderness protection, the West Fork of the Gila River is listed as impaired by the New Mexico Department of Environmental Quality for elevated stream temperatures, and following fires in 2011 and 2012, the stream was temporarily listed as impaired for turbidity (NPS 2016). Aluminum has also increased in the stream as a result of fire within the watershed (NPS 2016). 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). This assessment for Gila Cliff Dwellings NM focuses on the hydrology of the West Fork and of the Gila River downstream of the monument. Water quality for the West Fork of the Gila River is addressed in a separate assessment in this report.

Data and Methods

To assess the current condition of hydrology in Gila Cliff Dwellings NM, we used two indicators with four measures each for a total of eight measures. Indictors and measures were based on the National Park Service (NPS) Sonoran Desert Inventory and Monitoring Network's (SODN) surface water monitoring program at Gila Cliff Dwellings NM (Gwilliam et al. 2018a). We relied primarily on data collected by the U.S. Geological Survey (USGS) as reported in the National Water Information System (NWIS) database (USGS 2018a,b). Additional data and background information were available in SODN's 2016 water year (WY, 1 October - 30 September) monitoring report for Gila Cliff Dwellings NM (Gwilliam et al. 2018a).

Surface water quantity is an important indicator of the amount of water available for wildlife and plants and for maintaining ecosystem processes. To Streamflow data were recorded at the USGS stream gage (09430010) located in the monument on the West Fork of the Gila River at SODN's index site (see Figure 3-1 in Gwilliam et al. 2018a). Data for the

The West Fork of the Gila River flowing through Gila Cliff Dwellings NM. Photo Credit: NPS.

USGS stream gage at the index reach were available beginning 22 October 2016 (USGS 2018a). Because of the short duration of available data, we also used data from the USGS stream gage (09430500) located on the Gila River approximately 40 km (25 mi) downstream of Gila Cliff Dwellings NM at Gila, New Mexico (USGS 2018b). Data from this gage were available for WY 1928 through WY 2017 as well as part of WY 2018. Because the East Fork, Middle Fork, and other smaller tributaries also flow into to the Gila River before this downstream gage, these data only indicate the general status of conditions along the West Fork in the monument (Gwilliam et al. 2018a). The four measures of surface water quantity are the number of no-flow events, the number of 50-year or greater flood events, the number of bankfull events, and change in mean annual discharge.

We accessed the number of no-flow events through the USGS' water-year (WY) summary tables for the Gila River stream gage (USGS 2018b). Mean daily discharge data were available from 1 December 1927 through 18 July 2018. Beginning on 15 February 2017, data were earmarked as provisional. 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 of interest, we summarized the data by the number of events per WY and the dates, or length, of each event. Although of short duration, we also determined whether there were any no-flow events recorded at the West Fork gage.

The number of 50-year or greater flood events The probability of a 50-year flood event is 1 in 50, or a 2% chance of occurrence in any given year (USGS 2018c). According to the USGS StreamStats Data-Collection Station Report for the Gila River stream gage (09430500), the flow for a 50-year peak flood was estimated at 29,500 cfs (USGS 2018d). A 100-year or greater peak flood event was estimated at 43,500 cfs or greater (USGS 2018d). To determine when or if a 50-year flood event occurred at the Gila River stream gage, we downloaded instantaneous peak flow data from the NWIS website (USGS 2018b). Instantaneous peak flow data were available for WYs 1928 to 2017. An estimate of discharge for a 50-year flood event was not available for the West Fork stream gage.

A bankfull event is equivalent to a 1.5 to 2-year flood event, which has a 1 in 2, or 50%, chance of occurring in any given year (USGS 2018c, Gwilliam et al. 2013). Bankfull events are a natural disturbance that serve to scour channels of fine materials, move sediment through a channel, improve connectivity between upstream and downstream habitats, and maintain channel structure (Fitzhugh and Vogel 2010). Too many of these smaller flood events, however, may lead to loss of stream channel integrity. The 2-year flood event provided in the StreamStats Data-Collection Station Report for the Gila River was estimated at 1,910 cfs (USGS 2018d). We determined the years for which the instantaneous peak flow exceeded 1,910 cfs and then examined annual daily data for those years to determine the number of bankfull events per WY (USGS 2018b). An estimate of a 2-year flood discharge was not available for the West Fork of the Gila River at Gila Cliff Dwellings NM.

Mean annual discharge data for the Gila River were available for WYs 1929 to 2016 (USGS 2018b). We looked for trends in mean annual discharge and, if there were changes in discharge, we attempted to determine during which hydrologic season changes had occurred. For the seasonal analysis, we downloaded daily mean discharge data and summed total discharge by season. Hydrologic seasons were defined in Gila Cliff Dwellings NM's baseline water quality report as follows (NPS WRD 1998): 1 July - 31 October, 1 November - 14 March, and 15 March - 30 June. Because of the short record for the index reach at Gila Cliff Dwellings NM, changes in mean annual and seasonal discharge could not be determined.

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 by SODN staff at the West Fork index reach. SODN's stream sampling protocol has not been published as of the writing of this assessment so we could not provide details on data collection methods. Instead, we provide a brief description of each measure and its significance.

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 14). Reference conditions for all measures except change in mean annual discharge were based on Management Assessment Points (MAPS) developed by SODN for Montezuma Castle and Tuzigoot national monuments (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). For mean annual change in discharge, a stable or improving discharge would indicate good condition, while a decline in discharge would indicate moderate/significant concern.

Condition and Trend

Because the conditions for the following measures are based almost entirely on the Gila River stream gage, confidence for all measures is low. Although confidence in the actual USGS data for this stream gage is high, the data do not necessarily represent condition in the West Fork flowing through the monument.

Daily data from the West Fork gage indicate persistent flowing water; however, all data are provisional and there were some missing values (Figure 14). Therefore, our condition rating is based on the Gila River stream gage. There were zero no-flow events for the entire

Table 14. Reference conditions used to assess hydrology.

Indicators	Measures	Good	Moderate/Significant Concern
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%.

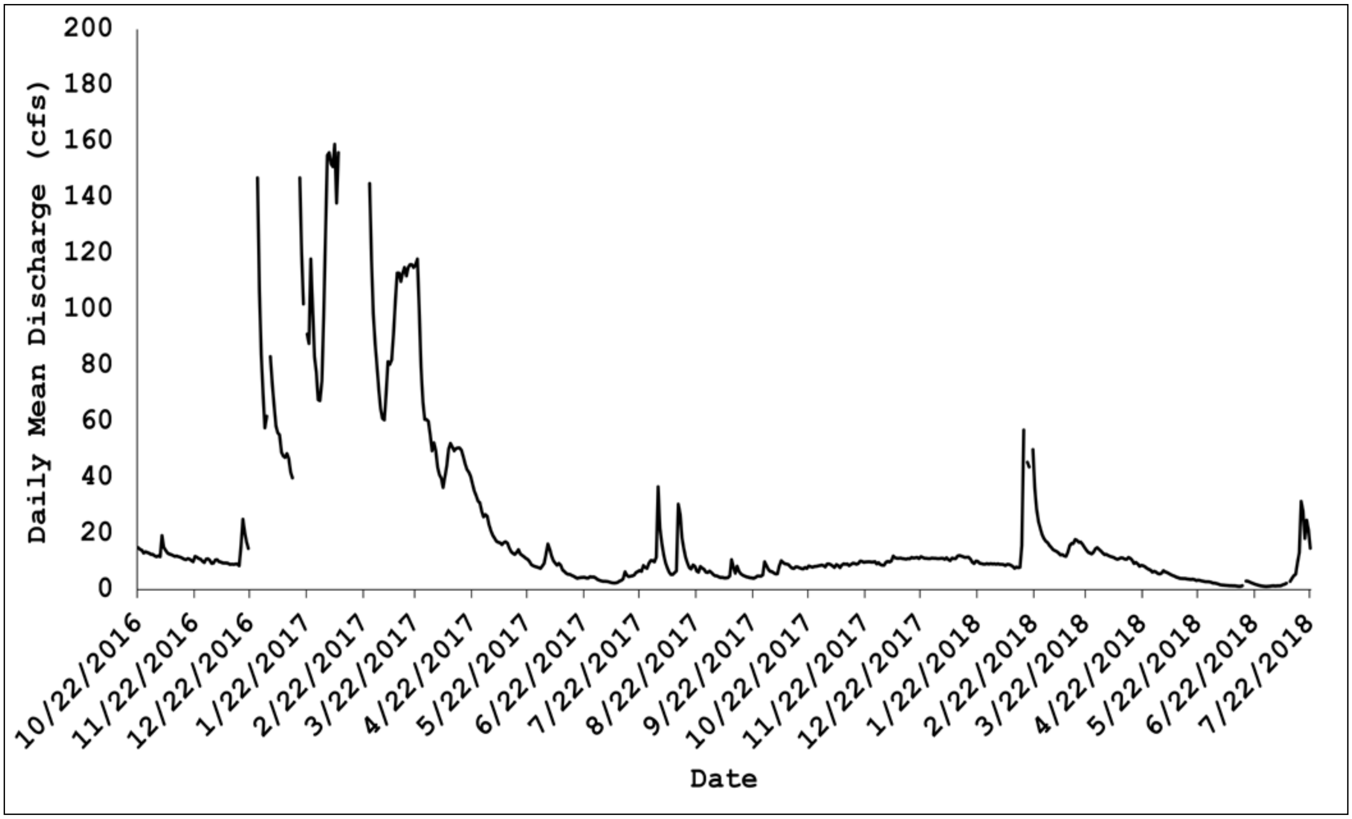


Figure 14. **Mean daily discharge for the West Fork of the Gila River stream gage (October 2016 - July 2018).**

record at the Gila River stream gage, which indicates good condition (daily data are not presented due to the length of the dataset). Trend is unchanging. Note that data from 15 February 2017 to 18 July 2018 are provisional.

There were two 50-year or greater flood events recorded at the Gila River stream gage from WYs 1928 to 2017 (Figure 15). The events occurred in 1979 and 1985, neither of which exceeded the 100-year flood discharge value. In 39 of the 90 years of data, peak flows occurred most often during August and September. February and March were also common months for peak flows (n = 21 years). The condition is good since there were only two 50-year flood events in the 90-year record. Although there was no trend in the occurrence of 50-year flood events, the overall trend in peak flows has increased at the Gila River gage (R^2 = 0.07, p = 0.01, t = 2.56). Because of the short record for the West Fork gage, peak flow data were not available; however, provisional daily data indicate that flows did not exceed 200 cfs on any given day (Figure 14). Data for the West Fork gage show that the highest flows occurred December through March.

Bankfull events occurred at least once in 49 of the 90 years of data (Figure 15). Bankfull events occurred regularly throughout the data record, and most bankfull events occurred sometime between 1 July and 14 March. NWIS summaries were only available from WYs 2006 to 2017, during which there were 28 bankfull events (Table 15). The large number (9) of

An undated historic photograph of a flood at the trailhead near the contact station in Gila Cliff Dwellings NM. Photo Credit: NPS.

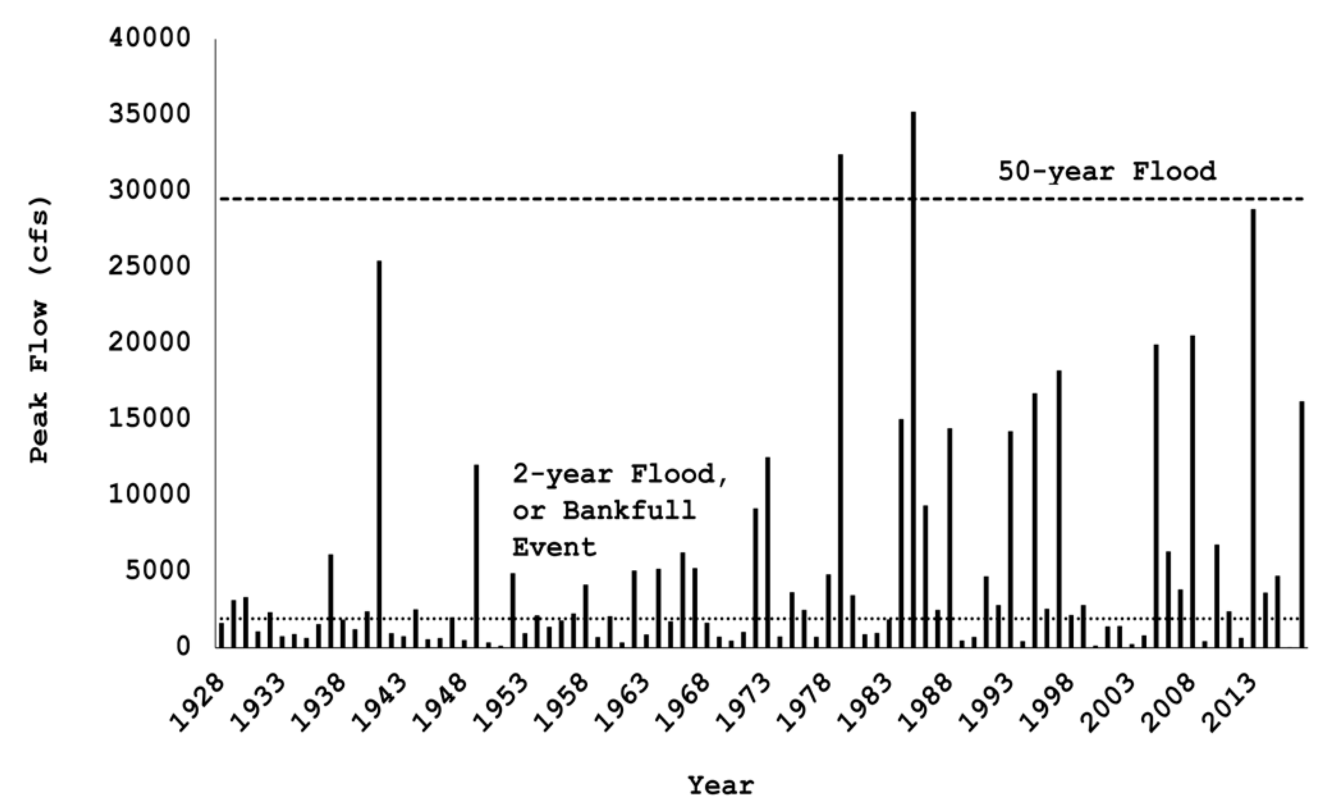


Figure 15. **Instantaneous peak annual flow at the Gila River USGS stream gage (1928-2017).**

bankfull events during 2013 was likely the result of fires that burned in and around the monument in 2011 and 2012 (Banister et al. 2014, NPS 2016). Fires reduce infiltration of precipitation into soils, resulting in increased runoff (Banister et al. 2014). Since more than one bankfull event occurred in four of the last 12 years (33%), the condition warrants moderate/significant concern. Trend from 2006 to 2017 is unchanging (R^2 = 0.02, p = 0.63, t = -0.50).

Table 15. **Summary of bankfull events from 2006 to 2017 at the Gila River stream gage.**

Water Year	Number of Bankfull Events
2006	6
2007	1
2008	4
2009	0
2010	1
2011	1
2012	0
2013	9
2014	1
2015	3
2016	1
2017	1

There was no trend in mean annual discharge from WY 1929 to WY 2016 (R^2 = 0.04, p = 0.06, t = 1.90) (Figure 16); however, from November to March, there was a slight but significant increase in mean annual discharge over time (R^2 = 0.06, p = 0.02, t = 2.38) (Figure 17). Variability in discharge began increasing after 1977 for this season. Seasonal discharge during July through October and March through June were not significant, but variability in annual discharge was greater after 1971 for July through October. Variability did not appear to change substantially from March through June over the period of record. These data indicate unchanging conditions for the most part and warrant good condition.

To date, SODN staff have measured sinuosity and cross-sectional area at the index reach at Gila Cliff Dwellings NM once, but those data were not available for this report (NPS, E. Gwilliam, ecologist, e-mail message, 6 February 2018). Regardless, reference conditions for these two measures are based on change over time. Therefore, the condition is unknown and confidence

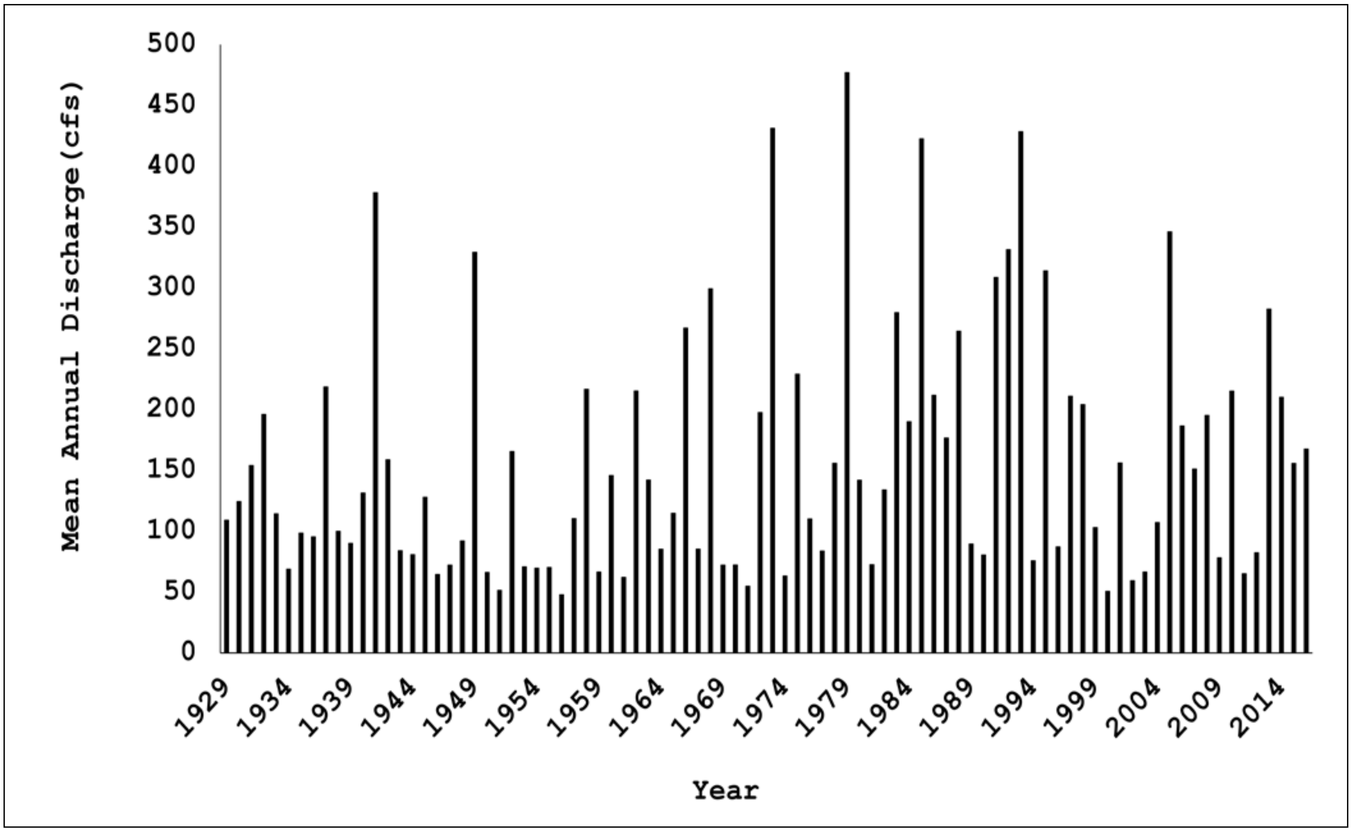


Figure 16. **Mean annual discharge at the Gila River stream gage (1929-2017).**

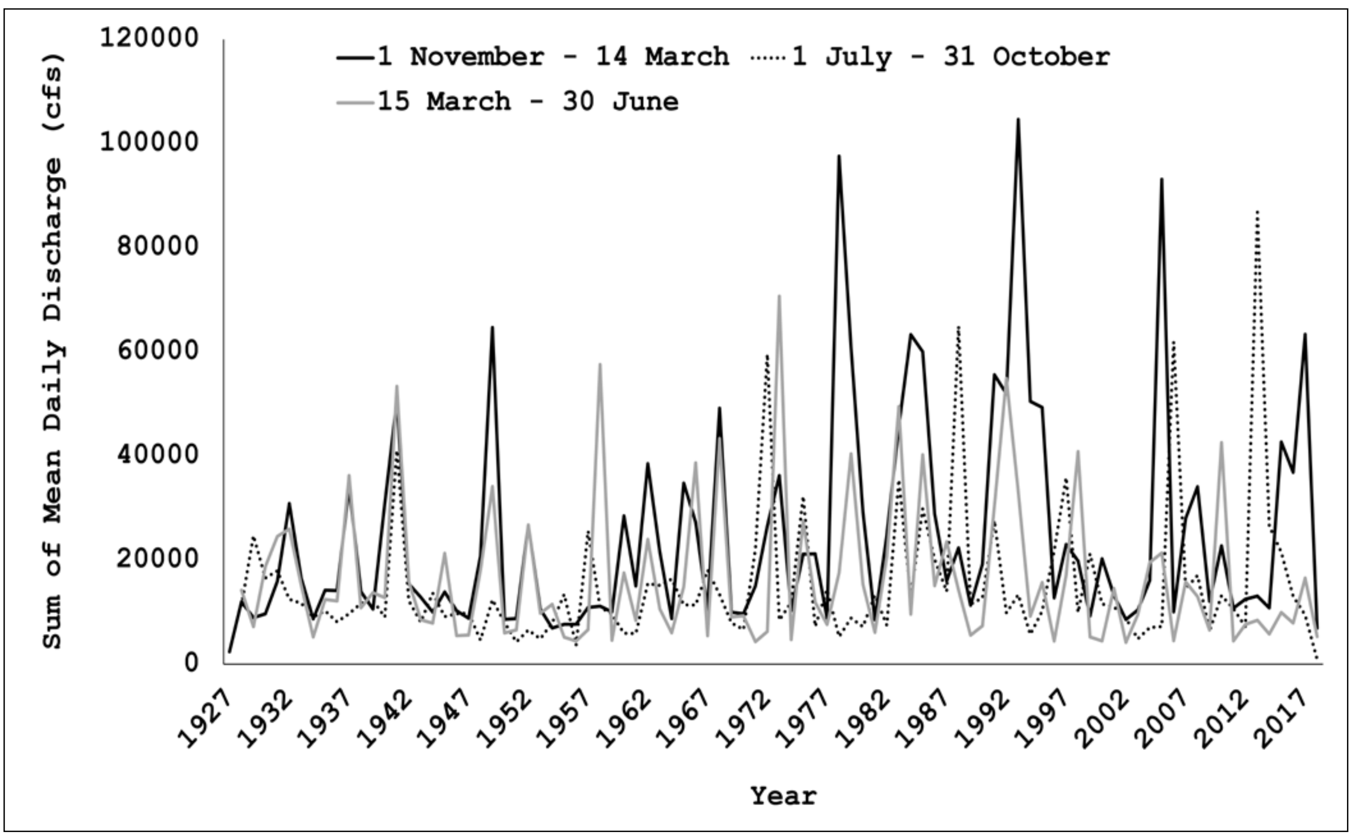


Figure 17. **Total seasonal discharge at the Gila River stream gage (1927-2017).**

is low because of the unknown condition rating. Data on particle size were collected in WY 2016 but have not been published, nor were they available for inclusion in this assessment. Therefore, the condition and trend is unknown. Confidence is low because of the unknown condition.

Overall Condition, Threats, and Data Gaps

Based on the measures used in this assessment, the condition of hydrologic resources (namely surface water quantity) at Gila Cliff Dwellings NM is in good condition with an unchanging trend (Table 16). Confidence in the condition rating, however, is low because of limited data for the stream gage within the monument. Instead, we relied on data from a USGS stream gage located 40 km (25 mi) downstream of the monument. The Middle Fork and East Fork as well as numerous smaller tributaries flow into the Gila River before this stream gage. As a result, the gage may not reflect conditions within the monument, which represents a key uncertainty in this assessment. Furthermore, we could not assess stream channel geomorphology so all four measures were assigned unknown condition. These four measures did not factor into the overall condition rating.

Because the entire watershed of the West Fork lies within the Gila Wilderness, there are relatively few anthropogenic threats to hydrologic resources at Gila Cliff Dwellings NM. Perhaps the most significant anthropogenic threat to the West Fork is climate change. Climate scenarios for the region predict less precipitation in fewer, larger events (Banister et al. 2014). A climate study for the monument revealed that temperatures are also increasing (Monahan and Fisichelli 2014). Air temperature determines whether precipitation falls as rain or snow with significant consequences for local hydrology, such as changes in the amount of winter snowpack, changes in the timing of snowmelt, and possibly increased severity of flooding (Knowles et al. 2006). Most recently, during the 2017-2018 winter snowfall was absent and the monument experienced record low water flows (R. Garcia, Gila Cliff Dwellings NM, email correspondence, dated October 3, 2018). Reduced streamflow, in response to climate change, will reduce the abundance of woody riparian vegetation, including narrowleaf cottonwood (*Populus angustifolia*), Arizona walnut (*Juglans major*), and velvet ash (*Fraxinus velutina*) that grow along the West Fork in the monument (NMDGF 2016). Reduced shade cover of riparian trees will likely lead to higher stream temperatures with negative effects on cold water-adapted fish and invertebrates. As more data become available for the stream gage within the monument, the condition of surface water quantity will be better understood.

Table 16. Summary of hydrology indicators, measures, and condition rationale.

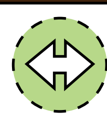
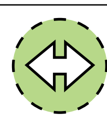
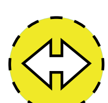
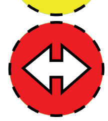
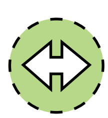
Indicators	Measures	Condition/Trend/ Confidence	Rationale for Condition
Surface Water Quantity	Number of No-Flow Events		There were zero no-flow events from December 1927 to July 2018, which is the entire length of available data. Trend is unchanging. Confidence in the condition rating is low because the data are from a downstream gage on the Gila River.
	Number of 50-year or Greater Flow Events		There were only two 50-year or greater flood events from WYs 1928 to 2017 (1979 and 1985). Therefore, the condition is good. Trend is unchanging, but confidence is low because the data are from a downstream gage on the Gila River.
	Number of Bankfull Events	 	Bankfull events occurred at least once in 49 of the 90 years of data and occurred regularly throughout the period of record (1928-2017). Most bankfull events occurred sometime between 1 July and 14 March. From 2006 to 2017, there were a total of 28 bankfull events with more than one bankfull event in four of the last 12 years (33%). These data warrant moderate/ significant concern. Trend is unchanging, but confidence is low because the data are from a downstream gage on the Gila River.
	Change in Mean Annual Discharge		There was no trend in mean annual discharge from WYs 1929 to 2016, but there was a slight significant increase in mean discharge November to March over all years. Overall, these data indicate good condition. Trend is unchanging, but confidence is low because the data are from a downstream Gila River gage.

Table 16 continued. ***Summary of hydrology indicators, measures, and condition rationale.***

Indicators	Measures	Condition/Trend/ Confidence	Rationale for Condition
Stream Channel Geomorphology	Sinuosity		Reference conditions were based on change over time, and only one sample has been collected to date. Those data 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.
	Cross-sectional Area		Reference conditions were based on change over time, and only one sample has been collected to date. Those data 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.
	Dominant Particle Size		Data on particle size were collected in WY 2016 but have not been published. These data were unavailable for inclusion in this assessment. Therefore, the condition and trend is unknown. Confidence is low because of the unknown condition.
	Particle Size Assessment		Data on particle size were collected in WY 2016 but have not been published. These data were unavailable for inclusion in this assessment. Therefore, the condition and trend is unknown. Confidence is low because of the unknown condition.
Overall Condition	Summary of All Measures		Based on the available data, the condition for hydrology is good. This condition rating is only based on the measures for which condition could be determined. Even so, all of the measures for which condition was determined, were rated as low confidence because the stream gage was located 40 km (25 mi) downstream of the monument. Although there is a stream gage in the West Fork within the monument, the data record is short. It is unknown how well the downstream gage approximates conditions in the monument. Trend appears unchanging.

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.

Water Quality

Background and Importance

Gila Cliff Dwellings National Monument (NM) lies at the confluence of the West and Middle Forks of the Gila River. A short 1.0-km (0.6-mi) stretch of the West Fork flows through the monument's main unit (NPS 2016). The West Fork of the Gila River is a high quality mountainous stream within a small 311 km^2 (120 mi^2) watershed (Gwilliam et al. 2018a). The stream segment flowing through the monument was designated as critical habitat for the spikedace (*Meda fulgida*) and loach minnow (*Tiaroga cobitis*), both of which are listed as endangered under the U.S. Fish and Wildlife Service's Endangered Species Act (USFWS 2017).

Local anthropogenic disturbances such as agriculture, industrial use, and dams are absent in the monument's watershed because the monument and the headwaters of the West Fork are situated within the Gila Wilderness (Gwilliam et al. 2018a). The Gila Wilderness was established in 1924 as America's first administratively determined wilderness, 40 years prior to Congress passing the Wilderness Act of 1964 (NPS 2016). Despite this protection, in 2010 the West Fork was listed as impaired by the State of New Mexico under the Clean Water Act owing to elevated temperatures (NPS 2016). Large wildfires in the region have also influenced water quality through increased erosion and enhanced release of organic and other compounds (Gwilliam et al. 2018a). Maintaining high water quality in the monument is critical to sustaining wildlife and plants that depend upon the aquatic environment.

Data and Methods

To assess the current condition of water quality in Gila Cliff Dwellings NM, we used six indicators, which were chosen to be consistent with the Sonoran Desert Network's (SODN) monitoring objectives at Gila Cliff Dwellings NM (Gwilliam et al. 2018a). The indicators are: core water quality, metals and metalloids, nutrients, microbiological organisms, inorganics and general water quality, and benthic macroinvertebrates. For a complete list of water quality measures collected during Water Year (WY, 1 October - 30 September) 2016 refer to Gwilliam et al. (2018a).

Water quality samples were collected at the West Fork of the Gila River index site, which is located at the pedestrian bridge near the monument's eastern boundary (see Figure 3-1 in Gwilliam et al. 2018a). Water samples were collected once each season in WYs 2011 through 2017. Because SODN's stream sampling protocol has not been published, we did not provide specific sampling details. Instead, we provided a brief summary of each measure and its significance. Although SODN collects data for many water quality parameters, we generally included only those that were associated with water quality standards as defined

Stream monitoring in Gila Cliff Dwellings National Monument. Photo Credit: NPS.

by State of New Mexico, the U. S. Environmental Protection Agency, or SODN.

The core water quality indicator included five measures: stream water temperature, specific conductivity, pH, dissolved oxygen, and turbidity. Stream water temperature fluctuates both daily and seasonally as well as with rates of discharge. All water quality parameters are influenced by temperature. For example, stream water with higher temperatures typically has a lower pH, which in turn dissolves more minerals from the surrounding rock than cooler water. This, in turn, influences specific conductivity (USGS 2016). Specific conductivity is the ability of water to conduct an electrical current and is dependent on the amount of dissolved solids in the water, such as salts (USGS 2016). The pH as measured in standard units (SU) 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 2016).

Dissolved oxygen measures the amount of gaseous oxygen dissolved in the stream (USGS 2016). 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 (USGS 2016).

Turbidity is a measure of water clarity. It is expressed by the amount of light scattered by materials in the water (USGS 2016). The higher the intensity of scattered light, the higher the turbidity. High concentrations of particulates in the water lessen the amount of light that penetrates the water column, which can affect fish, plants, and other aquatic life (USGS 2016). Particles also provide attachment places for pollutants and other harmful chemicals. Therefore, turbidity can be used as an indicator of potential pollution (USGS 2016). Turbidity is reported in Nephelometric Turbidity Units (NTU).

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

The nutrients indicator is also comprised of several measures, including nitrogen, phosphorus, and potassium. Nutrients, in particular 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 2016). 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 2016). An excess of nutrients could be the result of agricultural pollution, wastewater treatment plants, leaking septic tanks or and septic fields.

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 2016). The presence of *E. coli* serves as a proxy for organic pollution, providing an early warning for potential risks to aquatic and terrestrial biota. This bacterium is typically reported in cfu, or colony forming units.

The inorganics and general water quality indicator included a variety of measures. Some of the measures tested in water samples include alkalinity as $CaCO_3$, bicarbonate alkalinity as $CaCO_3$, fluoride, sulfate, total hardness, and anion/cation balance (Gwilliam et al. 2018a). Alkalinity provides an index of water's ability to neutralize acid. Fluoride occurs naturally in water bodies but is also added to municipal water supplies (USGS 2016). In high levels, fluoride ions can act as enzymatic poisons, inhibit enzyme activity, and interrupt metabolic processes in aquatic invertebrates and fish (Camargo 2003). High sulfate concentrations result in mineral dissolution of surrounding rocks or domestic and industrial waste. Hardness is the result of metallic ions dissolved in water. Anion/cation balance is a measure of water's ability to conduct electricity (USGS 2016). Even a small amount of salts (cations) can cause water to conduct electricity.

Finally, SODN uses two measures of the benthic macroinvertebrate indicator. The measures are: the New Mexico Stream Condition Index and the U.S. Environmental Protection Agency's (USEPA) multi-metric index (Jacobi et al. 2006, Stoddard et al. 2005). The values produced by these two indices are the sum of scores for richness, composition, diversity, feeding groups, and pollution tolerance (Jacobi et al. 2006, Stoddard et al. 2005). Both indices range on a scale from 0 to 100 of increasing water quality. Richness and composition are commonly used to assess water quality in New Mexico because benthic macroinvertebrates are easy to collect and differ in their tolerances to pollution in relatively predictable ways.

Reference Conditions

Table 17 lists each measure and the reference conditions for good, moderate concern, or significant concern. Reference conditions for nearly all measures were adopted from water quality criteria developed by the State of New Mexico's Surface Water Quality Bureau (NMSWQB) as reported in Gwilliam et al. (2018a) and NMSWQB (2018). The State of New Mexico has identified one beneficial use for the Middle Fork at Gila Cliff Dwellings (NM): high quality, coldwater aquatic life (Gwilliam et al. 2018a).

Table 17. Reference conditions used to assess water quality.

Indicators	Measures	Good	Moderate Concern	Significant Concern
Core Water Quality	Temperature (°C)	<23	–	≥23
	Specific Conductivity (µS/cm)	<300	–	≥300
	pH (SU)	6.6 - 9.8	–	< 6.6 or > 9.8
	Dissolved Oxygen (mg/L)	>6	–	≤6
	Turbidity (NTU)	<10 over background	–	≥ 10 over background
Metals and Metalloids	Lead, Selenium, Copper, Magnesium, Iron, Aluminum, and Others	There were no exceedences of state standards, or measures that exceeded state standards were acute occurrences and were the result of natural causes.	–	There were chronic exceedences for some measures as the result of unnatural causes.
Nutrients	N as Nitrate	<10 mg/L	–	≥10 mg/L
	Nitrate + Nitrite	<132 mg/L	–	≥132 mg/L
	Nitrogen, Phosphorus, Potassium, and Others	Plant nutrients from other than natural causes are not be present in concentrations that would produce undesirable aquatic life or result in a dominance of nuisance species in surface waters.	–	Plant nutrients from other than natural causes are present in concentrations that would produce undesirable aquatic life or result in a dominance of nuisance species in surface waters.
Microbiological Organisms	*E. coli* (cfu/100ml)	<575	–	≥575
Inorganics and General Water Quality	Alkalinity as $CaCO_3$, Bicarbonate Alkalinity as $CaCO_3$, Fluoride, Sulfate, Total Hardness, and Anion/Cation Balance, and Others	Values were within the range of expected values for the index site.	–	One or more values were outside of the range of expected values for the index site.
Benthic Macroinvertebrates	New Mexico Stream Condition Index	≥75	> 34 but <75	≤34
	USEPA Multi-metric Index	≥71	≥57 but <71	<57

Note: Refer to Gwilliam et al. (2018a) for a complete list of measures for WY 2016.

"High quality coldwater in reference to an aquatic life use means a perennial surface water of the state in a minimally disturbed condition with considerable aesthetic value and superior coldwater aquatic life habitat" (NMSWQB 2018). "A surface water of the state to be so categorized must have water quality, stream bed characteristics and other attributes of habitat sufficient to protect and maintain a propagating coldwater aquatic life population" (NMSWQB 2018).

Criteria for the State of New Mexico 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 the chronic criteria, which are more stringent than acute criteria. The more stringent criteria serve as an early warning sign of potential water quality issues. Due to the complexity and volume of water quality data, we reported the proportion of water samples that exceeded New Mexico State standards for those measures with numerical criteria (i.e., core water quality, metals and metalloids, microbiological organisms, and some measures of inorganics and general water quality). Except for dissolved nitrate and nitrate + nitrite, reference conditions for nutrients were based on narrative criteria developed by NMSWQB (2018). Reference conditions for some inorganics and general water quality measures were also based on narrative criteria developed by SODN (NPS, E. Gwilliam, aquatic ecologist, verbal communication, 15 May 2018).

The New Mexico Stream Condition Index reference conditions were based on criteria developed for high elevation (>2,286 m [>7,500 ft]), small catchment (<518 km^2 [<200 mi^2]) streams (Jacobi et al. 2006). Although the West Fork of the Gila River is technically considered a low elevation, large catchment stream by Jacobi et al. (2006), a memo published in 2009 by J. Hogan, Program Manager, Monitoring and Assessment Section of the New Mexico Surface Water Quality Bureau amended the criteria to account for variability in elevation and watershed size. The state ratings of "very good" and "good" were combined to form the good condition rating in this assessment, and "poor" and "very poor" were combined to form the significant concern condition rating. The "fair" state rating corresponds to moderate concern. Reference conditions for the USEPA multi-metric index pertaining to mountain habitat were derived from Stoddard et al. (2005).

Condition and Trend

For each WY, samples were analyzed for 81-89 measures with numerical reference conditions. Of these, the vast majority (≥95%) attained New Mexico State or other water quality standards (Table 18). For all measures, trends were evaluated based on the condition rating for each WY. For example, if pH met the state criteria for good condition in all WYs, we considered the trend to be unchanging. We did not report or evaluate specific values because reference conditions were based on whether measures met or exceeded the criteria.

None of the core water quality indicator measures exceeded state standards. Therefore, condition for all five measures is good. Trend appears unchanging based on the persistence of the good condition rating for each season and year sampled. Confidence in the condition rating is high.

For the metals and metalloids indicator, the good reference condition for at least one metal was exceeded during WYs 2012-2016 (Table 18). The metals were aluminum (WYs 2012-2016), dissolved lead (WY 2012), and selenium (WY 2014). The exceedence of selenium and dissolved lead appeared to be a

Table 18. Water quality exceedences.

Water Year	# Samples with Numerical Criteria	# Samples Exceeding Criteria	% of Compliant Samples	Measure Exceeding Criteria
2011	81	1	99	*E. coli*
2012	82	4	95	*E. coli*, Dissolved Lead, Cyanide, Aluminum
2013	82	2	98	Aluminum
2014	85	2	98	Aluminum, Selenium
2015	86	1	99	Aluminum
2016	86	3	97	*E. coli*, Aluminum
2017	86	1	99	Cyanide

Source: Data were provided by E. Gwilliam, SODN aquatic ecologist, and K. Raymond, SODN hydrologist.

short-term acute occurrence given that these metals were found in only two of the 208 samples collected over all seven water years. Although aluminum frequently exceeded state standards, this metal occurs naturally in the surrounding rocks, and exceedences were likely the result of precipitation that flushed sediment into the stream, particularly after forest fire (Gwilliam et al. 2018a). Therefore, the condition for metals and metalloids is good. Trend appears unchanging based on the persistence of the good condition rating for each season and year sampled. Confidence in the condition rating is high.

For the nutrients indicator, state standards exist for only two measures: nitrate and nitrate plus nitrite. Since state standards for these two measures were not exceeded during the seven years of sampling, the condition is good with an unchanging trend. Confidence in the condition rating is high. For all other measures for this indicator, no numerical state standards exist. Furthermore, most measures were below the detection limits of the instrumentation (Gwilliam et al. 2018a). Therefore, we could not evaluate their condition. Confidence in the condition rating for these measures is low because of the unknown condition and trend.

For the single measure of the microbiological organisms indicator, water samples exceeded *E. coli* reference conditions during WYs 2011, 2012, and 2016 (Table 18). Exceedences may have occurred as the result of two fires that burned in the watershed during 2011 and 2012. Exceedences could have also been due to higher than average stream discharge at the time of sampling, which increased total suspended solids (i.e., increased turbidity) due to runoff allowing for elevated levels of *E. coli* (Gwilliam et al. 2018a). Because there were only a few exceedences of the 208 water samples tested at the index site, *E. coli* does not appear to be cause for concern. Therefore, the condition is good. Trend is unchanging based on the persistence of the good condition rating across the majority of samples tested. Confidence in the condition rating is high.

For the inorganics and general water quality indicator, state standards for cyanide were exceeded in WYs 2012 and 2017. Although cyanide is produced by some bacteria, algae, and fungi, and is present in some plants, this chemical is usually the result of industrial waste and mining (Jaszczak et al. 2017). The source in the monument is unknown. Although only two samples tested positive for cyanide during the seven years of sampling, this chemical is extremely harmful to human health and wildlife. Reference conditions for the remaining measures were based on whether there were outliers in the water samples tested; however, only one report (WY 2016) has been published that summarized this information.

For WY 2016, all samples were within the range of expected values with the exception of hardness and cation/anion balance, which were high for one sample during WY 2016. The authors state that this indicates the presence of an analyte (likely an unidentified anion) in the sample (Gwilliam et al. 2018a). The overall condition for these measures is unknown because WYs 2011-2015 could not be evaluated without state standards. The overall condition for cyanide warrants moderate concern. However, confidence in the condition rating is low because it’s unclear whether two samples is enough to warrant concern.

For the benthic macroinvertebrates indicator, the mean New Mexico stream condition index was 58.4, while the mean USEPA multi-metric index was 62.2 (Table 19). A simple paired t-test indicated no significant difference between the two means ($n = 6$, $t = -0.87$, $p = 0.42$). The mean values for each index fell within the moderate concern condition rating. Neither the New Mexico stream condition index ($n = 6$, $t = 0.3$, $p = 0.8$) or the USEPA multi-metric index ($n = 6$, $t = 2.2$, $p = 0.09$) showed a significant trend over time, but the latter index showed slight improvement over time even though trends were not significant. These results warrant moderate concern with an unchanging trend. Confidence in the condition ratings are high.

Table 19. Indices of benthic macroinvertebrates.

Water Year	New Mexico Stream Condition Index	USEPA Multi-metric for Mountain Habitat
2012	58.7	58.4
2013	53.8	58.5
2014	55.7	50.9
2015	66.4	62.8
2016	60.8	64.7
2017	55.0	72.1
Mean	58.4	62.2

Source: Data were provided by E. Gwilliam, SODN aquatic ecologist.

Overall Condition, Threats, and Data Gaps

Table 20 summarizes the condition rating and rationale used for each indicator and/or measure. The condition rating applies to all measures for each indictor unless otherwise noted. Within each indicator, any measures that differed in their condition rating were listed separately. Nearly all measures included in this assessment were in good condition. Of the hundreds of samples obtained over the seven WYs, only five water quality parameters in 11 samples exceeded state or SODN criteria. This suggests high water quality in the West Fork of the Gila River flowing through the monument, especially considering that between 81 and 86 water quality parameters were tested within each sample. Confidence is high due to the seven years of sampling.

Measures with high confidence were weighted more heavily in the overall condition rating than measures with medium or low confidence. In this assessment, most measures were assigned high confidence, and those measures with high confidence were overwhelmingly in good condition. The overall trend is unchanging. As previously stated, we did not evaluate trend in actual values. Trend was based on seasonal and annual condition ratings for all measures. An analysis of trends in actual values over time, however, may indicate emerging concerns. A key uncertainty is whether the measures without numerical state reference conditions were within reasonable levels for this system. Future analyses will attempt to determine any outliers in the data as a way to identify potential issues (NPS, E. Gwilliam, aquatic ecologist, verbal communication, 15 May 2018).

There are few local anthropogenic threats to the West Fork of the Gila River because the monument lies within the Gila Wilderness, which also includes the headwaters of the Gila River watershed. Although two pharmaceuticals, which were not included in this assessment, were detected at the index site (Deet in October 2012 and propachlor oxo-acetic acid in May 2014).

Two recent fires were likely responsible for higher than normal concentrations of aluminum, increased turbidity, and reduced benthic macroinvertebrate diversity during the study period. Although fire is a natural ecosystem process in the region (NMDGF 2016), they can temporarily degrade aquatic ecosystems through increased erosion and enhanced release of organic compounds (Gwilliam et al. 2018a). The 2012 Whitewater-Baldy Complex Fire was the largest fire in New Mexico's recorded history and was preceded by the smaller 2011 Miller Fire (NPS 2016, USFS 2018a). Decades of fire suppression have allowed fuels to accumulate resulting in larger and more severe fires in the region (NMDGF 2016). The shift in fire regime as a result of historical suppression and climate change could alter the severity of fire effects on watersheds.

On a broader scale, rising temperatures will alter the type of precipitation (i.e., snow vs. rain) that falls in the region thereby changing the amount of winter snowpack, the timing of snowmelt, streamflow, and severity of flooding. Lower streamflow will reduce the abundance of woody riparian vegetation, including narrowleaf cottonwood (*Populus angustifolia*), Arizona walnut (*Juglans major*), and velvet ash (*Fraxinus velutina*) (NMDGF 2016). Some riparian habitat may be converted to upland plant-dominated habitat. Warmer temperatures could also increase the risk of invasion by exotic aquatic wildlife and reduce the favorability of streams for native cold-water adapted fish (NMDGF 2016). American bullfrogs (*Lithobates catesbeiana*) and crayfish (*Orcontectes* spp.) are already altering aquatic food webs in the monument (NPS 2016).

Hundreds of water samples have been collected to monitor changes in dozens of water quality measures in the monument. Because of this large volume of data, there are few data gaps. However, in this assessment, we did not report on or evaluate specific water quality values because reference conditions were based on whether samples met or exceeded the criteria. While, this generalized assessment indicates good water quality in the monument, a rigorous analysis of values over time would better inform current condition.

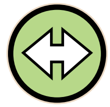
Sources of Expertise

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 20. Summary of water quality indicators, measures, and condition rationale.

Indicators	Measures	Condition/Trend/ Confidence	Rationale for Condition
Core Water Quality	Temperature (°C)		All samples attained New Mexico 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.
	Specific Conductivity (µS/cm)		All samples attained New Mexico 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.
	pH (SU)		All samples attained New Mexico 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)		All samples attained New Mexico 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.
	Turbidity (NTU)		One sample exceeded turbidity standards in water year 2016. However, all other samples attained state standards. The trend is unchanging based on the annual condition rating. Confidence is high.
Metals and Metalloids	Lead, Selenium, Copper, Magnesium, Iron, Aluminum, and Others		Dissolved lead, selenium, and aluminum standards were exceeded for six samples, but since exceedences were likely due to natural causes, the condition is good. The trend is unchanging based on the annual condition rating. Confidence is high.
Nutrients	Phosphorus, Potassium, and Others		The narrative criteria have not been evaluated by SODN. Therefore, the condition and trend for these measures are unknown. Confidence is low.
	Nitrogen (Nitrate, Nitrate + Nitrite)		None of the samples exceeded reference conditions during the seven years of sampling. Trend is unchanging based on the persistence of the good condition rating over time. Confidence in the condition rating is high.
Microbiological Organisms	*E. coli* (cfu/100 ml)		Three samples tested positive for *E. coli*, but exceedences were likely due to natural causes. Therefore, the condition is good. Trend is unchanging. Confidence is high.
Inorganics and General Water Quality	Cyanide		Cyanide exceeded state standards in WYs 2012 and 2017. The condition is of moderate concern. Trend is unknown. Confidence in the condition rating is low due to uncertainties regarding the source of cyanide and whether two samples is enough to warrant concern,
	Alkalinity as $CaCO_3$Total Hardness, and Anion/Cation Balance, and Others		All measures were within the range of expected values except for hardness and cation/anion balance in WY 2016, but other water years could not be evaluated based on data used in this assessment. The condition and trend are unknown, and confidence is low.
Benthic Macroinvertebrates	New Mexico Stream Condition Index		The mean (58.4) over all six years fell within the moderate concern condition rating. A simple regression analysis showed an unchanging trend. Confidence in the condition rating is high.
	USEPA Multi-metric Index		The mean (62.2) over all six years fell within the moderate concern condition rating. A simple regression analysis showed an unchanging trend, although the values improved over time. Confidence in the condition rating is high.

Table 20 continued. ***Summary of water quality indicators, measures, and condition rationale.***

Indicators	Measures	Condition/Trend/ Confidence	Rationale for Condition
Overall Condition	Summary of All Measures		The overwhelming majority of measures indicate good condition. Although there were some exceedences, most appear to be the result of natural disturbances. Confidence is high due to the number of samples and years of data collection. Overall trend is unchanging based on the consistency of condition ratings over the seven years of sampling.

Upland Vegetation and Soils

Background and Importance

The National Park Service (NPS) Sonoran Desert Inventory and Monitoring Network (SODN) surveys upland vegetation and soils across its 11 network parks, including at Gila Cliff Dwellings National Monument (NM), to better understand current condition and patterns of change over time (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.

Although Gila Cliff Dwellings NM is part of SODN, the monument lies east of the Sonoran Desert in the Arizona-New Mexico Mountains ecoregion (Hubbard and Studd 2010). Upland vegetation in the monument is distributed within two topographical areas. These two areas are narrow canyons occurring below 1,829 m (6,000 ft) and mesa tops occurring above 1,829 m (6,000 ft) (Hubbard and Studd 2010). Mesa tops tend to be drier and warmer than canyons because of increased exposure to sun and wind. This mesa-canyon pattern is typical of region (Hubbard and Studd 2010).

Canyon vegetation is typically composed of oneseed juniper (*Juniperus monosperma*), alligator juniper (*Juniperus deppeana*), and two-needle pine (*Pinus edulis*) with little shrub cover in the understory (Hubbard and Studd 2010). In contrast, mesas are represented by more typical pinyon-juniper woodlands dominated by short-statured two-needle pine and Utah juniper (*Juniperus osteosperma*) trees with an understory of perennial grasses and shrubs and a high amount of bare soil, rock, and gravel (Hubbard and Studd 2010). These coniferous forests are fire-adapted, with natural, low-intensity fire return intervals occurring every 9-15 years; however, fire suppression has altered natural fire regimes in and around the monument (Hubbard et al. 2012, NPS 2016). A century of fire suppression has led to an increase in woody vegetation, which has affected the hydrologic regime of the monument by drawing down the water table, influencing rates of evapotranspiration and water infiltration, water runoff, and streamflow (NPS 2016).

Data and Methods

This assessment is based on five indicators with a total of nine measures. The indicators are erosion hazard, erosion features, site stability, fire hazard, and non-native plants. Data were collected as part of SODN's upland vegetation monitoring program (Hubbard et al. 2012). SODN's protocol employs a random, spatially balanced sampling design with plots allocated by elevation strata. In the monument's main

Upland vegetation in Gila Cliff Dwellings NM. Photo Credit: NPS SODN.

unit, six plots were established between 1,372-1,829 m (4,500-6,000 ft, 400 stratum) and nine plots were established at >1,829 m (> 6,000 ft, 500 stratum). In the TJ unit, three plots were established at 1,372-1,829 m (4,500-6,000 ft) within the 400 elevation stratum.

Plots were 20 x 50-m (66 x 164 ft) with six, 20-m (66-ft) transects established every 10 m (33 ft) along the plot's long edge. The transects divided the plot into five subplots. Vegetation and soils were measured in all of the following three layers: field (0-.05 m [<1.6 ft]), subcanopy (>0.5-2.0 m [1.6-6.6 ft]), and canopy (>2.0 m [6.6 ft]). The first round of sampling occurred during 2009 and the second round of sampling occurred during 2012. However, we only included 2009 published data (Hubbard and Studd 2010) to avoid potential conflict with SODN's forthcoming publication on the effects of fire on upland and riparian vegetation in the monument (NPS, A. Hubbard, program manager, e-mail message, 19 July 2018).

Plots were surveyed during July and August. Raw data were provided by K. Bonebrake, SODN data manager, via e-mail on 8 December 2017 and were also published in Hubbard and Studd (2010). For brevity, we provide a brief description of each measure and why it is important rather than specific sampling details. Data collection methods for each measure are described in Hubbard et al. (2012) and Hubbard and Studd (2010).

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 and final measure of erosion hazard is the cover of annual grasses and forbs. Patterns of annual grass and forb cover can be used to estimate soil erosion. The greater the area of ground surface covered by plants, the lower the rates of erosion. However, if the ground surface is covered by more annual plants than perennial plants, erosion may be higher. This is because annual plants do not remain rooted in the ground. Each year annual plants die, usually after the first hard frost, after going to seed. Perennial plants persist longer and thus have greater soil-holding capacity.

For the erosion feature type indicator there is only one measure: the extent of area affected by a particular feature type. The extent of affected area by feature type was surveyed in 10 plots in each stratum. Plots were grouped into soil clusters based on statistically similar soil properties 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 stability (foliar cover of dead trees and foliar cover of dead shrubs), 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. Dead trees and shrubs 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.

SODN uses cover of litter and duff (i.e., fine fuels) as a measure of fire hazard (Hubbard et al. 2012). Gila Cliff Dwellings NM is a fire-adapted landscape. Fires are usually of low intensity and occur on average every 9-15 years (Hubbard et al. 2012). Suppression of natural fires, however, has led to an unnatural build-up of fuels. The amount of fine fuels on the landscape can inform fire hazard.

The last indicator (non-native plants) consists of two measures. The first measure is extent and refers to the frequency of non-native plants encountered across monitoring plots by strata (Hubbard et al. 2012). It is an effective way to monitor changes in the spread of non-native species over time. The second measure is cover, which is the area over which a species or group of species occurs. In this case, it was used to monitor non-native species invasion.

Reference Conditions

Reference conditions are described for resources in good and moderate/significant concern conditions for each of the nine measures (Table 21). Reference conditions were based on Management Assessment Points (MAPS) developed by SODN for Gila Cliff Dwellings NM (Hubbard and Studd 2010). 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 measure of erosion features.

Condition and Trend

For the following nine measures, trend could not be determined because this assessment includes only one year of data. Confidence is medium for all measures with a known condition rating because the data were collected more than five years ago and therefore may not reflect current condition. All data except for erosion features are presented in Table 22. Data for erosion features are presented in Table 23.

Bare ground cover (a measure of erosion hazard) averaged 2.2% ± 0.70 SE (standard error) in the 400 stratum and 3.4% ± 1.20 SE in the 500 stratum. Because these values were below the MAP of 20%, the condition is good.

Soil aggregate stability (a measure of erosion hazard) averaged 3.2 ± 0.4 SE in the 400 stratum and 2.71 ± 0.33 SE in the 500 stratum. The MAP was met in the 400 stratum but not in the 500 stratum. However, the standard error for the 400 stratum value includes values less than 3, which may indicate moderate/significant

Table 21. Reference conditions used to assess upland vegetation and soils in Gila Cliff Dwellings NM.

Indicators	Measures	Good	Moderate Concern/Significant Concern
Erosion Hazard	Bare Ground Cover (%)	Bare ground with no overhead vegetation is ≤ 20%.	Bare ground with no overhead vegetation is > 20%
	Soil Aggregate Stability (Class)	Average surface soil aggregate stability is ≥ Class 3.	Average surface soil aggregate stability is < Class 3.
	Annual Grass and Forb Cover (%)	≤ 33%	> 33%
Erosion Features	Extent of Affected Area by Feature Type (%)	No reference conditions established.	No reference conditions established.
Site Stability	Foliar Cover of Dead Trees (%)	Foliar cover of dead trees is ≤ 10%.	Foliar cover of dead trees is > 10%.
	Foliar Cover of Dead Shrubs	Foliar cover of dead shrubs is ≤ 10%.	Foliar cover of dead shrubs is > 10%.
Fire Hazard	Litter and Duff Cover (%)	Litter and duff cover is ≤ 80%.	Litter and duff cover is > 80%.
Non-native Plants	Extent	Extent of non-native plants is ≤ 50%.	Extent of non-native plants is > 50%.
	Cover	Total cover of non-native plants is ≤ 10%.	Total cover of non-native plants is > 10%.

Source: Hubbard and Studd (2010).

Table 22. Summary of 2009 upland plant and soils monitoring data in Gila Cliff Dwellings NM.

Indicators	Measures	400 Stratum (value ± standard error)	500 Stratum (value ± standard error)
Erosion Hazard	Bare Ground Cover (%)	2.2 ± 0.70	3.4 ± 1.20
	Soil Aggregate Stability (Class)	3.2 ± 0.4	2.71 ± 0.33
	Annual Grass and Forb Cover (%)	4.5 ± 1.0	9.8 ± 6.5%
Site Stability	Foliar Cover of Dead Trees (%)	0.1 ± 0.1	0.3 ± 0.2
	Foliar Cover of Dead Shrubs (%)	1.0 ± 0.7	1.3 ± 0.6
Fire Hazard	Litter and Duff Cover (%)	64.0 ± 6.40	50.8 ± 10.5
Non-native Plants	Extent (%)	60	10
	Cover (%)	0	0

Source: Hubbard and Studd (2010).

concern for the canyon as well. Therefore, we assigned a condition of moderate/significant concern for both strata.

Annual grass and forb cover (a measure of erosion hazard) averaged 4.5% ± 1.0 SE in the 400 stratum and 9.8% ± 6.5% SE in the 500 stratum. These values were well within the good condition rating.

The condition for the extent of erosion by feature type is unknown because reference conditions for this measure have not been developed. However, two plots showed high levels of erosion and may be cause for concern (Table 23). These plots exhibited a high amount of exposed bedrock, low rock fragment volume, and low canopy cover. These factors likely contributed to the high erosion observed in the two plots. The remaining plots, however, exhibited low erosion.

The two measures of site stability both indicate good condition. Foliar cover of dead trees averaged 0.1% ± 0.1 SE in the 400 stratum and 0.3% ± 0.2 in the 500 stratum. Foliar cover of dead shrubs averaged 1.0% ± 0.7 SE in the 400 stratum and 1.3% ± 0.6 SE in the 500 stratum.

Litter and duff cover (a measure of fire hazard) averaged 64.0% ± 6.40 SE in the 400 stratum and 50.8% ± 10.5 SE in the 500 stratum. These values indicate good condition for this measure.

Extent (a measure of the non-native plant indicator) in the 400 stratum averaged 60%, which indicates moderate/significant concern. In the 500 stratum, non-native plant extent was 10%, which is considered good. Common mullein (*Verbascum thapsus*) was the only non-native species encountered in 2009 according to data provided by SODN. Hubbard and

Table 23. Erosion area class by feature type at Gila Cliff Dwellings NM in 2009.

Soil Cluster	Stratum_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)
n*1	500_005	0	0	0	1-5	0	1-5	0	3
n*2	500_001	0	0	0	0	26-50	6-25	0	51
	500_002	0	0	0	1-5	1-5	1-5	0	6
n*3	400_001	0	0	0	1-5	0	0	0	0
n*4	400_002	0	0	0	0	26-50	0	0	38
	400_02TJ	0	0	0	1-5	1-5	0	0	3
	400_004	0	0	0	0	0	0	0	0
	400_005	0	0	0	1-5	0	1-5	0	3
	500_003	0	0	0	1-5	0	1-5	0	3
	500_004	0	0	0	1-5	0	0	0	0

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

Source: Nauman (2011).

Studd (2010) note that this species has completed the colonization phase and is widely distributed in the 400 stratum. Cover (also a measure of the non-native plant indicator) revealed that although non-native plants were encountered in both strata, they were sufficiently sparse to have not been recorded on line transects. Therefore, the condition is good for this measure in all three vegetation layers and in both strata.

Overall Condition, Threats, and Data Gaps

We used five indicators and nine measures (Table 24) to assess the condition of upland vegetation and soils at Gila Cliff Dwellings NM. Measures without a condition rating were not used to assess overall condition (one measure). In this assessment, all measures with a condition rating were assigned medium confidence. This is because the data were collected more than five years ago and may not reflect current conditions, especially because of two large fires that occurred during 2011 and 2012. Based on eight of the nine measures, upland vegetation and soils at Gila Cliff Dwellings NM is good. Trend could not be determined.

The two measures of concern were soil aggregate stability (both strata) and extent of non-native plants (400 stratum). It could be that soils at Gila Cliff Dwellings NM are inherently unstable, but more research is needed to assess this statement. The measure of erosion features indicated very little cause for concern, except for two plots, which exhibited high levels of sheet erosion. These two plots differed from the others sampled in that they exhibited more exposed bedrock and a more open canopy (Nauman 2011). They also exhibited lower rock fragment levels, and higher levels of rock fragments help stabilize soils (Nauman 2011).

Although Hubbard and Studd (2010) concluded that vegetation as of 2009 in Gila Cliff Dwellings NM was within the range of natural variability, there have been two major fires in and around the monument that have caused significant changes soil stability, water quality, and vegetation (NPS 2016). The Miller Fire in 2011 was followed by the Whitewater-Baldy Complex Fire in 2012 (NPS 2016). Some of these changes were temporary, such as high aluminum concentrations in the West Fork of the Gila River (Gwilliam et al. 2018a). Other consequences may be more long-term, such as changes to the structure and composition of vegetation. The extent to which upland vegetation has changed in the monument was not evaluated in this assessment and represents a key uncertainty. However, this is the topic of an ongoing study by SODN (NPS, A. Hubbard, program manager,19 July 2018 e-mail).

Common mullein was the only non-native species encountered in 2009, and this species was prevalent in the 400 stratum but not in the 500 stratum. However, the data indicate that common mullein cover is sparse and probably does not influence native vegetation to a measurable degree (Hubbard and Studd 2010). Wildfire coupled with climate change could alter non-native plant distribution. Although only one non-native plant was found in 2009, others do occur in the monument. NPSpecies lists 37 confirmed non-native species in Gila Cliff Dwellings NM (NPS 2018a). Changes in climate and the fire regime may promote the dispersal of some of these non-natives.

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 the monument, Monahan and Fisichelli (2014) found that recent climate conditions indicate a shift from the natural range of variability. Overall however, ecosystems in Gila Cliff Dwellings NM are relatively well protected. Often, small parks, such as Gila Cliff Dwellings NM, are vulnerable to factors beyond their borders, but because this monument is located within the protected area of the Gila Wilderness, edge effects are likely absent or minimal.

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.

Table 24. 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 2.2% ± 0.70 SE (standard error) in the 400 stratum and 3.4% ± 1.20 SE in the 500 stratum. Because these values fall below the MAP of 20%, the condition is good. Trend is unknown. Confidence is medium.
	Soil Aggregate Stability		Soil aggregate stability averaged 3.2 ± 0.4 SE in the 400 stratum and 2.71 ± 0.33 SE in the 500 stratum. The MAP was met in the 400 stratum but not in the 500 stratum. However, the 400 stratum value of 3.2 accounted for the SE may indicate moderate/ significant concern for this stratum as well. Trend is unknown. Confidence is medium.
	Annual Grass and Forb Cover		Annual grass and forb cover averaged 4.5% ± 1.0 SE in the 400 stratum and 9.8% ± 6.5% SE in the 500 stratum. These values fall well within the good condition rating. Trend is unknown. Confidence is medium.
Erosion Features	Extent of Affected Area by Feature Type		Of the ten plots sampled, two showed high rates of sheet erosion. These plots contained a high amount of exposed bedrock, low amount of rock fragments, and an open canopy. These factors likely contributed to erosion there. The remaining plots exhibited little erosion. Because there are no reference conditions for this measure, the condition and trend are unknown and confidence is low.
Site Stability	Foliar Cover of Dead Trees		Foliar cover of dead trees averaged 0.1% ± 0.1% SE in the 400 stratum and 0.3% ± 0.2% in the 500 stratum. These values fall well within the MAP for a good condition rating. Trend is unknown. Confidence is medium.
	Foliar Cover of Dead Shrubs		Foliar cover of dead shrubs averaged 1.0% ± 0.7% SE in the 400 stratum and 1.3% ± 0.6% in the 500 stratum. These values fall well within the MAP for a good condition rating. Trend is unknown. Confidence is medium.
Fire Hazard	Litter and Duff Cover		Litter and duff cover averaged 64.0% ± 6.40 SE in the 400 stratum and 50.8% ± 10.5 SE in the 500 stratum. These values indicate good condition for this measure. Trend is unknown. Confidence is medium.
Non-native Plants	Extent (400 Stratum)		Extent of non-native plants in the 400 stratum averaged 60%, which indicates moderate/significant concern. Trend is unknown. Confidence is medium.
	Extent (500 Stratum)		In the 500 stratum, non-native plant extent was 10%, which is considered good. Trend is unknown. Confidence is medium.
	Cover		Although non-native plants were encountered in both strata, they were sufficiently sparse to have not been recorded on line transects. Therefore, the condition is good for this measure in all three vegetation layers. Trend is unknown. Confidence is medium.
Overall Condition	Summary of All Measures		Only one non-native species was detected in monitoring plots, but cover for this species was sparse. Soil aggregate stability suggests possible issues with respect to erosion. All other measures, however, indicate good condition. Upland vegetation and soils at Gila Cliff Dwellings NM is within the range of natural variation. Trend is unknown. Confidence is medium.

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 woody plants, for breeding, foraging, migration habitat, and for regulating stream temperature by shading streambanks. Additional beneficial riparian attributes include erosion control, nutrient cycling, flood mitigation, increased groundwater recharge, and improved water quality, in part by buffering pollutants, making riparian areas highly productive ecosystems if functioning properly.

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 along the West Fork of the Gila River in Gila Cliff Dwellings National Monument (NM) to better understand current condition and patterns of change over time (Gwilliam et al. 2014a). 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. These topics are addressed in separate assessments in this report.

Gila Cliff Dwellings NM lies at the confluence of the West and Middle Forks of the Gila River. A 2.1 km (1.3 mi) stretch of the West Fork flows through the monument's main unit (Gwilliam et al. 2014b). Deciduous woody riparian vegetation growing along the banks of the West Fork include narrowleaf cottonwood (*Populus angustifolia*) and Arizona walnut (*Juglans major*) (Powell et al. 2006). Streamside vegetation provides important habitat for the endangered southwestern willow flycatcher (*Empidonax traillii extimus*) and shades aquatic habitat for endangered spikedace (*Meda fulgida*) and loach minnow (*Tiaroga cobitis*) (NPS 2016). Maintaining riparian vegetation in the monument is critical to 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. Data were collected as part of SODN's riparian plant monitoring program at Gila Cliff Dwellings NM (Gwilliam et al. 2018b). 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 26

Cottonwoods and willows growing along the Gila River in the Heart Bar State Wildlife Preserve downstream of Gila Cliff Dwellings NM. Photo Credit: © Janice Wei.

February 2019. Below we provide an overview of how data were collected.

Vegetation was surveyed during June 2011, July 2012, and May 2017 in three vegetation zones extending perpendicular to the river. We restricted our analysis to 2011 and 2012 data only to avoid potential conflict with a separate concurrent SODN study evaluating the effects of fire on riparian and upland vegetation (NPS, A. Hubbard, program manager, e-mail message, 19 July 2018). In general, riparian vegetation is sampled once every five years, but because of the 2011 Miller Fire, vegetation was re-sampled in 2012 (NPS, S. Studd, ecologist, e-mail message, 15 December 2017). However, it should be noted that there is no pre-fire baseline, and the three years of sampling only occurred after the fire along the West Fork Gila River.

Riparian vegetation along the West Fork of the Gila River in Gila Cliff Dwellings NM. Photo Credit: NPS.

The three zones were the aquatic, greenline, and the riparian zone. The aquatic zone includes vegetation with roots embedded in the stream channel. The greenline zone includes "vegetation found in the first line of perennial vegetation from the stream wetted edge, usually within 10 m (33 ft)" (Gwilliam et al. 2014b). The riparian zone "extends from the active river channel out to an indeterminate point where the transition to uplands is complete" (Gwilliam et al. 2014b). Data for the aquatic zone were not available for inclusion in this report.

Stream vegetation was surveyed in each zone using the point-intercept method. Transects were 20-m (65.6-ft) long perpendicular to stream channel cross-sections (i.e., transects were parallel to the stream channel). In 2011 and 2012, SODN surveyed 22 and 23 transects, respectively, in the greenline. In the riparian zone, SODN surveyed 56 and 54 transects in 2011 and 2012, respectively. 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]).

Loss of obligate wetland plants was evaluated using the measure of richness and distribution. Richness is the number of species occurring 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. 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. Monitoring changes in the lateral distribution of obligate wetland plants within zones helps scientists determine changes in stream vegetation width and the amount of habitat available for obligate wetland species. Obligate wetland species are expected to be more common in the aquatic and greenline zones than in the riparian zone as the plant community transitions to the uplands. This measure is less concerned with the number of obligate species than it is with the loss of obligate species by zone over time.

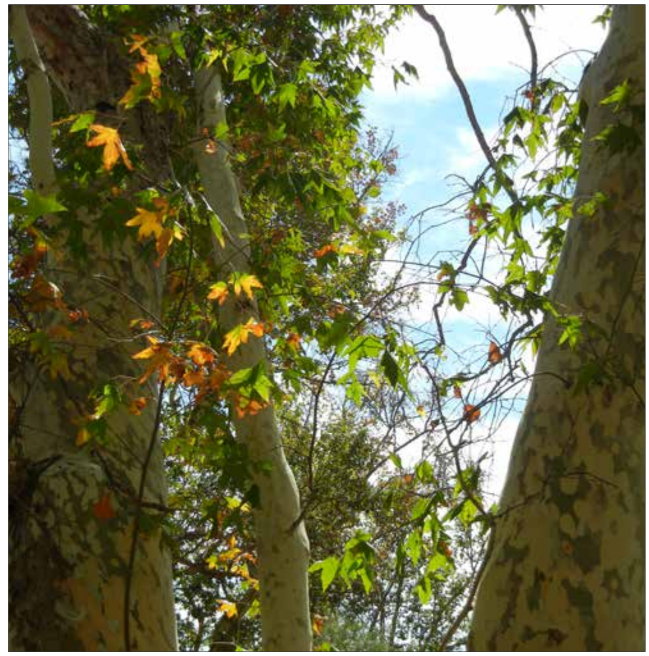
For each plant species, we determined its wetland status using the U.S. Army Corps of Engineers National Wetlands Plant List for the State of New Mexico arid west region (Lichvar et al. 2016). Plants were divided into five categories based on wetland status. The categories are: obligate wetland (OBL = 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).

Non-native plant dispersal and invasion was evaluated using the measures frequency and cover. Frequency indicates 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 the monument. 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.

Percent cover of non-native species 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 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). Percent cover was calculated by zone.

Reference Conditions

Reference conditions are described for resources in good and moderate/significant concern conditions for each of the three measures (Table 25). Reference conditions were based on Management Assessment Points (MAPS) developed by SODN for Montezuma Castle NM and Tuzigoot NM (Gwilliam et al. 2014b). We used MAPs developed for Montezuma Castle and Tuzigoot NM because no MAPs have been developed specifically for Gila Cliff Dwellings NM; however, the three parks are located within the same network. 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). We did not calculate the 95% confidence intervals for richness because there is no pre-fire baseline condition. Confidence intervals would have been calculated based on mean richness of wetland obligate taxa across the plots within each zone.



Arizona sycamores are facultative wetland species that grow in the riparian zone along the West Fork of the Gila River.

Table 25. Reference conditions used to assess riparian vegetation in Gila Cliff Dwellings NM.

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 transects	> 50% of transects
	Percent Cover	% total plant cover is ≤ 10% non-native in each structural layer.	% total plant cover is >10% non-native in each structural layer.

Source: Gwilliam et al. (2014b).

Condition and Trend

A total of 70 native species were documented along the West Fork of the Gila River during 2011 and 2012 (Table 26). Of these, 57 species were encountered in the riparian zone and 39 were encountered in the greenline. Only five of the 70 species were listed

Table 26. Native species in the greenline and riparian zones.

Species	Common Name	Wetland Status[1]	Zone[2]
Acer negundo	Boxelder	FACW	G,R
Achillea millefolium	Common yarrow	FACU	R
Agrostis scabra	Rough bentgrass	FAC	G
Allium acuminatum	Tapertip onion	UPL	G
Alnus oblongifolia	Arizona alder	FACW	G,R
Alopecurus aequalis	Shortawn foxtail	OBL	G
Amauriopsis dissecta	Ragleaf bahia	UPL	G,R
Argemone pleiacantha	Southwestern pricklypoppy	UPL	R
Artemisia carruthii	Carruth's sagewort	UPL	G,R
Artemisia dracunculus	Tarragon	UPL	G,R
Bouteloua hirsuta	Hairy grama	UPL	G,R
Brickellia californica	California brickellbush	FACU	R
Brickellia floribunda	Chihuahuan brickellbush	UPL	R
Bromus carinatus	California brome	UPL	G
Carex geophila	White mountain sedge	UPL	R
Carex occidentalis	Western sedge	UPL	R
Carex senta	Swamp carex	OBL	G,R
Conyza canadensis	Canadian horseweed	UPL	G,R
Corydalis aurea	Scrambled eggs	UPL	R
Cucurbita foetidissima	Missouri gourd	UPL	R
Datura wrightii	Sacred thorn-apple	UPL	G,R
Elymus arizonicus	Arizona wheatgrass	UPL	R
Elymus canadensis	Canada wildrye	FAC	G,R
Epilobium ciliatum	Fringed willowherb	FACW	G
Equisetum arvense	Field horsetail	FAC	R
Ericameria nauseosa	Rubber rabbitbrush	UPL	G,R
Forestiera pubescens	Stretchberry	FACU	R
Frangula betulifolia	Beechleaf frangula	FAC	R
Garrya wrightii	Wright's silktassel	UPL	R
Gaura hexandra	Harlequinbush	UPL	R
Geranium caespitosum	Pineywoods geranium	FAC	G,R
Glyceria striata	Fowl mannagrass	OBL	G
Humulus lupulus	Common hop	FACU	G,R
Juglans major	Arizona walnut	FAC	R
Juncus bufonius	Toad rush	FACW	G
Juniperus deppeana	Alligator juniper	FACU	R
Juniperus scopulorum	Rocky Mountain juniper	UPL	G,R
Lesquerella fendleri	Fendler's bladderpod	UPL	R
Mentha arvensis	Wild mint	FACW	G,R

[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] R = riparian zone; G = greenline.

Table 26 continued. Native species in the greenline and riparian zones.

Species	Common Name	Wetland Status[1]	Zone[2]
Mentzelia multiflora	Adonis blazingstar	UPL	R
Mirabilis longiflora	Sweet four o'clock	UPL	R
Muhlenbergia racemosa	Marsh muhly	FACW	G
Muhlenbergia rigens	Deergrass	FAC	R
Oenothera elata	Hooker's evening primrose	FACW	G
Oenothera neomexicana	New Mexico evening primrose	UPL	R
Oxalis alpina	Alpine woodsorrel	UPL	R
Parthenocissus quinquefolia	Virginia creeper	FAC	G,R
Pascopyrum smithii	Western wheatgrass	FAC	R
Persicaria lapathifolia	curlytop knotweed	FACW	G
Pinus ponderosa	Ponderosa pine	FACU	G,R
Platanus wrightii	Arizona sycamore	FACW	R
Poa fendleriana	Muttongrass	UPL	G
Populus angustifolia	Narrowleaf cottonwood	FACW	G,R
Pseudognaphalium canescens	Wright's cudweed	FACU	R
Quercus gambelii	Gambel oak	UPL	R
Quercus grisea	Gray oak	UPL	R
Rosa woodsii	Woods' rose	FACU	R
Rudbeckia laciniata	Cutleaf coneflower	FAC	G,R
Salix exigua	Narrowleaf willow	FACW	G
Salix irrorata	Dewystem willow	FACW	G,R
Salix lasiolepis	Arroyo willow	FACW	G,R
Schoenoplectus tabernaemontani	Softstem bulrush	OBL	R
Solanum jamesii	Wild potato	UPL	G,R
Solidago velutina	Threenerve goldenrod	UPL	R
Sphaeralcea fendleri	Fendler's globemallow	UPL	G,R
Sporobolus cryptandrus	Sand dropseed	FACU	G,R
Thalictrum fendleri	Fendler's meadow-rue	FAC	R
Verbesina encelioides	Golden crownbeard	FACU	G
Veronica anagallis-aquatica	Water speedwell	OBL	G
Vitis arizonica	Canyon grape	FACU	G,R

[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] R = riparian zone; G = greenline.

as obligate wetland plants. Three obligate wetland species occurred in the greenline and two occurred in the riparian zone. Thirteen species were listed as facultative wetland plants and 11 species were listed as facultative plants. The remaining 40 species were listed as facultative upland (11) or upland (29) species. The high number of upland species is probably because the stream reach is located relatively high in the watershed with a narrow stream channel and steep transition to uplands from the stream bed.

Native species richness was substantially higher in 2012 than during 2011 in both zones, particularly for the riparian zone. In the riparian zone, 18 native species were encountered in 2011, while 53 native species were encountered during 2012. In the greenline, there were 19 species in 2011 and 29 species in 2012. Nearly all species documented in 2012 but not in 2011 were perennials. These drastic changes are likely the result of the 2011 Miller Fire, but it's uncertain whether these effects will persist. Interestingly, only one obligate wetland species (water speedwell [*Veronica anagallis-aquatica*]) was documented in 2011. The remaining four species were all documented in 2012 only. Although data for 2017 have been collected, they were not included in this assessment, and because the reference conditions for this measure are based on loss of obligate riparian wetland species, we could not assign a condition to this measure. Also, it would be difficult to be confident about the current condition since the recent fire likely changed things dramatically and it has only been five years (to the most recent round of sampling). As a result, the confidence is low and trend is unknown. Although, the protocol has changed since data collection and future reporting will likely not include this measure.

For the frequency measure of the non-native plant dispersal and invasion indicator, there were thirty-six species encountered across both zones. Twenty-nine species were encountered in the greenline (Table 27) and twenty-six species were encountered in the riparian zone (Table 28). In the greenline, frequency averaged 82% in 2011 and 96% in 2012. Ten species that were not present in the frequency plots in 2011 were present in 2012. Common mullein (*Verbascum thapsus*), stinging nettle (*Urtica dioica*), and black bindweed (*Polygonum convulvulus*) all increased in frequency while sweetclover (*Melilotus alba*), watercress (*Nasturtium officinale*), and curly dock (*Rumex crispus*) declined in cover. Common mullein and sweetclover exhibited the greatest cover of all species in the greenline. Changes in frequency could be due to the 2011 Miller Fire, but this is unknown. Because frequency in the greenline exceeded 50% in both time periods, the condition warrants moderate/significant concern. Confidence is medium because the data are more than five years old. Trend could not be determined based on two years of data.

In the riparian zone, frequency averaged 13% in 2011 and 77% in 2012. This represents a six-fold increase in frequency of non-native species for this zone. Although frequency increased in the greenline, changes were less dramatic between the two years, perhaps because the greenline is closer to the stream channel with greater access to both surface and groundwater, which may have reduced the effects of the fire. Non-native plant frequency in 2011 ranged between 2% and 9% for the six species (Table 28). In 2012, frequency ranged from 2% to 57% across the 16 species. Sweetclover and common mullein both increased dramatically between the two time periods.

Table 27. Non-native plant frequency in the greenline.

Species	Common Name	2011 Frequency (%)	2012 Frequency (%)
Agrostis gigantea	Redtop	–	4
Agrostis stolonifera	Creeping bentgrass	–	4
Bromus diandrus	Ripgut brome	–	–
Bromus inermis	Smooth brome	–	–
Bromus tectorum	Cheatgrass	9	4
Cerastium arvense	Field chickweed	–	–
Cyperus esculentus	Yellow nutsedge	–	17
Descurainia sophia	Herb sophia	–	–
Digitaria sanguinalis	Hairy crabgrass	5	–
Echinochloa crus-galli	Barnyard grass	–	13
Lactuca serriola	Prickly lettuce	5	4
Macroptilium gibbosifolium	Variableleaf bushbean	–	4
Medicago lupulina	Black medick	–	4
Melilotus alba	Sweetclover	64	35
Nasturtium microphyllum	Onerow yellowcress	5	–
Nasturtium officinale	Watercress	32	9
Persicaria maculosa	Spotted ladysthumb	–	26
Plantago major	Common plantain	5	13
Poa pratensis	Kentucky bluegrass	–	26
Polygonum aviculare	Common knotgrass	–	–
Polygonum convolvulus	Black bindweed	14	35
Rumex acetosella	Common sheep sorrel	9	9
Rumex crispus	Curly dock	32	13
Sonchus asper	Spiny sowthistle	–	9
Thlaspi arvense	Field pennycress	–	–
Tragopogon dubius	Yellow salsify	5	–
Tribulus terrestris	Punturevine	–	4
Urtica dioica	Stinging nettle	9	17
Verbascum thapsus	Common mullein	50	65

Table 28. Non-native plant frequency in the riparian zone.

Species	Common Name	2011 Frequency (%)	2012 Frequency (%)
Agrostis gigantea	Redtop	2	–
Bromus diandrus	Ripgut brome	–	–
Bromus tectorum	Cheatgrass	–	2
Cyperus esculentus	Yellow nutsedge	–	13
Descurainia sophia	Herb sophia	–	–
Echinochloa crus-galli	Barnyard grass	–	–
Eragrostis curvula	Weeping lovegrass	–	2
Euphorbia esula	Leafy spurge	2	–
Lactuca serriola	Prickly lettuce	–	4
Lepidium draba	Whhitetop	–	–
Lolium perenne	Perennial ryegrass	–	2
Malva parviflora	Cheeseweed mallow	–	2
Medicago lupulina	Black medick	–	6
Melilotus alba	Sweetclover	4	28
Nasturtium officinale	Watercress	–	–
Persicaria maculosa	Spotted ladysthumb	–	6
Plantago major	Common plantain	2	–
Poa pratensis	Kentucky bluegrass	–	4
Polygonum convolvulus	Black bindweed	–	15
Rumex acetosella	Common sheep sorrel	–	–
Rumex crispus	Curly dock	–	4
Solanum nigrescens	Divine nightshade	–	2
Sonchus asper	Spiny sowthistle	–	2
Trifolium pratense	Red clover	–	
Urtica dioica	Stinging nettle	2	7
Verbascum thapsus	Common mullein	9	57

According to Rita Garcia, Gila Cliff Dwellings NM Chief of Interpretation, sweet clover and common mullein continue to spread both within and outside the riparian zone (10 October 2018, assessment review comment). Although frequency was low in 2011, the dramatic increase to 77% in 2012 warrants moderate/significant concern. Confidence is medium because the data are more than five years old. Trend could not be determined based on two years of data.

For the cover measure of the non-native plant dispersal and invasion indicator, total cover was higher in 2012 than in 2011 in the herbaceous and subcanopy layers across both zones. In contrast, cover in the canopy was lower during 2012 (Table 29). This pattern could be the result of reduced crown cover from the fire, which then stimulated growth in the understory. Cover of non-native species in the herbaceous and subcanopy layers also increased in 2012, but was well below 10%

Table 29. Percent total cover and cover of non-native species by zone and vegetation layer.

Zone	Layer	2011		2012	
		% Total Cover (SE)	% Non-native Cover (SE)	% Total Cover (SE)	% Non-native Cover (SE)
Greenline	Herbaceous	16 (4.3)	5 (2.5)	45 (4.8)	7 (2.1)
	Subcanopy	13 (4.1)	0 (0)	41 (6.0)	4 (1.7)
	Canopy	21 (6.5)	0 (0)	17 (6.1)	0 (0)
Riparian	Herbaceous	6 (1.7)	<0.1 (0.09)	40 (2.9)	4 (1.4)
	Subcanopy	7.5 (1.6)	0 (0)	28 (3.3)	1 (0.6)
	Canopy	37 (4.4)	0 (0)	10 (2.7)	0 (0)

in each vegetation layer in both zones. Non-native cover was highest overall in the herbaceous layer. These results indicate good condition for this measure. Confidence is medium because the data are more than five years old. Trend could not be determined.

Overall Condition, Threats, and Data Gaps

We used two indicators and three measures (summarized in Table 30) to assess the condition of riparian vegetation along the West Fork of the Gila River in Gila Cliff Dwellings NM. While percent cover of non-native plants was low, percent frequency was high, indicating the widespread occurrence but low abundance of non-native species. This resulted in an overall condition rating of moderate concern. Although there were few obligate wetlands species encountered along the sample reach, this could be a natural feature of this high elevation, narrow stream that transitions quickly to upland habitat. Confidence in the overall condition rating is medium. Trends could not be determined, but in the future, trends will be determined based on comparisons with future monitoring data. A key uncertainty is whether the transects captured all of the species (native and non-native) present in the riparian and greenline vegetation zones as well as the long-term effects of fire on vegetation in the monument.

A key driver to the persistence of riparian vegetation is access to groundwater; however, groundwater is not monitored at the monument (NPS 2018b). Streamflow, however, has remained stable over the last 90 years, and the river continues to flow perennially (data presented in the hydrology assessment in this report). The wilderness designation and relatively high elevation, mountainous habitat that supports the headwaters of the Gila River serve to protect water

Table 30. 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		Species richness was higher in the riparian zone (57) than in the greenline (39), with a total of 70 species. Furthermore, species richness increased in each zone over the two years. Only five of 70 species were obligate wetland species, four of which occurred in the greenline and two of which occurred in the riparian zone. More than half (57%) were considered either facultative upland or upland species. However, this high elevation, mountainous stream may have a naturally narrow and mixed corridor of species. Loss of obligate species could not be determined based on two years of data. Therefore, the condition is unknown. Because of the unknown condition, confidence is low. Trend will be based on comparisons with future surveys.
Non-native Plant Dispersal and Invasion	Percent Frequency (greenline)		Frequency exceeded 50% for 2011 and 2012 in the greenline and during 2012 for the riparian zone. There was a six-fold increase in frequency in the riparian zone from 2011 to 2012. The Miller Fire in 2011 likely contributed to this change. It is uncertain whether these are short-term effects; however, once a non-native species becomes established, it may be difficult or even impossible to control. Confidence in the condition rating is medium because the data are more than five years old.
	Percent Cover		Percent cover of non-native species in both zones was less than 10% in each layer and year. Non-native cover increased slightly from 2011 to 2012. Total cover (native and non-native plants) increased from 2011 to 2012 in the herbaceous and subcanopy layers but declined in the canopy. As with frequency, these changes were likely the result of the Miller Fire, which opened up the canopy and/or changed the soils and stimulated the seedbank. Confidence is medium because the data are more than five years old. Trend could not be determined based on two years of data.
Overall Condition	Summary of All Measures		Few obligate riparian wetland species occurred along the West Fork of the Gila River, but it's unclear whether there has been a loss of species over time or whether this is a natural feature of this high elevation stream. Non-native plant frequency exceeded 50% in 2012 for both zones and in 2011 for the greenline. Percent cover of non-native plants was well below 10% in both zones and all three vegetation layers. These results suggest an overall moderate concern condition. Confidence is medium because of the age of the data and uncertainties regarding whether changes in vegetation are short-term effects of the fire. Trend could not be determined based on two years of data.

resources and riparian vegetation in and around the monument.

Two of the greatest threats to riparian vegetation are the introduction and colonization of non-native species and climate change (NPS 2016). The duration and frequency of droughts are likely to increase as the climate continues to change. 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). A climate study for the monument revealed that temperatures are also increasing (Monahan and Fisichelli 2014). Air temperature determines whether precipitation falls as rain or snow with significant consequences for local hydrology, such as changes in the amount of winter snowpack, changes in the timing of snowmelt, and possibly increased severity of flooding (Knowles et al. 2006). While no precipitation variables were classified as extreme dry (i.e., exceeding 95% of the historical range of conditions), (Monahan and Fisichelli 2014) 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 not currently found in the monument. Once non-native species become established, they are often extremely difficult to control and most will never be completely eradicated (Mack et al. 2000). Other threats to native vegetation include unnaturally severe fires due to a long history of fire suppression and post-fire erosion (NPS 2016). These factors not only destroy native vegetation, but they also may increase the dispersal of non-native plants. Suppression in the uplands has introduced fire into areas that are not fire prone. Ozone is another concern for ozone-sensitive species. At Gila Cliff Dwellings NM, ozone levels, as they relate to vegetation, warrant moderate concern (NPS ARD 2016). Boxelder (*Acer negundo*) and narrowleaf willow (*Salix exigua*) are both considered ozone-sensitive riparian plants in the monument (NPS 2016).

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

Birds

Background and Importance

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

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

Although Gila Cliff Dwellings NM is part of SODN, the monument lies east of the Sonoran Desert in the Arizona-New Mexico Mountains ecoregion (Mau-Crimmins et al. 2005). The Arizona-New Mexico Mountains ecoregion is considered the most diverse in the southwestern U.S., supporting more species of bird and mammal than adjacent areas (Bell et al. 1999). Gila Cliff Dwellings NM, located within the Gila Wilderness, is divided into two separate units. The larger 194 ha (480 ac) western unit includes the monument's namesake cliff dwellings, while the smaller 21 ha (53 ac) TJ unit lies 1.6 km (1 mi) east of the main unit (Mau-Crimmins et al. 2005). Birds were surveyed in the main unit only.

Photo of a common black hawk, which is a species of concern in Gila Cliff Dwellings NM. Photo Credit: © Robert Shantz.

Data and Methods

This assessment is based on one indicator (species occurrence) with two measures (richness and composition, and presence of species of concern). The NPSpecies (NPS 2018a) bird list served as our foundation list of species for the monument. NPSpecies is typically updated using past surveys, such as those described below, and expert opinion. The list is included in Appendix B along with additional species reported by NPS staff or those that appear in the studies described here. For brevity, scientific names in the following tables are provided in Appendix B.

Richness and composition respresent two different aspects of community dynamics that are important for assessing changes occurring within bird communities and for determining how individual species respond to changing landscapes (Beaupré et al. 2013). We considered richness and composition together because richness alone provides limited information about biodiversity change. 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). Richness and composition was characterized in upland forested areas and in riparian habitat. Uplands in the monument are dominated by galleria forests of ponderosa pine (*Pinus ponderosa*), alligator juniper (*Juniperus deppeana*), and oneseed juniper (*Juniperus monosperma*) (Mau-Crimmins et al. 2005). Riparian habitat is dominated by Fremont's cottonwood (*Populus fremontii*) and Goodding willow (*Salix goodingii*) (Mau-Crimmins et al. 2005).

Richness and composition were evaluated using data from two studies. The first study was conducted by Powell et al. (2006) as part of a baseline inventory of birds (and other wildlife and plants) in the monument. Powell et al. (2006) surveyed breeding birds using the Variable Circular Plot (VCP) method. Six points were established along two transects: one in riparian habitat and one in upland habitat. Points were spaced a minimum of 250 m (820 ft) apart. Three of the riparian points were located outside the monument but were within 1.0 km (0.6 mi) or less of the boundary. Since the monument is located within the Gila Wilderness, we considered points outside the monument as representative of birds found within the monument.

All points were visited five times except for two upland points in 2002, which were surveyed four times. Surveys were conducted from April to July of 2001 and 2002, and counts lasted for eight minutes at each point. Flyovers and birds beyond 75 m (246 ft) from each point count station were excluded from analysis. We reported species richness by year and habitat type as well as a list of the 20 most commonly detected species over all survey years as a percentage of total detections.

The second study was conducted as part of SODN's inventory and monitoring program. SODN established two transects in similar locations to the 2001-2002 transects (Powell et al. 2006, Beaupré et al. 2013). As with Powell et al.'s (2006) points, some of the points established by SODN were located outside of the monument but were within 1.0 km (0.6 mi) of the boundary. However, some of the point count locations have changed slightly over time (see Beaupré et al. 2013 for the most current survey locations). The riparian transect was surveyed from 2009-2010 and 2012-2015. The upland transect was surveyed in 2010 and 2012-2015 (Beaupré et al. 2013). Surveys were conducted during May to July with two visits per point. The Miller Fire prevented sampling along both transects in 2011 (Ali et al. 2012).

SODN's protocol was similar to the VCP method in that six points were surveyed along each transect, points were spaced 250 m (820 ft) apart, flyovers were removed, and birds beyond 75 m (246 ft) from each point count station were excluded (Beaupré et al. 2013). However, there were some differences in data collection methods. Each point was generally surveyed twice (vs. 4-5 visits), counts lasted for six minutes at each point (vs. 8 minutes), and surveys were conducted during May through July (vs. April to July) (Beaupré et al. 2013). We reported species richness by year and habitat type 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.

To determine condition of richness and composition, we compared overall richness and richness by habitat type between the two studies with emphasis on the top 20 most commonly detected species in each survey. We also compared differences in species composition by determining which species were detected during the earlier study but not during the later study. Lastly, we compared the list in Appendix B, which was based on NPSpecies and any additional species observed by

NPS staff or reported in the surveys, to a checklist of birds for the Gila National Forest (Zimmerman 1995). Ideally, we would have longer-term historic data with which to compare species occurrence over time, but these data were not available. Nevertheless, the comparison used here provides a coarse assessment of persistence and a baseline for which to compare to future studies.

The species of conservation concern measure was evaluated using information from the New Mexico State Wildlife Action Plan (NMSWAP). In the NMSWAP, 49 species of concern were identified for the Arizona-New Mexico Mountains ecoregion (NMDGF 2016). However, not all these species occur in the monument. To develop a list of species of concern that are expected to occur in the monument, we cross-referenced the 49 species with the NPSpecies list (NPS 2018a). We then compared this list to the SODN survey data to determine the proportion of species of concern expected to occur in the monument that have been observed relatively recently (i.e., 2009-2015). Because SODN surveys occurred during the breeding season, we determined the proportion using only those species identified as breeding in or resident to the monument. However, we list all species of concern known to occur in the monument for reference.

Additionally, we included information for the federally threatened Mexican spotted owl (*Strix occidentalis lucida*) because Gila Cliff Dwellings NM is located in the Gila Mountains Recovery Unit (Ganey et al. 2011). Surveys for spotted owls were conducted during 2016 and 2017 using Autonomous Recording Units (ARU). The unit(s) were deployed in an area of the monument known to support spotted owls, but to date data from the ARUs have not been analyzed (NPS, K. Bonebrake, SODN Data Manager, e-mail message, 27 November 2017). Instead we report observational data provided by the monument's natural resource staff. Because of the sensitive nature of these data, we present presence/absence only and exclude information regarding location.

Reference Conditions

Reference conditions for the two measures are shown in Table 31. Reference conditions are described for resources in good, moderate concern, and significant concern conditions.

Condition and Trend

According to NPSpecies, 151 species are confirmed for the monument (Appendix B). An additional 45 species are listed as unconfirmed by NPSpecies; however, two unconfirmed species were reported by SODN. These species were northern shoveler (*Spatula clyptea*) and belted kingfisher (*Megaceryle alcyon*). The latter species has also been observed by NPS staff in addition to northern harrier (*Circus hudsonius*), which was not listed by NPSpecies (NPS, R. Garcia, Chief of Interpretation, comments to draft assessment provided via e-mail to Phyllis Bovin, 7 February 2018). SODN also reported four additional species that were not listed by NPSpecies. These species were Cassin's finch (*Haemorhous cassinii*), Eurasian collared-dove (*Streptopelia decaocto*), great-tailed grackle (*Quiscalus mexicanus*), and hooded oriole (*Icterus cucullatus*). In total, there are 158 species for the monument, but there may be as many as 202 if the remaining species can be confirmed.

Table 31. Reference conditions used to assess birds in Gila Cliff Dwellings NM.

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 monument were recorded by SODN.	A moderate number (>50 but <75%) of bird species recorded during early surveys in the monument were recorded by SODN (particularly if the species had previously been considered common in the monument).	Less than 50% of species recorded during early surveys in the monument were recorded by SODN (particularly if the species had previously been considered common in the monument).
	Presence of Species of Concern	A majority (>75%) of species of conservation concern that are expected to occur in the monument have been reported by recent surveys or observations.	A moderate number (>50 but <75%) of species of conservation concern that are expected to occur in the monument have been reported by recent surveys or observations.	Few (<50) species of conservation concern that are expected to occur in the monument have been reported by recent surveys or observations.

During the 2001 and 2002 inventory surveys, a total of 62 species were observed between riparian (50) and upland habitat (39) (Powell et al. 2006). Riparian richness was similar in both years, while upland richness was higher in 2002 (34) than in 2001 (26) (Figure 18). No non-native species were reported in either habitat. Among the 20 most commonly detected species in riparian habitat were spotted towhee (*Pipilo maculatus*), house wren (*Troglodytes aedon*), American robin (*Turdus migratorius*), and purple martin (*Progne subis*) (Table 32). Yellow-breasted chat (*Icteria virens*) and warbling vireo (*Vireo gilvus*) were the only two riparian obligate species among the top 20 species (Gardali and Ballard 2000, Eckerle and Thompson 2001). Riparian obligates are species that require riparian habitat for breeding. In uplands, painted redstart (*Myioborus pictus*), spotted towhee, and cordilleran flycatcher (*Empidonax occidentalis*) were among the top 20 species observed (Table 32). The top 20 species accounted for 84% (89% including the five species tied for the 20th spot) and 86% (92% including the six species tied for the 20th spot) of all species in riparian and upland habitat, respectively.

During SODN's 2009 to 2015 surveys, a total of 98 species were observed in riparian habitat and 78 species were observed in the uplands for a total of 110 species across both habitats. In general, annual richness was greater in riparian habitat than in the uplands, but richness varied by year (Figure 18). The 20 most commonly detected species along the riparian transect comprised nearly 73% of all detections across all years of surveys (Table 32). Spotted towhee, American robin, house wren, and yellow-breasted chat were among the most commonly observed species. Included in the top 20 were four riparian obligates: yellow-breasted chat, warbling vireo, common yellowthroat (*Geothlypis trichas*), and yellow warbler (*Setophaga petechia*) (Guzy and Ritchison 1999, Lowther et al. 1999, Gardali and Ballard 2000, Eckerle and Thompson 2001). In uplands, the top 20 most commonly detected species comprised 65% of all detections across all years of surveys. Violet-green swallow (*Tachycineta thalassina*), spotted towhee, mourning dove (*Zenaida macroura*), and ash-throated flycatcher (*Myiarchus cinerascens*) were the top four species in this habitat type. The first non-native species (Eurasian collared-dove) reported for the monument was observed in SODN's riparian and upland surveys beginning in 2013 and 2014, respectively. Two additional non-native species have been reported but not confirmed for the monument according to NPSpecies (NPS 2018a). These are ring-necked pheasant (*Phasianus colchicus*) and rock pigeon (*Columba livia*).

When comparing the two studies, we found that annual richness was greater during 2009-2015 than during 2001-2002 for both habitat types (Figure 18).

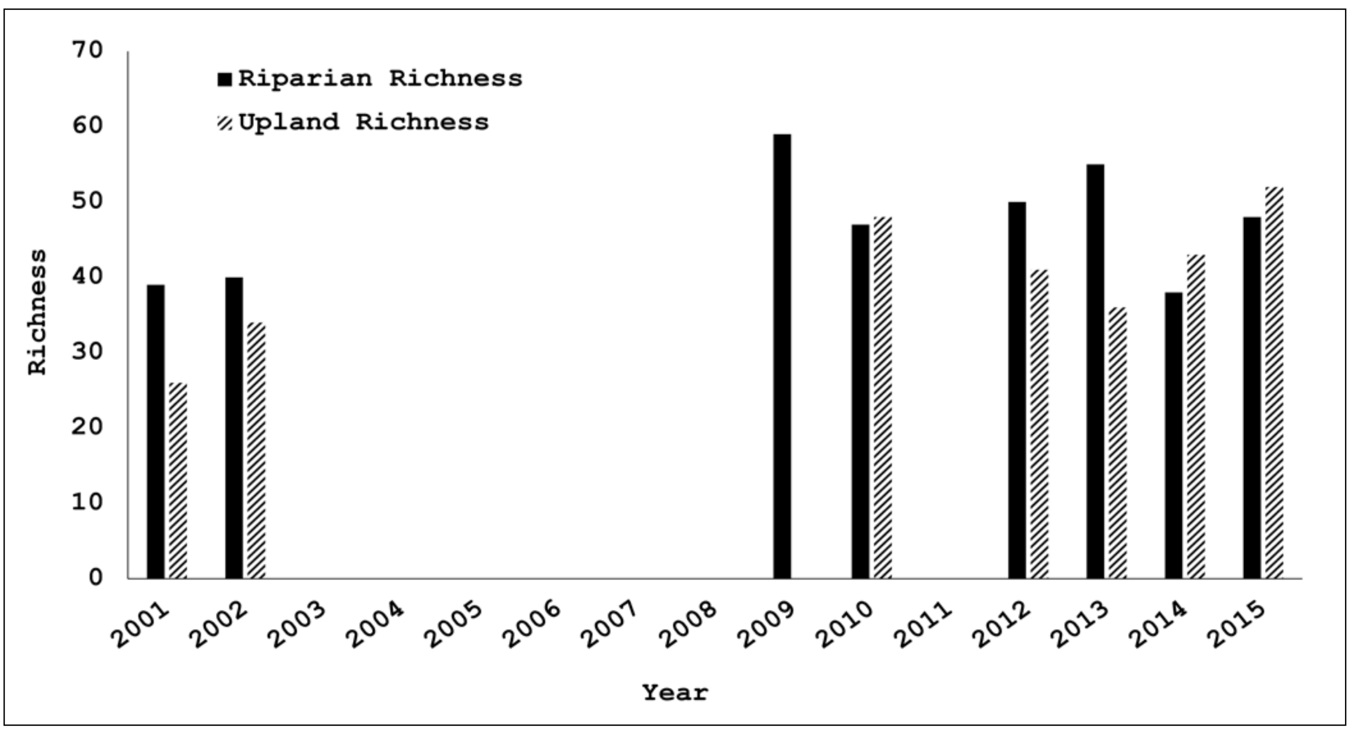


Figure 18. **Richness by year and habitat type in Gila Cliff Dwellings NM.**

Table 32. The 20 most commonly detected species by habitat during surveys.

Species	Riparian (%)		Uplands (%)	
	2001-2002	2009-2015	2001-2002	2009-2015
Acorn woodpecker	1.8	–	1.7	–
American robin	6.3	7.1	5.7	3.0
Ash-throated flycatcher	1.1	1.2	2.8	4.8
Bewick's wren	–	1.3	1.1	2.7
Black-headed grosbeak	5.0	4.0	4.5	3.0
Black-throated gray warbler	–	–	3.4	2.9
Blue-gray gnatcatcher	–	–	1.1	–
Blue grosbeak	2.5	1.7	–	–
Brewer's blackbird	2.0	–	–	–
Broad-tailed hummingbird	–	–	1.1	–
Brown-headed cowbird	1.1	–	–	–
Bushtit	1.6	–	6.2	–
Canyon towhee	1.4	–	–	–
Canyon wren	–	–	3.4	1.8
Cassin's kingbird	–	2.3	–	–
Common raven	–	1.7	1.7	2.2
Common yellowthroat*	–	2.4	–	–
Cordilleran flycatcher	–	–	7.3	–
Hairy woodpecker	–	–	1.1	2.4
Hepatic tanager	–	–	–	2.9
House finch	–	2.7	–	1.9
House wren	11.7	6.3	1.1	2.3
Mountain chickadee	–	–	1.1	–
Mourning dove	4.1	4.8	3.4	5.9
Northern flicker	2.3	2.6	–	2.1
Painted redstart	1.1	–	13.0	1.8
Pine siskin	–	–	–	1.8
Plumbeous vireo	1.4	–	4.5	2.3
Purple martin	6.3	3.4	–	–
Pygmy nuthatch	1.4	–	2.3	–
Red-faced warbler	–	–	2.8	–
Rock wren	–	–	1.1	–
Spotted towhee	16.9	12.3	11.3	6.5
Steller's jay	1.4	–	2.8	–
Turkey vulture	–	2.6	–	–
Violet-green swallow	5.0	4.7	–	10.4
Virginia's warbler	3.2	–	–	–
Warbling vireo*	5.0	2.6	1.7	–
Western tanager	1.1	–	5.7	–
Western wood-pewee	1.1	2.1	–	1.9
White-breasted nuthatch	–	–	–	2.4
Yellow-breasted chat*	4.3	5.7	–	–
Yellow warbler*	–	1.9	–	–
Total	89%	73%	92%	65%

* Riparian obligates (Guzy and Ritchison 1999, Lowther et al. 1999, Gardali and Ballard 2000, Eckerle and Thompson 2001).

In riparian habitat, 103 species were reported between the two studies (50 species in 2001-2002 and 98 in 2009-2015). While this is a near doubling of species richness, it's important to note that SODN surveys occurred over seven years while inventory surveys occurred over only two years. However, even annual richness was greater during later years than during the earlier years. Richness averaged 10 additional species per year during SODN surveys.

Of the 103 species reported during both survey efforts, five were only reported during 2001-2002 and 53 were only reported during 2009-2015. Nearly half (45) of all species were reported during both studies. When considering only the top 20 species, the results were similar: more than half (65%) of the top 20 species were the same between the two studies and nine of the top 10 species were the same (Table 32). We reviewed Powell et al. (2006) for incidental observations of the 53 species not observed during VCP surveys in 2001-2002. We found that thirty-four of the 53 species (64%) were reported by Powell et al. (2006) as incidental observations, in upland habitat, or during VCP surveys but beyond the 75 m (246 ft) threshold use for analysis. Of the 19 species that were not reported in Powell et al. (2006) at all, 11 were only detected three or fewer times during the seven years of SODN surveys.

In uplands, 82 species were reported between the two studies (39 species in 2001-2002 and 78 in 2010-2015) with 36 species (44%) reported by both studies. As with riparian habitat, species richness doubled from the earlier surveys to the later surveys. Although the longer time span of the later surveys partially accounts for higher species richness, even annual richness was generally higher during SODN's surveys: richness averaged 14 additional species per year during later surveys.

Three species were reported only in 2001-2002 and 42 species were reported only in 2010-2015. Again, we reviewed Powell et al. (2006) for any of the 42 species that may have been reported via incidental surveys, in riparian habitat, or outside of the distance thresholds established for surveys. Of the 42 species, only eight were not reported in Powell et al. (2006). Many of the remaining species were recorded in riparian transects, but incidental observations were also common. As with riparian habitat, about half of the top 20 species were the same between the two studies, which suggests some consistency in common species (Table 32).

With the exception of Brewer's blackbird (*Euphagus cyanocephalus*), the eight species reported in Powell et al. (2006) but not by SODN were rare during Powell et al.'s (2006) surveys, with only one or two individuals observed over the two years (Table 33). Although Brewer's blackbird was absent in 2009-2015 riparian monitoring, one observation was reported in 2010 uplands monitoring. Townsend's solitaire (*Myadestes townsendi*) was reported for the riparian transect in 2002 but not in SODN's riparian transect; however, this species is associated with conifers rather than riparian habitat (Bowen 1997) and was detected along SODN's upland transect in 2015. Black-chinned hummingbird (*Archilochus alexandri*) was reported in both habitat types during the earlier survey but not in SODN's upland surveys. This species is more closely associated with riparian areas than uplands so its absence in uplands during later years is not cause for concern (Baltosser and Russell 2000). Lincoln's sparrow (*Melospiza lincolnii*), white-crowned sparrow (*Zonotrichia leucophrys*), and Townsend's warbler (*Setophaga townsendi*) do not breed in the national monument and only move through the region during migration according to NPSpecies. Since the data used in this assessment were collected during the breeding season, their absence in later years is not cause for concern; it could be that these species had already migrated through the monument when surveys began (Appendix B). This is supported by the fact that the inventory surveys began in April, a month earlier than SODN's surveys. The remaining two species (gray

Table 33. Species reported during 2001-2002 surveys but not during 2009-2015 surveys at Gila Cliff Dwellings NM by habitat type.

Common Name	# of Detections	2001-2002 Habitat Type
Black-chinned hummingbird[1]	1	Uplands
Brewer's blackbird[2]	9	Riparian
Gray catbird	1	Riparian
Lincoln's sparrow	2	Riparian
Olive warbler	1	Uplands
Townsend's solitaire[3]	1	Riparian
Townsend's warbler	1	Upland
White-crowned sparrow	2	Riparian

[1] Species reported during SODN's riparian monitoring.

[2] Species was reported during SODN uplands monitoring.

[3] Species reported in SODN uplands monitoring.

catbird [*Dumetella carolinensis*] and olive warbler [*Peucedramus taeniatus*]) breed in the monument but are considered uncommon and only one individual of each species was detected during the earlier survey (Appendix B, Powell et al. 2006).

In summary, the two studies reported 114 species in both habitat types using standard point count methods. Although survey methods were similar, SODN surveys occurred over a much longer time period (seven years vs. two years). Because of the longer time frame, SODN surveys captured more diversity than Powell et al. (2006). While this partially explains increased overall richness in later years, it does not explain greater annual richness in later years. Several factors could account for differences in richness including observer bias, differences in methods, differences in exact point count locations, changes in habitat or some other factor. It is notable that SODN point counts were two minutes shorter than 2001-2002 point counts, there were more visits during the 2001-2002 surveys, and the 2001-2002 surveys occurred earlier in the breeding season. Given these factors, we might expect greater annual richness during the earlier surveys, but we found the opposite. This is not to imply species richness has increased; in fact, we showed that many of the species that were not reported during the VCP surveys were reported via other methods as part of that study. The reasons for differences in richness are unknown.

We also compared the monument's species list to the checklist for the Gila National Forest. The checklist for the Gila National Forest includes 166 breeding species, 114 non-breeding species, and 57 species considered casual or accidental (Zimmerman 1995). There were no studies of birds in the non-breeding season, but the NPSpecies list for the monument along with species reported by SODN and NPS staff, indicate that 158 species occur in the monument with as many as 202 species when including unconfirmed species. The list in Appendix B including unconfirmed species contains 59% of the species listed for the entire Gila National Forest. This is remarkable considering the Gila National Forest is 1.3 million ha (3.3 million ac) while the monument is only 215 ha (533 ac). Appendix B also lists three species not listed for the forest. These species are Eurasian collared-dove, which appears to be a relatively recent arrival, white ibis (*Eudocimus albus*), and dusky-capped flycatcher (*Empidonax oberholseri*). NPSpecies listed white ibis as unconfirmed and the flycatcher as rare.

Photo of a Mexican spotted owl, a threatened species that occurs in Gila Cliff Dwellings NM. Photo Credit: NPS/Rita Garcia.

Overall, these results suggest high species richness, few changes to the relative species composition between the two studies, and species composition that is representative of the surrounding landscape (i.e., Gila National Forest). Furthermore, only one non-native species (Eurasian collared-dove) has been confirmed for the monument. Since this species was not reported in Powell et al. (2006), it is likely a relatively recent addition. Lastly, only eight of the 62 species reported by VCP surveys in 2001-2002 were not observed during 2009-2015. This resulted in 87% of the initial species recorded during later surveys. 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.

For the species of conservation concern measure, we found that 24 of the 49 birds listed as priority species in the NMSWAP (NMDGF 2016) have been reported in the monument (Table 34). Of the 24 priority species,

Table 34. Species of conservation concern reported for Gila Cliff Dwellings NM.

Common Name	NMDGF Status	NMDGF Justification	NPSpecies Abundance	NPSpecies Tags	SODN Riparian	SODN Uplands
Bald eagle	Specialized or Limited Habitat	Vulnerable/Keystone	Rare	Migratory	–	–
Bank swallow	Specialized or Limited Habitat	Declining/Vulnerable/ Disjunct	Rare	Migratory	–	–
Bell’s vireo	Specialized or Limited Habitat	Vulnerable/Disjunct	Rare	Breeder	–	–
Black-throated gray warbler	Immediate Priority	Declining/Vulnerable	Uncommon	Breeder	X	X
Clark’s nutcracker	Susceptible	Declining	Occasional	Migratory	–	–
Common black hawk	Declining	Vulnerable	Uncommon	Breeder	X	–
Common nighthawk	Susceptible	Declining/Vulnerable	Uncommon	Breeder	–	–
Elf owl	Data Gap	Vulnerable	Rare	Breeder	–	–
Flammulated owl	Immediate Priority	Vulnerable	Rare	Migratory	–	–
Grace’s warbler	Immediate Priority	Declining/Vulnerable	Uncommon	Breeder	X	X
Juniper titmouse	Immediate Priority	Declining/Vulnerable	Uncommon	Breeder	X	X
Lewis’s woodpecker	Immediate Priority	Declining/Vulnerable	Rare	Migratory	X	–
Lucy’s warbler	Susceptible	Vulnerable	Uncommon	Breeder	X	–
Mexican spotted owl[1]	Federally Threatened	Vulnerable	–	–	–	–
Painted redstart	Immediate Priority	Vulnerable	Uncommon	Breeder	X	X
Peregrine falcon	Specialized or Limited Habitat	Vulnerable/Keystone	Rare	Breeder	–	–
Pinyon jay	Immediate Priority	Declining/Vulnerable	Uncommon	Breeder	–	X
Pygmy nuthatch	Susceptible	Declining/Vulnerable	Uncommon	Breeder	X	X
Red-faced warbler	Immediate Priority	Vulnerable	Uncommon	Breeder	X	X
Vesper sparrow	Susceptible	Declining/Vulnerable	Rare	Migratory	–	–
Virginia’s warbler	Immediate Priority	Declining/Vulnerable	Uncommon	Breeder	X	X
Western bluebird	Susceptible	Declining/Vulnerable	Uncommon	Breeder	X	X
Williamson’s sapsucker	Susceptible	Vulnerable	Uncommon	Resident	–	–
Yellow-billed cuckoo[2]	Federally Threatened	Declining/Vulnerable/ Disjunct	Rare	Breeder	–	–

Note: ’X’ indicates species was observed by that particular monitoring effort.

[1] U.S. Fish and Wildlife threatened species (USFWS 2017). NPSpecies lists this species as unconfirmed, but the species is present in the monument.

[2] U.S. Fish and Wildlife threatened species (USFWS 2017). Listing is for the western distinct population segment, which includes Gila Cliff Dwellings NM.

16 breed in the monument, six are migratory, and two are year-round residents (including Mexican spotted owl, which was reported as unconfirmed in NPSpecies but observed by monument staff).

Of the 18 species considered residents or breeding birds, 11 (61%) have been observed during SODN’s efforts or by NPS staff in recent years. Three of the remaining seven species of concern are not adequately observed using point count surveys (e.g., raptors and nocturnal species). In fact, species considered rare, as many species of concern are, require targeted search efforts. Given the reference conditions, this measure warrants moderate concern. However, confidence is low because no recent surveys (i.e., after 2015) have occurred and species of concern are best monitored through targeted surveys. Trend could not be determined.

Although the following information did not inform current conditon for the presence of species of conservation concern, we included a brief discussion of two key species that may be useful to monument staff. The western population of the yellow-billed cuckoo (*Coccyzus americanus*) is listed as threatened by the U.S. Fish and Wildlife Service’s Endangered

Species Program (USFWS 2017). However, this species was not encountered during surveys reported in this assessment but is considered to breed in the monument according to NPSpecies (NPS 2018a). Although the threatened Mexican spotted owl was listed as unconfirmed for monument by NPSpecies, at least one resident spotted owl currently occurs there (NPS, R. Garcia, Chief of Interpretation, e-mail message, 21 November 2017), and historic records indicate spotted owls have been previously documented in the monument (Ward et al. 1995). Observations during 2016 and 2017 revealed that there is at least one resident female owl (NPS, R. Garcia, Chief of Interpretation, e-mail message, 21 November 2017). A second owl was observed perched near the female in 2016, but observers were unable to identify whether it was a male, which are smaller than females, or a juvenile (NPS, R. Garcia, Chief of Interpretation, e-mail message, 21 November 2017).

Although Powell et al. (2006) surveyed for a variety of owls in 2001 and 2002 using broadcast methods, surveyors did not broadcast the calls of the Mexican spotted owl since specific protocols and permits are required. However, no spotted owls were detected during passive listening efforts. Finally, although willow flycatchers (*Empidonax traillii*) have been reported for the monument as an uncommon migratory species, the endangered southwestern subspecies (*E. t. extimus*) has not been reported there, probably because of the monument's relatively high elevation and lack of preferred habitat (Powell et al. 2006).

Overall Condition, Threats, and Data Gaps

We used one indicator and two measures (summarized in Table 35) to assess the condition of birds at Gila Cliff Dwellings NM. Despite its small size, the monument's avifauna is diverse, native species richness is high, and species composition reflects the vegetative communities that the monument provides. Measures with high confidence weigh more heavily into the overall condition rating than measures with medium or low confidence. In this assessment, richness and composition was considered good with medium confidence while presence of species of concern was considered moderate concern with low confidence. The overall condition was rated as good because of the apparent persistent of species over time.

Table 35. Summary of birds indicators, measures, and condition rationale.

Indicators	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Species Occurrence	Richness and Composition		A total of 158 species occur in Gila Cliff Dwellings NM (including species listed by SODN and NPS staff but not NPSpecies), but as many as 202 species may occur there if the remaining species are confirmed. Only eight species were observed during earlier (2001-2002) efforts that were not observed during later efforts (2009-2015). However, all but one of these eight species were observed on less than three occasions. Although annual richness was greater during later years than during earlier years, a majority of the species apparently absent in earlier years were observed via incidental surveys, in another habitat type, or beyond the point count distance threshold for inclusion. For these reasons, this measure is in good condition, but confidence is medium because of differences between the two studies. Trend could not be determined.
	Presence of Species of Conservation Concern		Half of the 49 species of concern for the Arizona-New Mexico Mountains ecoregion have been reported for the monument. Eighteen of the 49 species are considered resident or breeding birds at Gila Cliff Dwellings NM. Of the 18 species, 11 (61%) have been observed during SODN's efforts (2009-2015) or by NPS staff in recent years, including the federally threatened Mexican spotted owl. While the condition warrants moderate concern, confidence is low because species of concern are best monitored via targeted surveys. Trend is unknown.
Overall Condition	Summary of All Measures		The data used in this assessment suggest that there have been few changes to the bird community except for the introduction of the non-native Eurasian collared-dove. Although presence of species of conservation concern warrants moderate concern, confidence was low. Overall however, using the data available, the monument's bird community appears in good condition. However, information on changes in abundance, reproductive success, and current non-breeding season data are lacking. Confidence is medium and trends are unknown.

A key uncertainty is how abundance for some 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. A detectability analysis was beyond the scope of this assessment. Other uncertainties include differences in survey methods between the two studies used for comparison. While the methods were similar, differences in observer abilities and the number of minutes during which point counts were conducted (six minutes vs. eight minutes) could have contributed to some of the differences described in this assessment.

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 2016a). The federal Migratory Bird Treaty Act protects more than 1,000 species of bird, and many of these species are experiencing population declines because of increased threats within their range (USFWS 2016a). The Holloman Air Force Base has requested permission to fly over the monument and surrounding wilderness for training purposes with the intention of breaking the sound barrier on a regular basis, which has the potential to impact bird behavior and presence (NPS, R. Garcia, Chief of Interpretation, comments to draft assessment provided via e-mail to Phyllis Bovin, 7 February 2018).

Small NPS units, like Gila Cliff Dwellings NM, are especially vulnerable to factors beyond their borders. However, the monument is located within the designated wilderness of the Gila National Forest, thus edge effects are probably not an issue there (Powell et al. 2006). In fact, species commonly associated with humans, such as feral cats (nest predators), were absent and brown-headed cowbird (*Molothrus ater*) (native brood parasites) abundance was low (Powell et al. 2006). Brown-headed cowbird abundance was also low during SODN surveys, representing <1% of all detections by habitat type. Furthermore, there is only one non-native bird species (Eurasian collared-dove) in the monument, although rock pigeon and ring-necked pheasant have been reported (NPS 2018a).Riparian habitat is the most valuable habitat type in the monument in terms of bird diversity and is also the most imperiled habitat type across the southwest, primarily as a result of increasing human pressure on water resources and climate change (Cayan et al. 2010). Maintaining high quality riparian habitat depends on regular and adequate stream flow, the amount and timing of precipitation and spring snowmelt, groundwater discharge, and the rate of evapotranspiration (Ffolliot et al. 2003). A climate assessment for the monument shows that the climate has become warmer but not necessarily drier (Monahan and Fisichelli 2014). These results reflect trends occurring throughout the southwestern U.S. (Prein et al. 2016).

Following the Miller Fire in 2011 and the Whitewater-Baldy Complex Fire in 2012, there were minor increases in non-native plants along the riparian corridor (Gwilliam 2014). Overall however, the Gila River watershed has few anthropogenic threats (Gwilliam 2014). Uplands also appear to have few threats. A 2009 vegetation report for the monument indicates that upland vegetation is "well within the range of natural variability" and that non-native plants do not pose a threat (Hubbard and Studd 2010).

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 monument serves as a source for which to populate other areas outside of its boundaries. Additionally, the majority of surveys have occurred during the breeding season. However, 30% of all species recorded in the monument are migratory or resident (NPS 2018a), which suggests that the monument provides important year-round habitat for some species. Additionally, the NPSpecies list for the monument may require updates to reflect current taxonomy, potential changes in abundance information, and the addition of species confirmed by SODN and staff at the monument.

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.

Mammals

Background and Importance

Mammals are important to Gila Cliff Dwellings National Monument (NM) for their contributions to the monument's ecological system, serving as predators, prey, seed dispersers, pests, and grazers. They are also important to the monument for their connections to historic and current cultural values. The presence of permanent water sources, soil for agriculture, and a diverse and abundant variety of vegetation and wildlife for sustenance attracted prehistoric and Mogollon peoples to the area as evidenced by the excavation of 22 mammal species (Russell 1992).

According to Frey (2010), outside of the North American tropics, the upper Gila River watershed is one of only two "hot spots" for mammal diversity in North America. Due to its topographic relief and geographic location between several biogeographic regions, the upper Gila River watershed hosts very high mammal diversity, accounting for 77% of Arizona's and 65% of New Mexico's known native mammals (Frey 2010).

Data and Methods

To assess the condition of mammals for the national monument, we used one indicator of condition, species occurrence, with a total of two measures: richness and presence of species of conservation concern.

Richness is a measure of the number of species in an area, and the monument has had two inventories documenting the richness of mammals: Hayward and Hunt (1972) and Powell et al. (2006). In addition, Frey (2010) compiled research on mammal diversity within the entire Gila River watershed, which serves as a comparison for species richness and identifies those species that may not be included on formal conservation lists but are of local (i.e., Gila River watershed) concern.

The monument's first documented vertebrate inventory was conducted by the U.S. Forest Service (USFS) for the Gila Wilderness (Hayward and Hunt 1972). The one-year survey reported on mammals, herpetofauna, and bird species, with an emphasis on confirming mammal species and reporting on local population status. Hayward and Hunt (1972) used small mammal trapping, observations, and accounts from local residents and monument staff to assess the region's mammal populations. The only surveyed site within Gila Cliff Dwellings NM was at the Gila Center, located at the junction of the Middle and West Forks of the Gila River. This site is comprised of an open deciduous riparian habitat with influences from the

Elk in the Gila National Forest. Photo Credit: NPS/Bruce Fields.

piñon-juniper woodland slopes. Since Hayward and Hunt's (1972) survey effort covered a wider area, expanding beyond the monument's boundaries, we used the species recorded during this effort as a baseline to compare results from the monument's most comprehensive mammal survey conducted by Powell et al. (2006).

Powell et al. (2006) conducted a baseline inventory for the national monument to document small to large mammals from 2001 to 2002 using repeatable study designs and standardized field techniques (e.g., netting and investigation of roost sites for bats, small mammal trapping, infrared-triggered cameras, and incidental observations). The Powell et al. (2006) survey focused primarily on the Cliff Dwellings unit, which contained the majority of small mammal trapping and all camera traps. The smaller TJ unit had three small mammal-trapping sites and no camera traps. Survey sites used the same site and vegetation community designations as the herpetofauna survey work, which included perennial riparian area in the river bottom dominated by narrowleaf cottonwood (*Populus angustifolia*) and other deciduous trees; shady, moist, southwest to northeast tending canyon with perennial water dominated by walnut *(Juglans* spp.), oak (*Quercus* spp.), Douglas fir (*Pseudotsuga menziesii*), and cottonwood; xeric, open forest of juniper (*Juniperus* spp.) and pinyon pine (*Pinus* spp.) with rocky soils; burned slopes with a more open understory; and dry canyons except Cliff Dweller, dominated by ponderosa pine (*Pinus ponderosa*) and oak (Powell et al. 2006). Data from all survey methods were used to maximize species detection in order to determine species richness, which was calculated as the sum of species recorded, by community type, in each year (Powell et al. 2006). For more detailed information about the methods used by Powell et al. (2006), please refer to their report.

In 2010, Frey (2010) published research evaluating all recorded species in the upper Gila River watershed by compiling data found in museum collections, others' field research, and published works. Information focused on mammal diversity, geographically contiguous and endemic species populations, and species of concern found within the upper Gila River watershed. The species list generated from this effort was used to compare and contrast the species recorded for the monument by Hayward and Hunt (1972) and Powell et al. (2006).

And finally, the monument's NPSpecies mammals list (NPS 2018a), which was primarily developed using the previously described survey efforts at the monument, as well as voucher specimens and observations, was used to determine if any species that were considered abundant during any of the previously described efforts have not been documented at the monument.

The second measure used to evaluate the condition of mammals at the national monument is the presence of species of conservation concern. We used the national monument's list of mammal species and compared it to the Biota Information System of New Mexico (BISON-M 2018) for federal and state endangered, threatened, or species of conservation concern. BISON-M was developed by collaborating federal and state organizations as a virtual location for accounts on all vertebrate and many invertebrate species found throughout New Mexico and Arizona (BISON-M 2018). BISON-M provides a comprehensive listing of priority rankings, legal status, and reports on species.

We also compared the monument's list of mammals to information reported in Frey (2010) on the status of species within the Gila River region, with specific known threats. While formal conservation status lists focus on broader scales and can be influenced by subjective and socioeconomic factors, Frey (2010) intended to identify the status of species specifically within the ecological system of the upper Gila River. This type of quantitative assessment was based on specific conditions, habitats, and geography. The benefits of this type of species review are twofold: (1) even if a species is on a federal or state conservation list, the condition of the species in the Gila River watershed might not be the same, and (2) a species not federally or state listed, might merit research and conservation attention due local threats and species declines (Frey 2010).

Reference Conditions

Reference conditions for the two measures are shown in Table 36 and are described for good, moderate concern, and significant concern conditions. It's important to note that although efforts, techniques, and agendas varied among the surveys/studies over time, the data represent the best available information, to date.

Table 36. Reference conditions used to assess mammals in Gila Cliff Dwellings NM.

Indicator	Measures	Good	Moderate Concern	Significant Concern
Species Occurrence	Richness	We consider the condition good if all or nearly all of the species recorded during early surveys/observations in the monument were recorded during the most recent surveys.	Condition is of moderate concern if several mammal species recorded during early surveys in the monument were not recorded during more recent surveys (particularly if the species had previously been considered common in the monument).	Condition is of significant concern if a substantial number of mammal species recorded during early surveys in the monument were not recorded during later surveys (particularly if the species had previously been considered common in the monument).
	Presence of Species of Conservation Concern	A moderate to substantial number of species of conservation concern occur in the monument, which indicates that the NPS unit provides important habitat for these species and contributes to their conservation.	A small number of species of conservation concern occur in the monument.	No species identified as species of conservation concern have been recorded in the monument.

Condition and Trend

Based on either Hayward and Hunt (1972), Powell et al. (2006), or NPSpecies (NPS 2018a), a total of 57 mammal species have been documented either as present in the monument or within the adjacent area (Table 37). Thirty-eight of these species (or 66.7%) have been recorded specifically within the national monument by Hayward and Hunt (1972) and/or Powell et al. (2010) (denoted by an X in Table 37). Fifteen species have been observed outside the monument's boundaries within the adjacent Gila National Forest but believed to be present in the monument. These species are denoted by XX in Table 37. The remaining four species have not been documented by either of the two monument-specific surveys but are listed as 'present' in NPSpecies (2018). Frey's (2010) study reports that only two of these four species have been documented within the Gila River watershed. These species are denoted by 'Present" in NPSpecies occurrence (2018) column and en-dashes in both Hayward and Hunt (1972) and Powell et al. (2006) columns in Table 37.

Hayward and Hunt (1972) documented 12 mammals within the monument's Gila Center survey plot, and an additional 34 species were documented in the surrounding study area but are expected to occur at the monument. Over half of the species recorded at the Gila Center were comprised of rodents. The monument's TJ mesa was the only site in the Gila Wilderness to host the Ord's kangaroo rat (*Dipodomys ordii*), silky pocket mouse (*Perognathus flavus*), and the southern grasshopper mouse (*Onychomys torridus*), but all were considered rare. Ord's kangaroo rat is characteristically found in grassier habitats than those of the TJ unit and is believed to have arrived from the east.

The most abundant species recorded during Hayward and Hunt's (1972) region-wide survey were the rock squirrel (*Spermophilus variegatus*) and Botta's pocket gopher (*Thomomys bottae*), followed by the western white-throated woodrat (*Neotoma albigula*) and raccoon (*Procyon lotor*), which were listed as common. The abundance categories of the remaining species documented by Hayward and Hunt (1972), and listed in Table 37, were designated as occasional or considered uncommon.

During the Powell et al. (2006) baseline inventory, 30 species were confirmed in the monument and four were recorded just outside the monument's boundaries (note that Powell et al. (2006) states that 35 species were recorded but only 34 unique species are listed in their Appendix D). Species richness detection was highest from incidental observations with 14 species; nine were detected from wildlife cameras and nine from small mammal trapping. Eight species of bats were detected using bat netting. The West Fork of the Gila River was the most diverse community type, with 12 species confirmed by trapping and infrared cameras (Powell et al. 2006).

Table 37. Mammal species list for Gila Cliff Dwellings NM.

Group	Common Name	Scientific Name	Hayward and Hunt (1972)	Powell et al. (2006)	Frey (2010)	NPSpecies (2018a) Occurrence
Ungulates	Antelope	*Antilocarpa americana*	X	–	C	–
	Elk	*Cervus elaphus*	XX	X	A	Present
	Mule deer	*Odocoileus hemionus*	XX	X	A	Present
	White-tailed deer	*Odocoileus virginianus*	XX	XX	O	Present
Carnivores	American black bear	*Ursus americanus*	XX	X	O	Present
	Bobcat [1]	*Lynx rufus*	X	–	U	Present
	Coyote	*Canis latrans*	XX	X	A	Present
	Gray fox	*Urocyon cinereoargenteus*	XX	X	C	Present
	Hooded skunk	*Mephitis macroura*	–	–	U	Present
	Mountain lion	*Puma concolor*	XX	X	U	Present
	Raccoon	*Prcyon lotor*	X	X	R	Present
	Ringtail	*Bassariscus astutus*	XX	–	R	–
	Spotted skunk	*Spilogale putorius*	XX	–	C	–
	Striped skunk	*Mephitis mephitis*	X	X	C	Present
	White-backed hog-nosed skunk	*Conepatus mesoleucus*	–	X	U	Present
New World Pigs	Collared peccari	*Pecari tajacu*	–	X	U	Present
Lagomorphs	Black-tailed jackrabbit	*Lepus californicus*	XX	XX	A	Present
	Desert cottontail	*Sylvilagus audubonii*	–	–	C	Present
Bats	Allen's big-eared bat [2]	*Idionycteris phyllotis*	XX	–	U	–
	Arizona myotis	*Myotis occultus*	–	X	R	–
	Big brown bat	*Eptesicus fuscus*	XX	X	U	Present
	Big free-tailed bat	*Nyctinomops macrotis*	–	X	U	Present
	Mexican (Brazilian) free-tailed bat	*Tadarida brasiliensis*	–	X	U	Present
	California myotis	*Myotis californicus*	XX	X	U	Present
	Eastern small-footed myotis	*Myotis leibii*	–	–	–	Present
	Fringe-tailed myotis	*Myotis thysanodes*	XX	–	U	–
	Hoary bat	*Lasiurus cinereus*	XX	X	U	Present
	Little brown myotis	*Myotis lucifugus*	–	–	–	Present
	Long-eared myotis	*Myotis evotis*	X	–	R	–
	Long-legged myotis	*Myotis volans*	XX	–	R	–
	Silver-haired bat	*Lasionycteris noctivagans*	XX	X	R	Present
	Small-footed myotis	*Myotis leibii*	XX	–	U	–
	Southwestern myotis	*Myotis auriculus*	XX	X	R	Present
	Spotted bat	*Euderma maculata*	XX	–	U	–
Rodents	Abert's squirrel	*Sciurus aberti*	–	X	O	Present
	American beaver	*Castor canadensis*	X	XX	R	Present
	Botta's pocket gopher	*Thomomys bottae*	X	X	U	Present

Notes: X denotes species observed in the national monument. XX denotes species observed outside of monument boundary. A = abundant, C = common, O = occasional, U = uncommon, R= rare.

[1] Bobcats were not confirmed during Hayward and Hunt (1972) survey but a rabid one was reported by national monument staff.

[2] Genus was formerly *Plecotus.*

[3] Two subspecies exist within Gila National Forest: *Neotamias cinereicollis cinereicollis* and *Neotamias cinereicollis cinereus*.

[4] Two species of voles were listed as common but only long-tailed vole was mentioned in the list of mammals. However, Mexican vole and long-tailed vole were listed in Hayward and Hunt (1972) Table 2.

Table 37 continued. *Mammal species list for Gila Cliff Dwellings NM.*

Group	Common Name	Scientific Name	Hayward and Hunt (1972)	Powell et al. (2006)	Frey (2010)	NPSpecies (2018a) Occurrence
Rodents *continued*	Brush mouse	*Peromyscus boylii*	XX	X	C	Present
	Chickaree (American red squirrel)	*Tamiasciurus hudsonicus*	XX	–	O	–
	Cliff chipmunk	*Neotamias dorsalis*	XX	X	C	Present
	Common muskrat	*Ondatra zibethicus*	XX	XX	R	Present
	Deer mouse	*Peromyscus maniculatus*	XX	X	A	Present
	Gray squirrel	*Sciurus arizonensis*	XX	–	R	–
	Gray-collared chipmunk [3]	*Eutamias cinereicollis*	X	–	O	–
	Long-tailed vole [4]	*Microtus longicaudus*	XX	–	O	–
	Mexican vole [4]	*Microtus mexicanus*	XX	X	O	Present
	Mexican woodrat	*Neotoma mexicana*	XX	X	O	Present
	Ord's kangaroo rat	*Dipodomys ordii*	X	–	C	–
	Pinon mouse	*Peromyscus truei*	XX	X	C	Present
	Rock squirrel	*Spermophilus variegatus*	X	X	A	Present
	Silky pcoket mouse	*Perognathus flavus*	X	–	C	–
	Southern grasshopper mouse	*Onychomys torridus*	X	–	U	–
	Teasel-eared squirrel	*Sciurus aberti*	XX	–	O	–
	Western harvest mouse	*Reithrodontomys megalotis*	XX	X	U	Present
	Western white-throated woodrat	*Neotoma albigula*	XX	X	A	Present
Shrews	Desert shrew	*Notiosorex crawfordi*	–	X	U	Present
	Wandering shrew	*Sorax vagrans*	XX	–	–	–
TOTAL		57	12 (in) 34 (out)	30 (in) 4 (out)	–	38

Notes: X denotes species observed in the national monument. XX denotes species observed outside of monument boundary. A = abundant, C = common, O = occasional, U = uncommon, R= rare.

[1] Bobcats were not confirmed during Hayward and Hunt (1972) survey but a rabid one was reported by national monument staff.

[2] Genus was formerly *Plecotus.*

[3] Two subspecies exist within Gila National Forest: *Neotamias cinereicollis cinereicollis* and *Neotamias cinereicollis cinereus*.

[4] Two species of voles were listed as common but only long-tailed vole was mentioned in the list of mammals. However, Mexican vole and long-tailed vole were listed in Hayward and Hunt (1972) Table 2.

The most abundant small mammal captured throughout the monument was the brush mouse (*Peromyscus boylii*). The western harvest mouse (*Reithrodontomys megalotis*) was the second most abundant species but was found only in four or fewer plots, unlike the western white-throated woodrat, which was captured 27 times at 8 of the 17 plots. Although the data from infrared cameras were not sufficient to generate a relative abundance for the species captured, the most commonly detected species were unidentifiable woodrats (n=17), gray fox (*Urocyon cinereoargenteus*; n=12), and the striped skunk (*Mephitis mephitis*; n=10). The most common bat species netted included the Mexican freetailed (*Tadarida brasiliensis)* and silver-haired bats (*Lasionycteris noctivagans)*.

During Powell et al.'s survey, none of the rare rodent species documented by Hayward and Hunt (1972) were confirmed. Possible reasons for the lack of confirmation in 2002 could be from natural fluctuations in the local population, seasonal timing of the trapping, or changes in the grassy habitat. According to the species status for the upper Gila River watershed (Frey 2010), silky pocket mouse and Ord's kangaroo rat occur in high densities contiguously over narrow habitat specificities of the semi-desert and desertscrub. While silky pocket mouse was listed as a species of concern and sensitive species in 2010, no threats or risk of population loss to the upper Gila River watershed population were identified.

While data weren't specifically collected in the monument during the Frey (2010) effort, the highest species richness within the upper Gila River biotic community types was found in the Madrean and Great Basin conifer woodlands (n=27), the Plains Grassland (n=24), and the ponderosa pine forest type of Montane Conifer woodlands (n=22), all of which occur in Gila Cliff Dwellings NM.

According to Frey's (2010) study, of the 107 species in the upper Gila River watershed, nine are considered abundant. All nine species have high population densities and inhabit more than five contiguous biotic communities. These mammals include bighorn sheep (*Ovis canadensis*), elk (*Cervus elaphus*), mule deer (*Odocoileus hemionus*), coyote (*Canis latrans*), black-tailed jackrabbit (*Lepus californicus*), western white-throated woodrat, deer mouse (*Peromyscus maniculatus*), porcupine (*Erethizon dorsatus*), and rock squirrel. With the exception of mule deer, none of these species are at risk for population loss or have identifiable threats. All but two of these species (bighorn sheep and porcupine) have been recorded at the monument.

Excluding bat species, out of the total 86 mammal species found in the upper Gila River watershed, 47 of those species are present, expected, or extirpated from the monument (Frey 2010, Powell et al. 2006). Ten mammals have been extirpated from the watershed, five of which once occurred in the monument. These species were extirpated through predator and rodent extraction programs, human harvesting, and/or habitat changes. These species are discussed under the presence of conservation concern measure.

The Powell et al. (2006) inventory was the most comprehensive survey to date for the monument, recording 34 species, with no non-natives observed. While Hayward and Hunt (1972) surveyed an area larger than the monument, of the 12 species they specifically noted as occurring within the monument, seven of those have not been confirmed since the Powell et al. (2006) effort. The lack of current confirmation of these species is not too concerning for the condition of Gila Cliff Dwellings NM's mammals.

Of the seven species, Ord's kangaroo rat, southern grasshopper mouse, and silky pocket mouse have not been recorded at the monument since the 1970s, but all three species still inhabit the upper Gila River watershed and are not at risk or have any threats to their populations even though they are classified as rare due to isolation from more ideal habitat and concentrated populations in other parts of the region (Hayward and Hunt 1972, Frey 2010). The remaining species include antelope (*Antilocarpa americana*), bobcat (*Lynx rufus*), long-eared myotis (*Myotis evotis*), and the gray-collared chipmunk (*Eutamias cinereicollis*). According to Frey (2010), the antelope is common, the gray-collared chipmunk is occasional, the bobcat is uncommon, and the long-eared myotis is rare throughout the Gila River watershed. In addition Powell et al. (2006) report that they recorded or documented most of the common species that occur in the monument. They state "the only species known to have been in the area during the time of our inventory, but which we did not find, were the bobcat and Mexican gray wolf (*Canis lupus baileyi*)." Of all surveyed mammal groups, bats were most underreported and will require more effort to adequately document their presence (Powell et al. 2006). Recent correspondence (email dated, 16 April 2018) from R. Garcia, Chief of Interpretation, Gila Cliff Dwellings NM states that pronghorn are non-existent in the area of the Forks of the Gila where the monument is located and bobcats are moderately common, including in Cliff Dweller Canyon and the surrounding area. Beavers (*Castor canadensis*) have reintroduced themselves to the West Fork of the Gila just south of the monument, approximately one-quarter mile. Elk will come down to the riparian area near the park, but are only rare occasional visitors (personal correspondence, R. Garcia, Chief of Interpretation, Gila Cliff Dwellings NM).

Based on the comparison between the two monument-specific surveys and Gila River watershed surveys, we consider the mammal richness at the monument to be in good condition, however, we assign a low confidence level due to the fact that Powell et al. (2006) did not observe any of the rare rodent species documented by Hayward and Hunt (1972). The trend is unknown. The confidence in the assessment was further confounded by Hayward and Hunt's (1972) survey occurring primarily outside monument boundaries. Refer to the data gap discussion for information related to a monument-specific survey that could not be located for this comparison.

None of the species that have been documented within the national monument are listed as federally or state endangered, threatened, or species of concern (BISON-M 2018, USFWS 2017). However, the spotted bat (*Euderma maculata*) is listed as Species of Greatest Conservation Need in New Mexico (BISON-M 2018) and was recorded by Hayward and Hunt (1972) in the surrounding area. Although, Frey (2010) indicates that it is uncommon throughout the Gila River watershed. Ten species have been extirpated from the Gila River watershed, five of which once occurred in the monument (Frey 2010). The Mexican gray wolf and a subspecies of elk were reintroduced after being extirpated (Frey 2010). The reintroduction of the wolf is a sensitive topic in this part of New Mexico, and its recovery has been slow. It is the only federally listed threatened or endangered species, known by range and habitat to occur in the monument (ESRI 2018) but has yet to be confirmed since its repatriation (Hoffmeister 1986). Other monument species that were extirpated include river otter (*Lontra canadensis*), black-footed ferret (*Mustela nigripes*), and brown bear (*Ursus arctos*). Since Frey's (2010) study, several species have been removed from the federal Species of Concern and USFS sensitive species lists (BISON-M 2018).

According to Frey's rarity rank, five (10.6%) of the monument's species are considered to be extremely rare, with only eight species ranked as common. The remaining species range from rare to very rare. The high number of rare species is the result of heterogeneous habitats that allow the subdividing of resources and greater specialization by species (Frey 2010). Even though most of the monument's species are not legally protected, given the fact that a high proportion are considered rare within the Gila River watershed, and the monument provides important habitat for these species, we consider the condition to be good, with medium confidence and an unknown trend.

Overall Condition, Threats, and Data Gaps

To assess the condition of mammals at the national monument, we used one indicator, with two measures, which are summarized in Table 38. Overall, we consider the condition of mammals at the monument to be in good condition, with an unknown trend and a low confidence level. It's important to mention that the surveys occurred prior to the Miller Fire of 2011, which passed through the monument. The Whitewater-Baldy Complex of 2012 covered a large part of the watershed directly above the park. The massive floods of 2013 (results of the previous fires) created intense scouring and dramatically altered the landscapes of the Forks of the Gila. Mammal populations likely changed as a result of the fires and represents a key uncertainty until research can be conducted.

Very few national parks are large enough to encompass a self-contained ecosystem to adequately conserve most wildlife species' life cycle needs (Monahan et al. 2012). Thus, partnerships that focus on landscape-scale conservation goals are critical for achieving resource sustainability. Due to the monument's small size, similar land management actions with adjacent USFS land, and historic interagency data collection, mammal data have been collected with different standards, agendas, and study area ranges. During the Hayward and Hunt (1972) survey, the TJ unit, which

Table 38. Summary of mammal indicators, measures, and condition rationale.

Indicators	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Species Occurrence	Richness		While seven species documented during the earlier Hayward and Hunt (1972) survey were not recorded during the most recent Powell et al. (2006) inventory, based on Powell et al. (2006) species accumulation curves, the majority of the monument's mammals have been documented and mammal richness at the monument is in good condition. However, confidence in the assessment is low due to the lack of confirmation of those seven species, with an unknown trend.
	Presence of Species of Conservation Concern		The monument contains habitat that supports a high proportion of mammals considered rare throughout the Gila River watershed. As a result, the monument plays an important role in the conservation of these rare species, resulting in a good condition rating, with medium confidence and an unknown trend.
Overall Condition	Summary of All Measures		Since both measures of condition were good, the same is true for the overall condition of mammals at Gila Cliff Dwellings National Monument. However, the confidence level is low based on all species (not just ones of conservation concern). Trend is unknown.

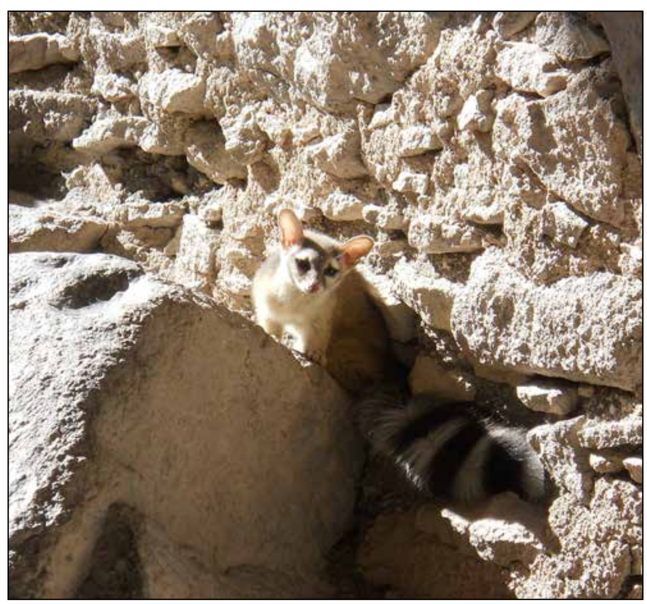
reflected a transition of open riparian to grassland and juniper woodland, was the only site surveyed. The survey by Powell and others (2006) extended beyond the monument's boundaries to include the Cliff Dweller Canyon watershed (on surrounding USFS land) to provide a better representation of species diversity and abundance. While habitat zones varied in vegetation description throughout the surveys, the most recently described habitat zones were (1) West Fork Gila River (perennial riparian, dominated by deciduous trees), (2) Middle Fork Gila River (similar to West Fork, with less vegetation and more open pools), (3) Cliff Dweller Canyon (perennial water, walnut, oak, Douglas fir, cottonwood), (4) Mesa/Slopes (rocky slopes of pinyon-juniper open forest), (5) Burned Slope (like Mesa/Slopes but burned in last 15 years), and (6) Dry Canyons (ponderosa pine and oak). While the Gila River watershed survey did not include monument-specific sites, Frey (2010) collected data from sites throughout the region, representing most community types from the confluence of the San Francisco and Gila rivers at 3,306 ft (1,008 m) to the mountaintops at 11,404 ft (4,476 m). Thus, our reporting zone for Gila Cliff Dwellings NM mammals assessment is the entire monument.

Most native mammals are susceptible to human development, harassment, habitat loss, poor water quality, and human-influenced mortality (Drost and Ellison 1996). Medium-sized to large mammals are more prone to stressors related to an accumulation of human activity because their home ranges most likely surpass the monument boundaries. In the case of Gila Cliff Dwellings NM, accumulation of human activity is limited to USFS and monument recreationalists due to the remote location and surrounding designated wilderness. Because of limited home ranges for small mammals, which likely confine most of them to small areas, the monument has greater control over and a better chance of eliminating stressors that occur within their boundaries. Any significant human-caused impacts would be direct impacts, such as roadkill, poaching, and harassment. Historic human development of the area could have negatively affected species no longer observed, such as badger (*Taxidea taxus*), porcupine (*Erethizon dorsatum*), some rodents, and large fauna like pronghorn and wolf, but the area's historic impacts have not been documented. The effects associated with climate change could have significant impacts on species with specific habitat associations and/or that reside on the edge of their range. Flooding, drought, wildland fires, and temperatures all affect preferred habitat and food sources that will likely change in composition and location in response to environmental conditions. These changes can alter species richness and abundance, benefiting some species and making it more difficult for others. Habitat conditions may serve as an indicator of the health or condition of wildlife species's richness over time.

Inventory work for small to large mammals at Gila Cliff Dwellings NM is almost complete based on the number of species documented relative to the sample period (Powell et al. 2006). Further targeted efforts were recommended to reconfirm the presence of Ord's kangaroo rat, silky pocket mouse, and southern grasshopper mouse (Hayward and Hunt 1972, Powell et al. 2006). Also, rock squirrel and Botta's pocket gopher were two of the most common species (at least region-wide) in 1972, but no longer are the most common, which may warrant further monitoring.

Sonoran Desert Inventory and Monitoring Network monitoring will eventually monitor medium and large mammals using wildlife cameras. The implementation of a wildlife camera network will increase the chances of confirming the more elusive species at the monument.

Finally, the year before Hayward and Hunt's (1972) survey, Hayward had trapped mammals in collaboration with the monument for a different project and generated a species list. Unfortunately,



The ringtail is present, but rare, at Gila Cliff Dwellings NM. Photo Credit: NPS.

documentation of Hayward's efforts during that monument-specific survey was not located. Information from this survey would provide valuable park-specific data from which to make more direct comparisons to the Powell et al. (2006) results and is considered to be a data gap.

Sources of Expertise

Anna Mateljak (formerly Iwaki), Biological Science Technician, formerly with NPS Sonoran Desert Inventory and Monitoring Network authored this assessment. Kim Struthers, NRCA Coordinator and Science Writer/Editor with Utah State University, completed the layout and editing.

Herpetofauna

Background and Importance

Gila Cliff Dwellings National Monument (NM), located along the isolated reaches of the Upper Gila River, contains evergreen woodlands, conifer forests, and deciduous riparian vegetation habitat communities that are ideal for supporting high herpetofauna diversity (Powell et al. 2006). Reptiles and amphibians, also known together as herpetofauna, have strong habitat associations that serve as good indicators for assessing ecosystem integrity, and southwestern New Mexico hosts one of the richest herpetofaunal communities in the continental United States due to the heterogeneous habitats associated with elevational gradients and intermixing biogeographic regions (Jennings et al. 2010). The monument is also situated at the confluence of the Middle and West Forks of the Gila River, where rich marshland and water flow contribute to high water-dependent species. Monitoring herpetofauna populations in the national monument is important for detecting ecosystem stability or change over time.

Data and Methods

To assess the condition of reptiles and amphibians at Gila Cliff Dwellings NM, we used one indicator, species occurrence, with a total of three measures: species presence/absence, species nativity, and species of conservation concern.

Herpetofauna data collected during surveys within the national monument and general vicinity, including the U.S. Forest Service's (USFS) Gila National Forest (NF), were used to compare species presence/absence at the monument over time. The regional surveys were conducted by Hayward and Hunt (1972), Painter (1985), and Jennings et al. (2010) along portions of the Upper Gila River and within the Gila and San Francisco River drainages. Some of the surveys included study sites within the monument or in close proximity to the monument. The results from these surveys were compared and cross-referenced to the monument's baseline survey that was conducted by Powell et al. (2006) and to the monument's NPSpecies list (NPS 2018a). These surveys are summarized below.

B.J. Hayward and D.L. Hunt conducted a herpetofauna survey in 1972, which included sites within the monument, as part of the larger USFS Wilderness Ranger District vertebrate inventory in Gila NF (Powell et al. 2006). While the emphasis was mostly on mammals and bird species, there were some opportunistic recordings of herpetofauna. Hayward and Hunt compiled local species accounts and

Crevice spiny lizard is one of the common reptile species known to occur at Gila Cliff Dwellings NM. Photo Credit: NPS/Bruce Fields.

observations throughout nine habitats, six of which were found within the national monument. These six habitat types included pinyon-juniper woodland, pine-oak woodland, Ponderosa pine (*Pinus ponderosa*) forest, Douglas fir (*Pseudotsuga menzeisii*) forest, riparian forest, and deciduous riparian. The 1972 survey was part of a larger effort intended to span many years, and the authors described the herpetofauna species recordings as ones that they literally “tripped over.” Species for the monument were listed in the report and serve as the first survey to compare species presence/absence.

Between January - December 1984, herpetofauna species were collected throughout the Gila-San Francisco River drainages (Painter 1985)— an area that produces the majority of water flow for the region and that is an ideal wildlife corridor for dispersal (Jennings et al. 2010). The survey techniques included pitfall traps, road cruising, electrofishing, and visual searches (Painter 1985). Specimens were added to the Museum of Southwestern (SW) Biology at the University of New Mexico (UNM). Distribution maps for each species were created and included locations of specimens that were previously collected throughout the same area (Painter 1985). Distribution maps were reviewed to identify species observed either within the national monument or in close proximity of the monument.

The survey work conducted by Powell et al. (2006) between 2001 to 2002 is the monument’s first (and only) exclusive published herpetofauna inventory. Researchers used repeatable study designs and standardized field techniques, including several plot-based and non plot-based surveys of intensive, extensive, road transects, and pitfall traps at non-random locations to inventory common and rare species (Powell et al 2006). Six general locations were sampled to represent the different vegetation communities in the monument. In addition, due to the similar adjacent land management practices, the Powell et al. (2006) survey was extended beyond the monument’s boundary to include the watershed of Cliff Dweller Canyon to increase species detection and provide a better estimate of relative abundance (Powell et al. 2006). Species richness was calculated from the sum of species observed, which was then categorized by year and habitat type. Relative abundance was calculated by mean number of detections per survey, per person hour, and per survey hour depending on survey type (Powell et al. 2006).

The intensive surveys consisted of time-constrained, area-constrained, and time-and-area constrained approaches, but not every habitat was surveyed using the three types most likely due to plot access and survey compatibility with the terrain. In addition, extensive surveys were conducted that were not constrained by time or area.

Prior to the Powell et al. survey, six herpetofauna species had been collected from within the monument. An additional nine species were collected from within 30 km (18.6 mi) of the monument. These species were vouchered and are currently located at the Museum of SW Biology at UNM (Powell et al. 2006).

Following the monument’s baseline inventory conducted by Powell et al. (2006) in 2001 and 2002, Jennings et al. (2010) collected data in 2006 and 2007 to determine species composition and associated habitat affiliations of near-stream herpetofauna of the Gila River. Their study also focused on collecting data associated with species of concern within the larger, surrounding area (Jennings et al. 2010).

Jennings et al. (2010) selected 49 study sites, which were divided between the lower, middle, and upper reaches of the Gila River in New Mexico. The Upper Gila sites (n=25) ranged in elevation from 1,525 m to 1,830 m (~5,000 - 6,000 ft). While most of the Upper Gila River survey sites were located outside of the monument, four sites were located within the Cliff Dwellings unit and one may have been located within TJ unit but the coordinate could not be confirmed (Jennings et al. 2010).

Each site was surveyed once a year for two years, between 0900–1800 hours, documenting the number of species along a 300 m- (984 ft)-width of river plus 15-m (15 ft) swath along both sides Methods included visual encounter surveys and dip nets as well as turning objects over along the sides of the river. Environmental conditions were also recorded but surveys only occurred during favorable weather conditions (i.e., warm, no rain, no heavy wind) (Jennings et al. 2010).

NPSpecies (NPS 2018a) is a database that is maintained by the National Park Service (NPS) and relies on previously published surveys, such as those included in this assessment, and expert opinion, to maintain a record of the presence or potential presence of species in national parks. The NPSpecies list also serves as a reference, especially to highlight potential data gaps of unconfirmed, but probable, species expected to occur within the monument. The monument's amphibian and reptile scientific names were updated following the standard English names of amphibians and reptiles of North America north of Mexico, Eighth edition (SSAR 2017).

To determine the condition of the second measure, species nativity, we used the NPSpecies 'nativeness' designation (NPS 2018a). If any non-native amphibian and reptile species were identified, they were evaluated for impact(s) to native species, especially those of conservation concern. In general, non-native species are known to have many potential adverse effects on native species of wildlife. Non-native (including feral) species may prey on native species, compete for food and other resources, impact habitat, and introduce and/or spread disease. In some cases, amphibians and/or reptiles in the Southwest have experienced population declines or changes in distribution due to non-native invasive species.

To assess the third measure, Species of Conservation Concern, New Mexico wildlife species are designated as threatened and endangered under the New Mexico Wildlife Conservation Act (NMDGF 2018). For each endangered or threatened species, the NMDGF develops a recovery plan. The Biota Information System of New Mexico (BISON-M), a database of all vertebrate species in New Mexico, including federally threatened and endangered species, is maintained (BISON-M 2018). BISON-M also includes Species of Greatest Conservation Need (SGCN) that have been designated for New Mexico. We cross-referenced the monument's herpetofauna species list to those listed for the state of New Mexico to determine which species were of conservation concern.

Reference Conditions

Reference conditions for the three species occurrence measures are listed in Table 39 and are described for resources in good, moderate concern, and significant concern conditions.

Condition and Trend

Table 40 lists the 25 herpetofauna species that have been observed during at least one of the four surveys within Gila Cliff Dwellings NM. An additional two species, lowland leopard frog (*Lithobates yavapaisensis*) and Mojave rattlesnake (*Crotalus scutulatus*) are listed on the monument's NPSpecies list (NPS 2018a) as unknown and unconfirmed, respectively, but were not included in Table 40 since they haven't been observed during any of the monument's surveys. Also, the Mexican spadefoot (*Spea multiplicata*) was once considered common in the area during the 1970s but has not been observed during any of the surveys so was not included in Table 40. Park staff did send a photo asking for verification as to whether it was of a

Table 39. Reference conditions used to assess herpetofauna.

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

Table 40. Amphibian and reptile species at Gila Cliff Dwellings NM.

Group	Common Name	Scientific Name	Hayward and Hunt (1972)	Painter (1985)[1]	Powell et al. (2006)	Jennings et al. (2010)	SW Biology UNM
Amphibians	American bullfrog[2]	*Lithobates catesbeianus*	X	X	X	X	X
	Arizona toad	*Anaxyrus microscaphus*	–	X	X	X	X
	Canyon treefrog	*Hyla arenicolor*	–	–	X	–	–
	Chiricahua leopard frog	*Lithobates chiricahuensis*	–	X	–	–	X
	Red spotted toad	*Bufo punctatus*	X	–	–	–	–
	Woodhouse's toad	*Anaxyrus woodhousii*	X	–	–	–	X
Reptiles	Arizona mountain kingsnake	*Lampropeltis pyromelana*	X	–	–	–	–
	Black-necked gartersnake	*Thamnophis cyrtopsis*	–	X	X	X	–
	Black-tailed rattlesnake	*Crotalus molossus*	X	–	X	X	–
	Bull or gopher snake	*Pituophis catenifer*	X	–	X	X	–
	Chihuahuan spotted whiptail	*Aspidoscelis exsanguis*	–	–	X	X	–
	Clark's spiny lizard	*Sceloporus clarkii*	–	X	X	–	–
	Collared lizard	*Crotaphytus collaris*	X	–	X	–	–
	Crevice spiny lizard	*Sceloporus poinsettii*	X	X	X	–	–
	Eastern fence lizard	*Sceloporus undulatus*	–	X	X	X[3]	–
	Greater short-horned lizard	*Phrynosoma hernandesi*	–	X[4]	X	X	–
	Madrean alligator lizard	*Elgaria kingii*	X	–	X	–	–
	Mountain patch-nosed snake	*Salvadora grahamiae*	–	–	X	–	–
	Narrow-headed gartersnake	*Thamnophis rufipunctatus*	–	X	X	–	X
	Ornate box turtle	*Terrapene ornata*	X	–	–	–	–
	Ornate tree lizard	*Urosaurus ornatus*	–	X	X	X	–
	Ring-necked snake	*Diadophis punctatus*	X	–	X	–	–
	Sonoran spotted whiptail	*Aspidoscelis sonorae*	–	–	–	X	–
	Striped whipsnake	*Coluber taeniatus*	X	–	X	–	–
	Western terrestrial gartersnake	*Thamnophis elegans*	–	X	X	X	X

[1] Some species were observed just outside the monument.

[2] Species is non-native.

[3] Species was listed as southwestern fence lizard (*Sceloporus cowlesi*) by Jennings et al. (2010) but its synonym is *S. undulatus* (UTEP 2016), which is common at the monument (NPSpecies list, NPS 2018a).

[4] Five species of short-horned lizards were previously assigned to the single species *Phrynosoma hernandesi* but were recently separated into individual species, including *P. douglasii* documented by Painter (1985). We counted both species as one.

Note: X = Species observed in the monument except during the Painter (1985) survey, which recorded species in and adjacent to the monument.

Mexican spadefoot. Utah State University's resident herpetologist, Alan Savitzky, stated the following in email correspondence dated 22 January 2019:

> I can assure you that the frog is not a spadefoot toad of any species. Body shape, foot shape, and color are all wrong for a spadefoot. It's a bit of an odd color and skin texture (but that could be the water's effect), but it looks to me like a plain old Bullfrog, *Lithobates catesbeianus* (or Ranacatesbiana; the taxonomy is in dispute). I can't think of anything else that it might be.

Six amphibians have been observed within the monument, with the non-native species, American bullfrog (*Lithobates catesbeiana*), representing the only species recorded during all four surveys and including a specimen that was collected and housed at Museum of SW Biology at UNM. The Arizona toad (*Anaxyrus microscaphus*) was observed during three of the four surveys, including the most recent survey. Four were recorded during only one survey and will be discussed later in the assessment. A total of 19 reptiles have been observed, including nine snakes, nine lizards, and one turtle species. None of these 19 species were observed during all four surveys, although eight (four snakes, four lizards) were observed during three surveys and are listed as either common or abundant on the monument's NPSpecies list (NPS 2018a). An additional seven species (four lizards, three snakes) were observed during two surveys, all of which were observed during the monument's baseline inventory conducted by Powell et al. (2006). Four reptiles were recorded during one survey only and will be discussed later in the assessment.

During each of the three regional surveys conducted by Hayward and Hunt (1972), Painter (1985), and Jennings et al. (2010), 12, 11, and 11 herpetofauna species were recorded within the national monument, respectively, with the exception of Painter's observations, which also included species in close proximity to the monument. As to be expected, the highest number of species (19 - three amphibians and 16 reptiles) were observed during the monument's first intensive herpetofauna inventory conducted by Powell et al. (2006). All species found in the Powell et al. expanded survey area beyond the monument's boundary were also confirmed within the monument (Powell et al. 2006). Since the Powell et al. (2006) survey was the most comprehensive, we summarize some of the key results below.

During Powell et al. (2006) intensive surveys, consisting of time-constrained, area-constrained, and time-and-area constrained, nine species were confirmed. The burned slope community habitat had the lowest species richness with two species recorded in 2001 and three species recorded in 2002. In 2001, the West Fork Gila River contained the highest number with six species observed (Powell et al. 2006).

Extensive surveys that were not constrained by time or area confirmed 13 species. Nine species, representing the highest species richness, occurred in the West Fork Gila River followed by the Middle Fork and Dry Canyon sites, both with eight species. The lowest species-rich habitat was the Mesa/slopes with five confirmed species. Incidental observations that weren't tied to any habitat type or survey method, confirmed the survey's highest number (18 or 94.7% of all species observed during the baseline inventory) of species.

The collared lizard (*Crotaphytus collaris*), Clark's spiny lizard (*Sceloporus clarkii*), ring-necked snake (*Diadophis punctatus*), and mountain patch-nosed snake (*Salvadora grahamiae*) were only confirmed by incidental observations, and all are considered rare or uncommon at the monument. The road transect surveys documented five species, with no new species confirmations.

During the Powell at al. (2006) survey, the ornate tree lizard (*Urosaurus ornatus*) and eastern fence lizard (*Sceloporus undulatus*) were the most abundant and widespread species throughout all habitat types. The extensive surveys resulted in the highest detection for the ornate tree lizard (n=222), American bullfrog (n=211), Arizona toad (n=182), and the eastern fence lizard (n=137). Also, during incidental observations, the same three species were the highest detected: ornate tree lizard (n=80), eastern fence lizard (n=72), and the American bullfrog (n=64). The Powell et

The Madrean alligator lizard is frequently seen within the monument, especially around the Visitor Center. Photo Credit: NPS/Rita Garcia.

al. (2006) survey was the only instance when the mountain patch-nosed snake and the canyon treefrog (*Hyla arenicolor*) were documented as occurring in the monument. Park staff also sent a photo of a canyon tree frog that was taken outside of Cave 2 at the monument's cliff dwellings.

Eight of the 25 (32%) or approximately one-third of the herpetofauna species observed within the national monument were recorded during only one of the four surveys. The earliest survey conducted by Hayward and Hunt (1972) recorded four species, red spotted toad (*Bufo punctatus*), Woodhouse's toad (*Anaxyrus woodhousii*), Arizona mountain kingsnake (*Lampropeltis pyromelana*), and ornate box turtle (*Terrapene ornata*). Painter (1985) recorded the Chiricahua leopard frog (*Lithobates chiricahuensis*). As previously mentioned, Powell et al. (2006) recorded two species, canyon treefrog and mountain patch-nosed snake, and Jennings et al. (2010) recorded the Sonoran spotted whiptail (*Aspidoscelis sonorae*). All of the remaining species that were observed during either Hayward and Hunt (1972), Painter (1985), or Jennings et al. (2010), were also observed during the Powell et al. (2006) survey.

Of the six species identified during only one survey other than those recorded by Powell et al. (2006), four (Chiricahua leopard frog, red spotted toad, Woodhouse's toad, and Arizona mountain kingsnake) may occur at the monument based on documentation in the area. Chief of Interpretation, Rita Garcia, stated that park staff had received several reports from visitors and park staff of kingsnake sightings within the monument, but unfortunately, photos were not of high enough quality for confirmation (email correspondence dates 29 November 2018). Of the remaining two species, the ornate box turtle first recorded by Hayward and Hunt (1972) was later observed by Painter (1985) in the Lower Gila River area only, was not listed by Powell et al. (2006) as a possibility at the monument, and was not recorded by Jennings et al. (2010) throughout their entire survey area. Two of the eight species recorded during only one survey (Chiricahua leopard frog and Sonoran spotted whiptail) are species of conservation concern. In 2002, the Chiricahua leopard frog was federally-listed as threatened (USFWS 2017) due to 82% reduction through its historic range. While leopard frogs' historical populations in New Mexico are extirpated, recent reintroductions as part of recovery efforts have had positive results (Painter et al. 2017), but it's not a surprise that this species hasn't been observed at the monument during more surveys. While the Sonoran spotted whiptail isn't federally or state listed, it is considered vulnerable according to the Natural Heritage New Mexico State Rank (as cited in BISON-M 2018) and was first observed in the monument during Jennings et al. (2010) survey. Painter et al. (2017) lists it as locally common in the Gila and San Francisco river drainages and in the Peloncillo and Animas mountains. Chief of Interpretation, Rita Garcia, stated that both giant and spotted whiptails are frequently sighted within the monument (email correspondence dates 29 November 2018).

Based on Hayward and Hunt's records from the early 1970s, the relative abundance of the red spotted toad has declined from abundant to 'may occur' at the monument (Powell et al. 2006) and wasn't observed throughout the upper and lower Gila River areas during the Jennings et al. (2010) survey. The Arizona mountain kingsnake and the canyon tree frog declined from common (Hayward and Hunt 1972) to rarely documented (Powell et al. 2006, Jennings et al. 2010). And while Woodhouse's toad was only recorded at the monument by Hayward and Hunt (1972), during the Jennings et al. (2010) survey, a little over 8,000 were observed in the lower Gila River survey sites. Powell et al. (2006) still lists it as 'possibly occurring' at the monument.

While the species accumulation curve for the monument's baseline survey suggests that the majority of reptiles expected to occur at the monument have been documented, the presence of amphibians has declined, except for the increased abundance of the non-native American bullfrog (Powell et al. 2006). For these reasons, the monument's condition of herpetofauna species presence/absence warrants moderate concern, and without more recent survey data, the trend is unknown.

For the species nativity measure, only one non-native species, American bullfrog, was observed. Unfortunately though, the bullfrog has been the only species observed, sometimes in very high numbers, during all surveys and is considered to be a significant contributor to amphibian declines, especially the leopard frogs, which are likely extirpated from the monument. In addition, while not an amphibian or reptile, the non-native crayfish (*Oronectes* spp.) is having major negative effects on native populations. Where crayfishes are abundant, leopard frogs are rare or not present (Fernandez and Rosen 1996). Both of these non-natives are considered to be primary natural resource issues of concern at the monument (NPS SODN 2019), warranting a condition of significant concern, with medium confidence and unknown trend. Of the 25 herpetofauna species that have been observed at or near the monument, four are of conservation concern (Table 41). These include the federally threatened Chiricahua leopard frog and the narrow-headed garter snake (*Thamnophis rufipunctatus*), the Arizona toad, which is listed as a New Mexico SGCN, along with the two just mentioned, and the Sonoran spotted whiptail, which is considered to be vulnerable by the Natural Heritage New Mexico (BISON-M 2018).

The lowland leopard frog has been negatively impacted by the non-native, invasive American bullfrog. Photo Credit: NPS/Nic Perkins.

The leopard frog species, Chiricahua and lowland, have been regionally declining along their outer range boundaries (BISON-M 2018). The Chiricahua leopard frog is federally threatened, as well as a USFS Sensitive species, a New Mexico Species of Greatest Conservation Need, and an Arizona Species of Special Concern (BISON-M 2018). Critical habitat has been designated in five New Mexico counties, including Catron. Several observations of the Chiricahua leopard frog within the Gila River region can be found in the surveys between the 1970s to the 1999s (Hayward and Hunt 1972, Painter 1985, Degenhardt 1996). Unfortunately though, field documentation by either Powell et al (2006) or Jennings et al (2010) was unsuccessful, although reintroductions may help reestablish this species as shown by some success in other areas.

The narrow-headed gartersnake has been observed at the monument since the 1980s (Painter 1985) and have been reported as occurring around the visitor center and housing areas (Rita Garcia, Chief of Interpretation, email correspondence, 29 November 2018). Three subspecies are found in the Mexican highlands of the Sierra Madre Occidental along the Mogollon Rim of Arizona and New Mexico and into Mexico. The subspecies that occurs in the United States and at the monument is *T.r. rufipunctatus*. Due to climatic changes during the Pleistocene, the subspecies became restricted to its current Gila and Salt rivers watersheds and has been extirpated from 60% of its United States historic range (Wood et al. 2011, Schwalbe and Rosen 1988, Hibbitts et al. 2009). Out of the five national forests that host the gartersnake's range, the Gila Forest has the only statement about accomplishing approved management practices and implementing recovery plans for threatened and endangered species (Holycross and Rosen 2011). The U.S. Fish and Wildlife Service has proposed to designate critical habitat for this species, which includes Catron County (USFWS 2013).

Table 41. Amphibian and reptile species of conservation concern at Gila Cliff Dwellings NM.

Common Name	Federal Status	New Mexico Status	Natural Heritage New Mexico Rank
Arizona toad	–	Species of Greatest Conservation Need	Imperiled (S2)
Chiricahua leopard frog	Threatened, Critical Habitat	Species of Greatest Conservation Need and Species of Special Concern, formerly Threatened	Critically Imperiled (S1)
Narrow-headed gartersnake	Threatened, Proposed Critical Habitat	Threatened and Species of Greatest Conservation Need	Imperiled (S2)
Sonoran spotted whiptail	–	–	Vulnerable in (S3)

The Arizona toad is not federally or state listed but is a New Mexico SGCN and is considered imperiled by Natural Heritage New Mexico due to habitat loss and fragmentation and introduced, non-native species (BISON-M 2018). The Sonoran spotted whiptail has also been ranked by Natural Heritage New Mexico due to its decreasing numbers (BISON-M 2018), although the very first observation of this species at the monument occurred during the last survey conducted by Jennings et al. (2010).

In addition, four species that have been observed at the monument, including Arizona mountain kingsnake, collared lizard, mountain patch-nosed snake, and ornate box turtle, have been removed from New Mexico's SGCN list due to increasing numbers ((BISON-M 2018).

With all leopard frog species absent in the last 40 to 50 years of surveys and research, they are most likely locally extirpated. Any reintroduction efforts may be futile given the high numbers of predatory American bullfrogs. And while Arizona toad populations have declined, becoming a species of conservation concern, populations at Gila Cliff Dwellings NM have increased. The narrow-headed gartersnake, on the other hand, has experienced significant regional population declines, although population confirmations by Painter (1985) and Powell et al. (2006) have shown consistent occupation.

Given the fact that the monument provides high quality protected habitat for four species of conservation concern and for four species that have been removed from the state's conservation concern list, we rate the overall condition as good, with medium confidence and an unknown trend.

Overall Condition, Threats, and Data Gaps

To assess the condition of herpetofauna at the national monument, we used one indicator, with three measures (summarized in Table 42). We consider the overall condition of amphibians and reptiles to be of moderate concern, with an unknown trend and a medium confidence level.

Herpetofauna species are susceptible to changes in water resources, habitat loss and fragmentation, introduction of exotic species, pollution, overkill and disease (Malone 1999). While terrestrial herpetofauna reflect high diversity and have a larger habitat area, water-dependent species are restricted to aquatic habitats. As a habitat specialist, changes in aquatic systems have substantial effects on native species. Many invasive and exotic species are able to adapt to new areas through corridors such as roads and waterways. Frogs, toads, gartersnakes, and whiptails are susceptible to the predation and competition of the American bullfrog, crayfish and exotic fish. The direct elimination by humans and increased collection for scientific and personal interest has negative effects on herpetofauna (Schwalbe and Rosen 1988). The viability of water flow and quality could become a

Table 42. Summary of herpetofauna indicators, measures, and condition rationale.

Indicators	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Species Occurrence	Species Presence / Absence		The presence of amphibians at the monument has declined, except for the increased abundance of the non-native American bullfrog. For these reasons, the monument's condition of herpetofauna species presence/absence warrants moderate concern, and without more recent survey data, the trend is unknown.
	Species Nativity		While only one non-native species has been observed at the monument, the American bullfrog, its abundance and known ability to greatly impact native species, such as the leopard frogs, and water-dependent snake species warrants significant concern with an unknown trend without more recent data.
	Species of Conservation Concern		The monument provides high quality and protected habitat for four species of conservation concern and for four species that have been removed from the state's conservation concern list, we rate the overall condition as good with medium confidence and an unknown trend.
Overall Condition	Summary of All Measures		Based on the amphibian presence decline, and the well-documented detrimental effects of the non-native American bullfrog on native species, the overall condition of herpetofauna is of moderate concern. Without more recent survey data, the trend is unknown.

problem in response to climate change, with changes in sedimentation, especially caused by erosion after fires, temperature, flooding, and drought (Holycross and Rosen 2011).

Two recent fires were likely responsible for higher than normal concentrations of aluminum, increased turbidity, and reduced benthic macroinvertebrate diversity. Although fire is a natural ecosystem process in the region (NMDGF 2016), it can temporarily degrade aquatic ecosystems through increased erosion and enhanced release of organic compounds (Gwilliam et al. 2018a). The 2012 Whitewater-Baldy Complex Fire was the largest fire in New Mexico's recorded history and was preceded by the smaller 2011 Miller Fire (NPS 2016, USFS 2018a). Decades of fire suppression have allowed fuels to accumulate resulting in larger and more severe fires in the region (NMDGF 2016). The shift in fire regime as a result of historical suppression and climate change could alter the severity of fire effects on watersheds.

On a broader scale, rising temperatures will alter the type of precipitation (i.e., snow vs. rain) that falls in the region thereby changing the amount of winter snowpack, the timing of snowmelt, streamflow, and severity of flooding. Lower streamflow will reduce the abundance of habitat for water-dependent species.

The impressive herpetofauna diversity in the Gila River watershed has attracted historic and current research. Additional targeted surveys were recommended to confirm historic documentation of amphibian species described by Hayward and Hunt (1972) that haven't been documented since (Powell et al. 2006). Collaborative efforts with surrounding agencies and private landowners is recommended to confirm the presence of unconfirmed species. Based on regional declines in the narrow-headed gartersnake and local research on genetics, preferred habitat, and seasonal responses (Jennings and Christman 2011, Wood et al. 2011, Hibbits et al. 2009), further work is needed to determine current population status and areas of critical habitat, although USFS Gila Forest regulatory mechanisms have not shown significant improvements for the species (Holycross and Rosen 2011).

Sources of Expertise

Anna Iwaki, former Biological Science Technician with NPS Sonoran Desert Inventory and Monitoring Network SODN was the author of the first assessment draft. The draft was updated by Kim Struthers, with Utah State University.

Fish

Background and Importance

New Mexico has one of the most diverse fish assemblages of any interior southwestern state (Propst 1999). Historically, 66 native fish species inhabited New Mexico's streams, rivers, and lakes; however, 11 species of fish have been extirpated or have gone extinct over the last 100 years as a result of habitat alteration and non-native species introductions (Propst 1999). Further, few extant native fish species occupy their historical ranges (Propst 1999). Fish are not only inherently valuable components of stream communities, but they are also indicators of stream health. Monitoring fish assemblages and community dynamics was identified as an important element of a comprehensive, long-term monitoring program at Gila Cliff Dwellings National Monument (NM) (Mau-Crimmins et al. 2005).

Gila Cliff Dwellings NM is situated at the confluence of the West and Middle forks of the Gila River—New Mexico's last free-flowing river (NPS 2016). The smaller TJ Unit overlooks the confluence of these two forks, while a short 1.0 km (0.6 mi) stretch of the West Fork flows through the monument's main unit (NPS 2016). This short section of river was designated as critical habitat for the spikedace (*Meda fulgida*) and loach minnow (*Tiaroga cobitis*), both of which are listed as endangered by the U.S. Fish and Wildlife Service's Endangered Species Program (USFWS 2017). The monument also has suitable habitat for the federally threatened Gila trout (*Oncorhynchus gilae*), although the species does not currently occur there (NPS 2018a).

Despite the absence of dams along the West Fork and its situation within the Federally designated Gila Wilderness, this river is listed as impaired by the State of New Mexico under the Clean Water Act owing to elevated temperatures (NPS 2016). Large wildfires in region have also affected water quality (Gwilliam 2014). Overall however, surface water quality in the monument appears to be good (water quality was addressed in a separate assessment) (Gwilliam 2014).

Data and Methods

This assessment is based on one indicator (species occurrence) with a single measure (richness and composition). Fish are not currently monitored within the monument; however, two monitoring sites located near the monument serve as a proxy.

During 2005 to 2008 the first systematic inventory of the East, Middle, and West forks of the Gila River was conducted by the New Mexico Department of Game and Fish (NMDGF) in cooperation with the Gila National Forest (Paroz et al. 2010). A total of 12 sampling locations were established along the

Photo of a Gila trout mockup on display at the Gila Cliff Dwellings NM Contact Station. Photo Credit: © B. Neilson.

West Fork, 11 of which were located upstream of the monument (Figure 19). Location #2 was established nearest to the monument. Fish along the West Fork were surveyed on one day in May at each site during 2006 and 2007. Location #2 was surveyed during 2006. The total area sampled per site ranged from 155 m^2 to 662 m^2 (1,668-7,126 ft^2), and each reach surveyed was at least 200 m long (656 ft) (Paroz et al. 2010). Fish were sampled using backpack electrofishing and dipnets supplemented by seining in some locations. All non-native fish captured were removed, while native fish were released (Paroz et al. 2010). We reported the number of individuals captured by species for location #2 and for all sites combined for comparison.

From 1989 to 2008 and 2015 to 2017, the NMDGF surveyed a site referred to as Gila Cliff Dwellings (Figure 19). The site was located just downstream of the monument's boundary. Fish were sampled using backpack electrofishing and dipnets. Data for 1989-2008 were published in Propst et al. (2009) and 2015-2017 data were provided by the NMDGF via the U.S. Fish and Wildlife Service (USFWS, A. Dean, fish biologist, e-mail message, 18 January 2018). For the years 1989-2008 and 2015-2017, we reported presence/absence and proportion of fish captured that were native. For 2015-2017 we reported the number of individuals by species over the three years of surveys. Abundance data by species were not reported in Propst et al. (2009).

Reference Conditions
Reference conditions are described for resources in good, moderate concern, and significant concern conditions (Table 43).

Condition and Trend
According to NPSpecies, 15 species of fish occur in the monument, seven of which are native, including the federally endangered loach minnow and spikedace

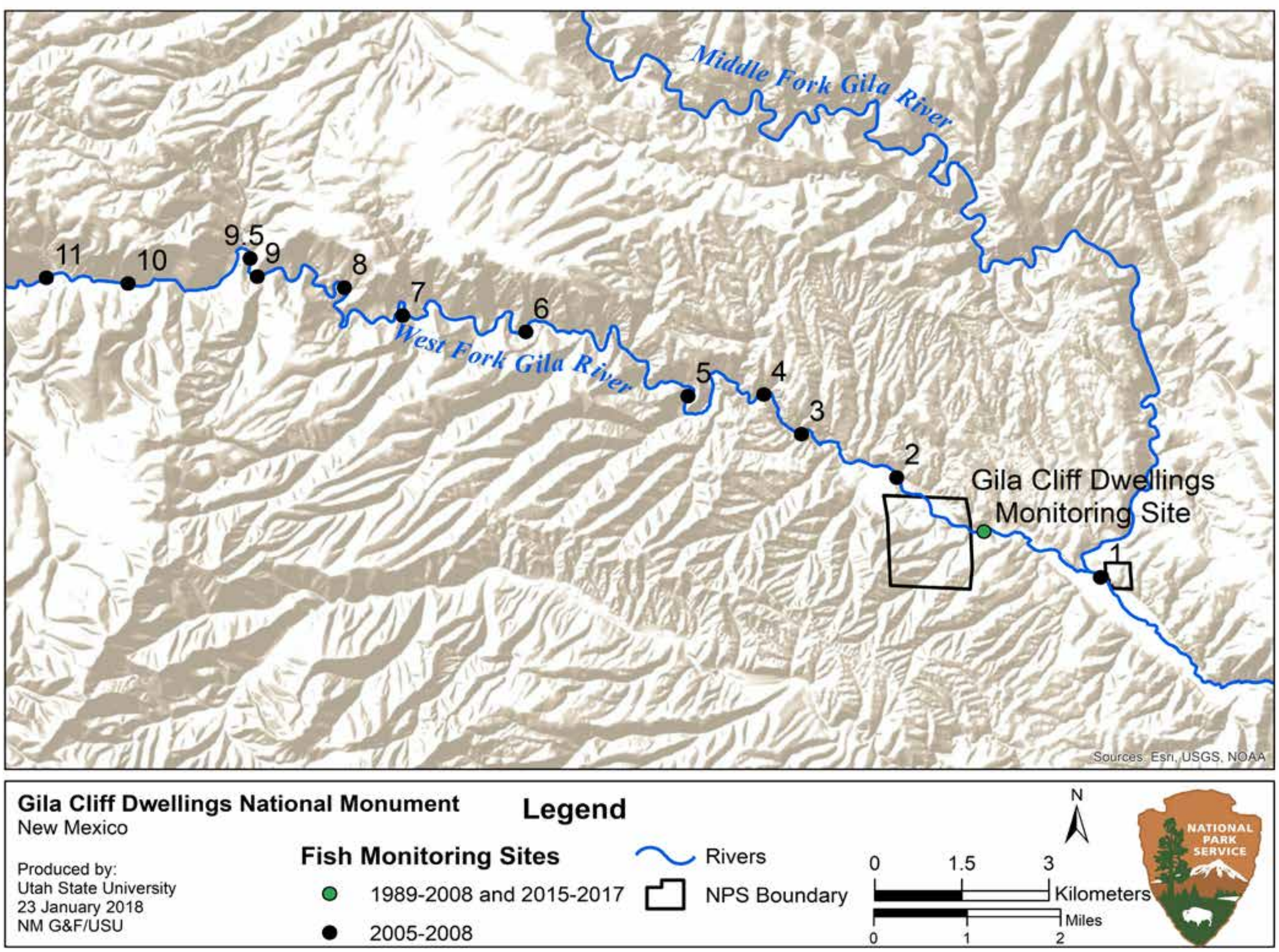


Figure 19. Map of fish monitoring locations along the West Fork of the Gila River above and below Gila Cliff Dwellings NM.

Table 43. Reference conditions used to assess fish in Gila Cliff Dwellings NM.

Indicator	Measure	Good	Moderate Concern	Significant Concern
Species Occurrence	Richness and Composition	Richness and composition reflects a healthy fish community composed of native fish species and no non-native fish species.	Richness and composition reflects a moderately healthy fish community with mostly native fish species and few non-native species.	Richness and composition reflects an unhealthy fish community with few native species and mostly non-native species.

(NPS 2018a, Table 44). In their State Wildlife Action Plan, NMDGF also listed roundtail chub (*Gila robusta*) as an immediate priority species and the desert (*Catostomus clarkii*) and Sonora sucker (*Catostomus insignis*) as susceptible species owing to declining and/or disjunct populations and aspects of their life history that make these species particularly vulnerable to decline within the next 10 years (NMDGF 2016).

During the 2006-2007 inventory along the West Fork, 11 species were captured across all 12 sites, including five non-native species (Table 45). On 23 May 2006, a total of 480 individuals from eight species were captured at location #2. Smallmouth bass (*Micropterus dolomieu*) and rainbow trout (*Oncorhynchus mykiss*) were the two non-native species captured there, but these non-natives were rare, representing less than 1% of all captures. Smallmouth bass was not listed by NPSpecies. The native Sonora sucker represented 39% of all captures, spikdace comprised 25% of all captures, and roundtail chub represented 18% of all captures. The roundtail chub was identified as headwater chub (formerly *G. nigra*) in Paroz et al. (2010); however, this species was reclassified as roundtail chub in 2016 and is no longer a recognized species (USFWS 2016b). Overall, native species comprised 98% of all individuals captured at location #2 and 87% of all captures across the twelve sites sampled.

During the 1989-2008 and 2015-2017 surveys, most native fish species were consistently present during all monitoring years (Table 46). Speckled dace (*Rhinichthys osculus*) and desert sucker were the only two species present during all years (21) of monitoring at the Gila Cliff Dwellings site. Longfin dace (*Agosia chrysogaster*) and Sonora sucker (*Catostomus insignis*) were present in all but one year and spikedace was present in all but two years. Roundtail chub was

Table 44. Fish species reported by NPSpecies for Gila Cliff Dwellings NM.

Common Name	Scientific Name	New Mexico Department of Game and Fish Status	New Mexico Department of Game and Fish Justification	Native
Desert sucker	*Catostomus clarkii*	*Susceptible Species*	*Declining, Vulnerable*	*Yes*
Loach minnow[1]	*Rhinichthys cobitis*	*Federally Listed*	*Declining, Vulnerable, Disjunct*	*Yes*
Longfin dace	*Agosia chrysogaster*	–	–	*Yes*
Roundtail chub	*Gila robusta*	*Immediate Priority*	*Declining, Vulnerable, Disjunct*	*Yes*
Sonora sucker	*Catostomus insignis*	*Susceptible Species*	*Declining, Vulnerable*	*Yes*
Speckled dace	*Rhinichthys osculus*	–	–	*Yes*
Spikedace[1]	*Meda fulgida*	*Federally Listed*	*Declining, Vulnerable, Disjunct*	*Yes*
Bluegill	*Lepomis macrochirus*	–	–	No
Brown trout	*Salmo trutta*	–	–	No
Fathead minnow	*Pimephales promelas*	–	–	No
Green sunfish	*Lepomis cyanellus*	–	–	No
Largemouth bass	*Micropterus salmoides*	–	–	No
Smallmouth bass[2]	*Micropterus dolomieu*	–	–	No
Rainbow trout	*Oncorhynchus mykiss*	–	–	No
Western mosquitofish	*Gambusia affinis*	–	–	No
Yellow bullhead	*Ameiurus natalis*	–	–	No

[1] Species are listed as endangered by the U.S. Fish and Wildlife Service's Endangered Species Program (USFWS 2017).

[2] Not listed by NPSpecies but captured during 2006 monitoring efforts near the monument.

Sources: NMDGF (2016) and NPS (2017).

Table 45. Fish species captured along the West Fork of the Gila River during 2006-2007.

Common Name	Location #2 # of Individuals (% of total)	All Locations (1-11) # of Individuals (% of total)
Desert sucker	39 (8)	310 (15)
Longfin dace	0 (0)	4 (<1)
Roundtail chub[1]	88 (18)	161 (8)
Sonora sucker	188 (39)	592 (29)
Speckled dace	36 (8)	605 (29)
Spikedace	119 (25)	119 (6)
Brown trout[2]	7 (1)	134 (6)
Fathead minnow[2]	0 (0)	1 (<1)
Rainbow trout[2]	1 (<1)	96 (5)
Smallmouth bass[2]	2 (<1)	16 (<1)
Yellow bullhead[2]	0 (0)	24 (1)
Total	480 (100)	2,062 (100)

[1] Species was originally identified as headwater chub (*Gila nigra*) but was reclassified as roundtail chub (*G. robusta*) in September 2016 (USFWS 2016b).

[2] Non-native species.

Source: Paroz et al. (2010).

present in only three of 10 years during 1989 to 1998, but from 1999 to 2008, this species was present in seven of 10 years and in 2017. Loach minnow (*Rhinichthys cobitis*) was consistently present from 1989 to 2001, absent from 2002 to 2008, and then present again from 2015 to 2017.

Five non-native species were present at this site with rainbow trout and brown trout (*Salmo trutta*) consistently present. Smallmouth bass was last reported in 2005, and yellow bullhead (*Ameiurus natalis*) and western mosquitofish (*Gambusia affinis*) were last reported in 1997 and 2000, respectively. The proportion of total fish caught that were native ranged from 89% in 1994 to 100% in each of the last three years of monitoring (2015-2017).

During 2015 to 2017, desert sucker comprised 37% of all species captured followed by speckled dace (21%), spikedace (17%), and Sonora sucker (12%) (Table 47). Six of the seven species were captured during all three years. Roundtail chub was rare with only a single capture during 2016 and 2017. For some

Table 46. Presence/absence of fish at the Gila Cliff Dwellings site during 1989-2008 and 2015-2017.

Species	Year																						
	89	*90*	*91*	*92*	*93*	*94*	*95*	*96*	*97*	*98*	*99*	*00*	*01*	*02*	*03*	*04*	*05*	*06*	*07*	*08*	*15*	*16*	*17*
Desert sucker	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Loach minnow	X	X	X	X	X	X	X	X	X	X	X	–	X	–	–	–	–	–	–	–	X	X	X
Longfin dace	X	X	X	X	X	X	X	X	X	X	X	X	X	X	–	X	X	X	X	X	X	X	X
Roundtail chub[1]	–	–	X	X	–	–	X	–	–	–	X	–	X	–	X	X	X	X	–	X	–	–	X
Sonora sucker	X	X	X	X	X	X	X	X	X	X	X	–	X	X	X	X	X	X	X	X	X	X	X
Speckled dace	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Spikedace	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	–	X	–	X	X	X	X	X
Brown trout[2]	–	–	–	X	X	X	X	X	X	X	X	X	X	X	–	–	X	X	X	X	–	–	–
Rainbow trout[2]	X	X	X	X	X	X	X	X	X	X	X	–	X	–	–	X	–	–	X	X	–	–	–
Smallmouth bass[2]	X	–	X	X	X	–	–	–	X	–	–	–	–	–	–	X	X	–	–	–	–	–	–
Western mosquitofish[2]	–	–	X	X	–	–	–	–	–	–	–	X	–	–	–	–	–	–	–	–	–	–	–
Yellow bullhead[2]	–	X	–	–	–	–	X	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–

[1] Species was listed as headwater chub (*Gila nigra*) in the database provided but was reclassified as roundtail chub (*G. robusta*) in September 2016 (USFWS 2016b).

[2] Non-native species.

Note: X = species present.

Table 47. Fish species captured West Fork of the Gila River downstream of Gila Cliff Dwellings NM.

Common Name	2015	2016	2017	# of Individuals (% of total)
Desert sucker	17	44	143	204 (37)
Loach minnow	3	16	30	49 (9)
Longfin dace	7	7	9	23 (4)
Roundtail chub*	0	0	1	1 (<1)
Sonora sucker	15	21	29	65 (12)
Speckled dace	8	9	101	118 (21)
Spikedace	5	81	11	97 (17)
Total	55	178	324	557 (100)

* Species was listed as headwater chub (*Gila nigra*) in the database provided but was reclassified as roundtail chub (*G. robusta*) in September 2016 (USFWS 2016b).

species, captures varied widely by year. For example, eight and nine speckled dace were captured during 2015 and 2016, respectively, while 101 individuals were captured during 2017. No non-native species were captured during 2015-2017.

Overall Condition, Threats, and Data Gaps

Overall, these results indicate a consistent presence of seven species of native fish and a decline in the presence of non-native species, particularly western mosquitofish and yellow bullhead (Table 48). Although no non-native species were captured at the Gila Cliff Dwellings site during 2015-2017, 10 individuals of three non-native species were captured at location #2 above the monument in 2006 and two species were captured below the monument in 2008. Because there are no barriers to fish passage along this stretch, it is likely that non-native species persist in waters in and around the monument, albeit in low numbers. For these reasons, the condition for fish at Gila Cliff Dwellings NM warrants moderate concern. A key uncertainty is whether the apparent decline in non-native species richness has actually occurred and will persist.

There are an estimated 10-12 species of native fish in the Gila River Basin (Propst 1999), seven of which have been documented in the West Fork above and below the monument in recent years (this assessment). Spikedace and loach minnow are both endemic to the Gila drainage, and Sonora sucker and desert sucker are near-endemics (Propst 1999). It is not clear whether the three to five remaining species listed by Propst (1999) historically occurred along the West Fork in and around the monument, but none of them were listed by NPSpecies (NPS 2018a). These species are Gila trout and Gila topminnow (*Poeciliopsis occidentalis*), which are both known to occur in portions of the Gila River drainage, and the Colorado pikeminnow (*Ptychocheilus lucius*) and razorback sucker (*Xyrauchen texanus*), which may have occurred in the the lower portions of the Gila River drainage (Propst 1999). Propst (1999) also listed the Gila chub (formerly *Gila intermedia*), but as with the headwater chub, this species has been reclassified as the roundtail chub (USFWS 2016b).

A persistent threat to native fish is the presence of introduced species. Although present in low numbers,

Table 48. Summary of fish indicator, measure, and condition rationale.

Indicators	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Species Occurrence	Richness and Composition		Seven native fish species have been captured near the monument in recent years, including the federally endangered spikedace and loach minnow. Desert sucker, speckled dace, Sonora sucker, and spikedace were the most commonly captured species. Only 10 individuals of three non-native species were captured during 2006, but none were captured during 2015-2017. These results suggest a fish community composed largely of native species with few non-native species. Confidence in the condition rating is high, but trend is unknown.
Overall Condition	Summary of All Measures		Overall native richness was high and non-native richness was low. Presence/absence data indicate stable conditions for native species richness and a decline in non-native species richness, but there were not enough data to assign trend with confidence. Confidence in the overall condition rating is high despite the lack of monitoring sites within the monument because the two locations near the monument are close enough to serve as a proxy. A key uncertainty is whether the apparent decline in non-native richness has actually occurred. Data gaps include thresholds of water quality and quantity required to maintain healthy populations of native fish in the monument.

smallmouth bass, rainbow trout, and brown trout are predators of small-bodied native fish, including speckled dace, spike dace, and loach minnow (Pilger et al. 2010). The presence of non-native species can alter food webs and native species community dynamics (Pilger et al. 2010). Non-native bullfrogs (*Lithobates catesbeianus*) and virile crayfish (*Orconectes virilis*) are also present in the monument's waters (NPS 2016). The bullfrog has the highest relative abundance of the three amphibians, two of which are native, in the monument and is thought to be partly responsible for regional declines in native fish, and crayfish may compete with native insectivorous fish for food resources (NPS 2016).

During 2007-2012, NMDGF conducted mechanical removals of non-native fish along the West Fork downstream of the monument and near the confluence with the main stem of the Gila River to determine if mechanical removals might suppress non-native predators (Propst et al. 2015). More than 1,100 fish were removed during the study. Spikedace responded positively to removals, but the effects of these efforts for other species were unclear. These efforts may have been partly responsible for the lack of non-native fish captured during 2015-2017, but this is unknown.

Water quality and quantity are also important factors that influence fish assemblages. Maintaining high quality stream habitat depends on regular and adequate stream flow, the amount and timing of precipitation and spring snowmelt, groundwater discharge, and the rate of evapotranspiration (Ffolliot et al. 2003). Because the West Fork is not dammed and occurs largely within the protection of the Gila Wilderness, there is little threat from diversions or polluted inflows; thus, the primary threat to water quantity is climate change. A climate assessment for the monument shows that the climate has become warmer but not necessarily drier (Monahan and Fisichelli 2014). These results reflect trends occurring throughout the southwestern U.S. (Prein et al. 2016). The West Fork of the Gila River, like many rivers in the southwest, is characterized by a relatively steady base flow fed by natural springs with frequent high-flow events in response to storm runoff at certain times of the year (Gori et al. 2015). Native fish species are adapted to this flow regime and respond positively to high flow events. High flow events may also limit non-native fish dispersal (Gori et al. 2015). Changes to the flow regime as a result of climate change could alter native fish assemblages in the West Fork (hydrology was addressed in a separate assessment).

The majority of water quality measures for the monument's surface waters were within the range of normal except for temperature as well as a temporary spike in aluminum, nitrate, and turbidity due to wildfire activity in 2011 (Miller Fire) and 2012 (Whitewater-Baldy Complex Fire) (Gwilliam 2014). Although fire is a natural component of the Arizona-New Mexico Mountains ecoregion, excess sediment can bury fish eggs, reduce dissolved oxygen concentrations, and reduce habitat for invertebrate prey species, all of which can affect fish abundance and richness (Gwilliam 2014). How native fish have responded or will respond to changes in water quality and quantity in the monument's surface waters is unknown (NPS 2016).

Sources of Expertise

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


View from dwelling at Gila Cliff Dwellings NM. Photo Credit: NPS/B. Fields.

Discussion

The majority of the natural resources assessed for Gila Cliff Dwellings National Monument's (NM) Natural Resource Condition Assessment (NRCA) are in good condition (Table 49). The exceptions include aspects of air quality, herpetofauna, and fish, which were of moderate concern overall. Of the nine natural resources evaluated for current conditions, eight are linked to the monument's significance statement that describes how the "springs, rivers, narrow canyons, unique caves, and the resulting biodiversity in and around Gila Cliff Dwellings NM, enticed and sustained human cultures for thousands of years" (NPS 2016).

Managing the monument's natural resources in light of current and rapidly changing environmental conditions such as increasing temperatures, increasing populations of non-native species (e.g., American bullfrog (*Lithobates catesbeianus*), trout, and bass species, etc.) 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. And, given the fact that the monument is surrounded by the 1.3 million-ha (3.3 million-ac) Gila National Forest (NF) (USFS 2018b), and located within the forest's Wilderness Ranger District (Figure 20), provides exceptional opportunities to coordinate resource protection efforts with U.S. Forest Service (USFS) personnel.

The NF's Wilderness District covers an area of 277,684 ha (686,171 ac), with the majority of the area designated as wilderness (USFS 2018b). This designation means that the wilderness character of the area will not be altered by the intrusion of roads or other evidence of human presence. This added protection of surrounding public land is also important because currently (as of 2019) there is no resource management staff at Gila Cliff Dwellings NM and current "staff relies heavily on outside researchers and advisors for resolution to resource management issues" (NPS 2016). Thus, considering management objectives and subsequent actions and goals from a

Table 49. Natural resource condition summary for Gila Cliff Dwellings NM.

Significance Statement	Resource	Overall Condition	Overall Condition Discussion
–	Air Quality		Good air quality influences a visitor's experience of natural landscapes and is essential to ecosystem health. Air quality in the monument warrants moderate concern despite the park's remote location. Visibility, ozone levels, and wet mercury deposition all warranted moderate concern during 2011-2015. Nitrogen deposition warranted significant concern, and only sulfur deposition was considered good. Trend in visibility did improve from 2006 to 2015. While protecting air quality is fundamental to ecosystem health, the majority of threats originate from outside the monument and are, therefore, difficult to manage.
Rivers	Hydrology		Based on the available data, the condition for hydrology is good. This condition rating is only based on the measures for which condition could be determined. Even so, all of the measures for which condition was determined, were rated as low confidence because the stream gage was located 40 km (25 mi) downstream of the monument. Although there is a stream gage in the West Fork within the monument, the data record is short. It is unknown how well the downstream gage approximates conditions in the monument. Trend appears unchanging.
Rivers	Water Quality		The majority of measures indicate good condition. Although there were some exceedences, most appear to be the result of natural disturbances. Confidence is high due to the number of samples and seven years of data collection. Overall trend is unchanging based on the consistency of condition ratings over the years.
Biodiversity	Upland Vegetation		Only one non-native species was detected in monitoring plots, but cover for this species was sparse. Soil aggregate stability suggests possible issues with respect to erosion. All other measures, however, indicate good condition. Upland vegetation and soils at Gila Cliff Dwellings NM is within the range of natural variation. Trend is unknown. Confidence is medium.
Biodiversity	Riparian Vegetation		Few obligate riparian species occurred along the West Fork of the Gila River, but it's unclear whether there has been a loss of species over time. Non-native plant frequency was low in the riparian zone in both years, but exceeded 50% in the riparian zone during 2012. Percent cover of non-native plants was well below 10% in both zones and vegetation layers. These results suggest an overall good condition for riparian vegetation. Confidence is medium because of the age of the data and uncertainties regarding whether changes in vegetation are short-term effects of the fire. Trend could not be determined based on two years of data.
Biodiversity	Birds		The data used in this assessment suggest that there have been few changes to the bird community except for the introduction of the non-native Eurasian collared-dove. Although presence of species of conservation concern warrants moderate concern, confidence was low. Overall however, using the data available, the monument's bird community appears in good condition. However, information on changes in abundance, reproductive success, and current non-breeding season data are lacking. Confidence is medium and trends are unknown.
Biodiversity	Mammals		Seven species documented during the earlier Hayward and Hunt (1972) survey were not recorded during the most recent Powell et al. (2006) inventory, resulting in a low confidence level. However, based on the Powell et al. (2006) species accumulation curves, the monument's mammal richness at the monument is in good condition and contains habitat that supports a high proportion of mammals considered rare throughout the Gila River watershed. Trend is unknown.
Biodiversity	Herpetofauna		Based on the decline of amphibian presence and the well-documented detrimental effects of the invasive, American bullfrog, the overall condition of herpetofauna is of moderate concern. Without more recent survey data, the trend is unknown.
Biodiversity	Fish		Data indicate stable conditions for native species richness and a decline in non-native species richness, but there were not enough data to assign trend. Confidence in the overall condition rating is high despite the lack of monitoring sites within the monument because the two locations near the monument are close enough to serve as a proxy.

Source: Significance statement is from NPS (2016).

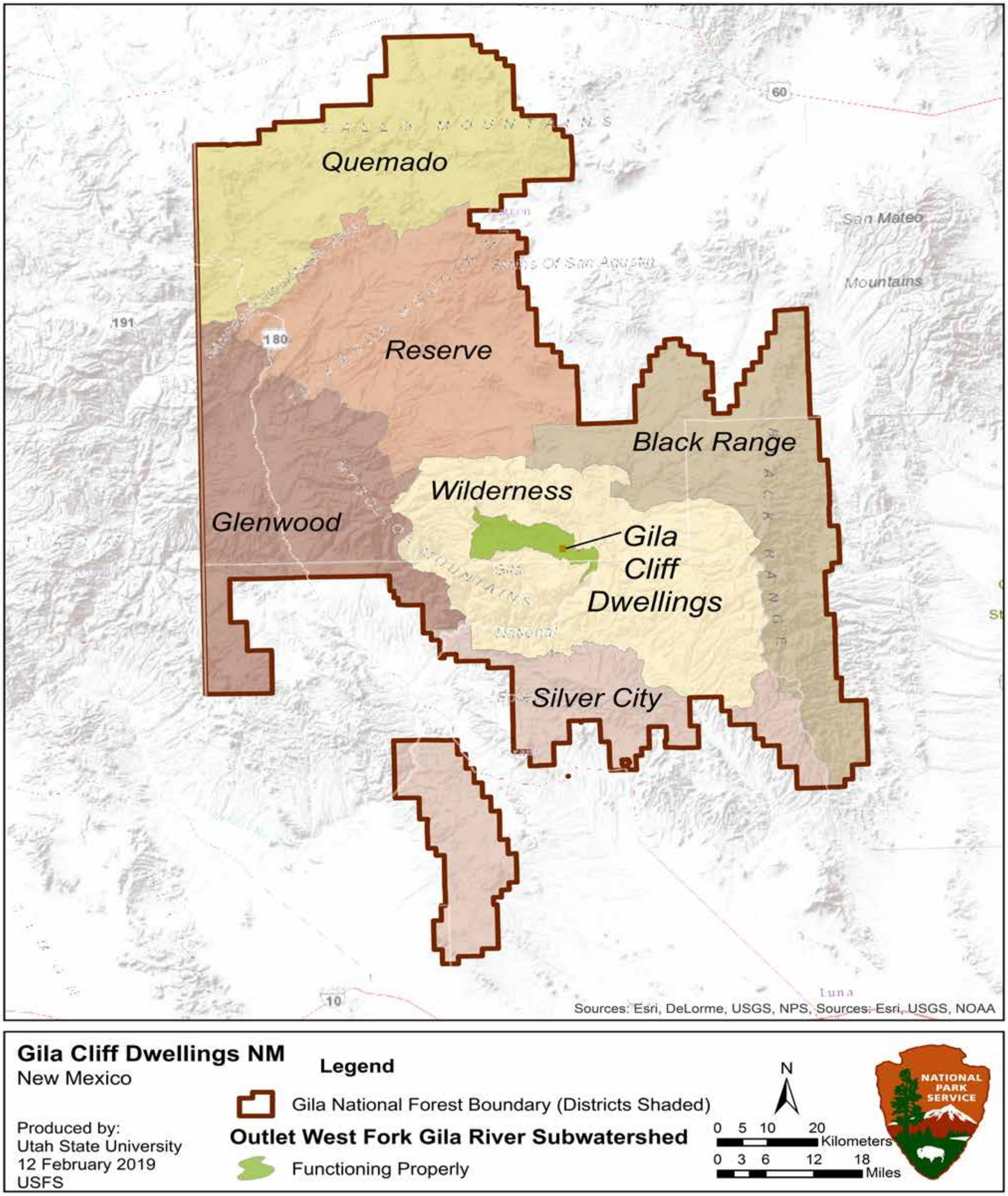


Figure 20. **Gila Cliff Dwellings NM is surrounded by the Gila National Forest and located within the Wilderness District of the forest. It is also located in the Outlet West Fork Gila River subwatershed, which is functioning properly.**

strategic, landscape-scale perspective will more likely maintain or improve resource conditions within the monument since most resources rely on factors that transcend political boundaries for their survival needs. Furthermore, 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 the monument's effort in coordinating resource management from a broader perspective, the USFS' (FY) 2011 Watershed Condition Framework (WCF) assessment for the Outlet West Fork Gila River subwatershed (where both the TJ and Cliff Dwellings units of the monument are located (Figure 20) is presented in this chapter. (Table 50). 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

Table 50. USFS Watershed Condition Framework (WCF) (2011) assessment for aquatic and terrestrial systems in the Outlet West Fork Gila River subwatershed.

WCF Resource Group	WCF Core Indicator	WCF Core Attributes	Outlet West Fork Gila River Condition
Aquatic Physical	Water Quality	Impaired Waters (503d Listed) Water Quality (Unlisted)	
	Water Quantity	Flow Characteristics	
	Aquatic Habitat	Habitat Fragmentation Large Woody Debris Channel Shape & Function	
Aquatic Biological	Aquatic Biota	Life Form Presence Native Species Exotic and/or Invasive Species	
	Riparian/Wetland Vegetation	Vegetation Condition	
Terrestrial Physical	Roads & Trails	Open Road Density Road Maintenance Proximity to Water Mass Wasting	
	Soils	Soil Productivity Soil Erosion Soil Contamination	
	Fire Regime	Fire Condition Class Wildfire Effects	
Terrestrial Biological	Forest Cover	Loss of Forest Cover	
	Rangeland Vegetation	Vegetation Condition	
	Invasive Species	Extent and Rate of Spread	
	Forest Health	Insects and Disease Ozone	

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 monument]; 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).

The WCF evaluation for the Outlet West Fork Gila River watershed was rated as functioning properly in (FY) 2011. Since then an additional WCF assessment was completed in (FY) 2017 for approximately one-fourth of the subwatersheds because of changing conditions or new information (USFS 2017). Two-hundred and ninety-one of these were then identified as priority based on "agency restoration priorities, the urgency of management action to address conditions and threats to the watershed, or alignment with partner strategies and priorities" (USFS 2017). The Outlet West Fork Gila River is not one of those priority watersheds. The fortunate reality is that 54% of the Gila NF subwatersheds are functioning properly; Additionally, almost 46% are functioning at risk, and only one, Snow Canyon, is considered of impaired function (USFS 2011).

Fifty percent of the indicators in the Outlet West Fork Gila subwatershed WCF are considered to be in good condition. These include all of the terrestrial biological indicators, which represent forest cover, rangeland vegetation, terrestrial invasive plant species and insects and disease. In contrast, all of the indicators for terrestrial physical are in fair condition. These indicators are related to roads and trails and associated mass wasting, along with soil erosion, contamination, and productivity. Fire regime is also in this group and is considered fair. We do not know whether this indicator was evaluated prior to the Miller Fire of 2011 and the Whitewater-Baldy Complex of 2012. However, we do know that conditions were not degraded to the extent of warranting a follow-up WCF evaluation in (FY) 2017.

The aquatic physical and biological indicators are split between good and fair conditions. Water flow and riparian/wetland vegetation condition are considered good. Water quality, channel shape and function, habitat fragmentation, large woody debris, aquatic life form presence and invasive species are all considered fair throughout the subwatershed.

While the monument's NRCA indicators and measures don't exactly reflect those of the WCF, the majority of the categories align, and as a whole, the localized conditions at the monument are in better condition as compared to the subwatershed conditions. Exceptions include the presence of non-native aquatic species and ozone, which warranted moderate concern ratings.

The monument is located within the NF's developed recreation area of the Gila Wilderness. This receives the highest amount of visitation of all wilderness areas throughout the Gila NF (USFS 2018b). Visitor use facilities such as campgrounds, picnic areas, trails, and the USFS-NPS shared Interpretive Visitor Center characterize features within the recreation areas. In consideration of maintaining resource conditions, facilities and activities need to be well-organized and capable of accommodating increased use, especially due to the proximity of water sources (USFS 2018b). The ease of accessibility to the monument (i.e., via road) also creates a vector for potential non-native plant infestations. Focusing limited resources on early detection invasive plant surveys and signs of riparian resource trampling/soil compaction may be beneficial so immediate removal and restoration can occur. Also, coordinating bullfrog removal with the USFS to reduce its negative impacts, may improve native aquatic species' health.

Given the fact that the monument faces pressures of limited personnel and funding to fully monitor, take action, and protect resources, establishing partnerships provides a means for achieving shared conservation goals. Furthermore, the monument's Foundation Document states that their resource management actions and strategies should be coordinated with the forest's plan (NPS 2016), with the understanding that there are different mandates between the NPS and USFS agencies to consider. Once the USFS has finalized their forest management plan (March 2018 draft), perhaps shared activities addressing landscape-scale drivers can be identified and implemented to protect resources at the watershed level.

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Appendix A. Scoping Meeting Participants and Report Reviewers

Table A-1. Scoping meeting participants.

Name	Affiliation and Position Title
Deborah Angell	National Park Service Sonoran Desert Inventory and Monitoring Network, Data Manager (former)
Steve Buckley	National Park Service Sonoran Desert Inventory and Monitoring Network, Botanist (former)
Beth Fallon	National Park Service Sonoran Desert Inventory and Monitoring Network, Vegetation Mapping Biological Technician (former)
Robert Gallardo	U.S. Forest Service Gila National Forest, Wilderness District Fire Ecologist
Evan Gwilliam	National Park Service Sonoran Desert Inventory and Monitoring Network, Aquatic Ecologist
Ronnie Sue Helzner	U.S. Forest Service Gila National Forest, Wilderness District Natural Resources Staff Lead
Andy Hubbard	National Park Service Sonoran Desert Inventory and Monitoring Network, Program Manager
Al Koss	U.S. Forest Service Gila National Forest, Wilderness District Ranger
Catherine Light	National Park Service Chamizal National Memorial, Superintendent
Kara Naber	National Park Service Gila Cliff Dwellings National Monument, Interpretive Ranger
Steve Riley	National Park Service Gila Cliff Dwellings National Monument, Park Manager
Sarah Studd	National Park Service Sonoran Desert Inventory and Monitoring Network, Vegetation Ecologist
Dan Winkler	National Park Service Sonoran Desert Inventory and Monitoring Network, Vegetation Mapping Biological Technician (former)

Table A-2. Report reviewers.

Name	Affiliation and Position Title	Sections Reviewed or Other Role
Jeff Albright	National Park Service Water Resources Division, Natural Resource Condition Assessment Series Coordinator	Washington-level Program Manager
Phyllis Pineda Bovin	National Park Service WASO Denver Service Center Planning Division, Natural Resource Specialist	Regional Program Level Coordinator and Peer Review Manager
Kelly Adams and Todd Wilson	National Park Service, Grants and Contracting Officers	Executed agreements
Fagan Johnson	National Park Service Inventory & Monitoring Division, Web and Report Specialist	Washington-level Publishing and 508 Compliance Review
Alyssa S. McGinnity	Contractor to National Park Service, Managed Business Solutions, a Sealaska Company	Washington-level Publishing and 508 Compliance Review
Andy Hubbard	National Park Service Sonoran Desert Inventory and Monitoring Network, Program Manager	Air Quality, Mammals, Assessments
Rita Garcia	National Park Service Gila Cliff Dwellings National Monument, Chief of Interpretation	Park Resource Expert Reviewer of All Condition Assessments
Ksienya Taylor	National Park Service Air Resources Division, Natural Resource Specialist	Air Quality Assessment
Don Weeks	National Park Service, Intermountain Regional Office, Natural Resources Division, Physical Resources Program Manager	Hydrology Assessment
Kerensa King	National Park Service Water Resources Division, Contaminants Specialist	Water Quality Assessment
Kara Raymond	National Park Service Southern Arizona Office, Hydrologist	Hydrology, Water Quality, Riparian & Aquatic Vegetation, Upland Vegetation, Herpetofauna Assessments
Kristen Philbrook	National Park Service Intermountain Region Office, Wildlife Biologist	Mammals, Herpetofauna 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

Table A-2 continued. Report reviewers.

Name	Affiliation and Position Title	Sections Reviewed or Other Role
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 and Aquatic Vegetation Assessment

Appendix B. Gila Cliff Dwellings NM Bird List

Listed in the table below are the bird species reported for Gila Cliff Dwellings National Monument according to NPSpecies (NPS 2018a), the 2009-2015 Sonoran Desert Network (SODN) annual landbird monitoring surveys in upland and riparian habitat (Beaupré et al. 2013), and observations by monument staff. The SODN surveys were conducted using standardized bird sampling methods. For descriptions of the effort, see the Data and Methods section of the birds condition assessment or Beaupré et al. (2013). Scientific names were updated with the current taxonomy used by the American Ornithological Society (AOS 2017). Common names were also updated to reflect current accepted names. A total of 202 species are contained in the table, 151 of which are considered "present" according to NPSpecies. SODN reported two additional species that are considered "unconfirmed" by NPSpecies and four species that were not reported in NPSpecies at all. Monument staff noted two species that were either "unconfirmed" or not listed by NPSpecies. The western distinct population of the yellow-billed cuckoo (*Coccyzus americanus*) is listed as threatened by the U.S. Fish and Wildlife Service's Endangered Species Program and is the only species listed by the USFWS in the monument (USFWS 2017).

Table B-1. Bird species list for Gila Cliff Dwellings NM.

Common Name	Scientific Name	Occurrence	Abundance	NPSpecies Tags	SODN Riparian Surveys	SODN Upland Surveys
Abert's towhee	*Melozone aberti*	–	–	–	–	X
Acorn woodpecker	*Melanerpes formicivorus*	Present	Common	Breeder	X	X
American avocet	*Recurvirostra americana*	Unconfirmed	–	–	–	–
American coot	*Fulica americana*	Unconfirmed	–	–	–	–
American dipper	*Cinclus mexicanus*	Unconfirmed	–	–	–	–
American goldfinch	*Spinus tristus*	Present	Occasional	Vagrant	X	–
American kestrel	*Falco sparverius*	Present	Uncommon	Breeder	X	–
American redstart	*Setophaga ruticilla*	Present	Common		–	–
American robin	*Turdus migratorius*	Present	Common	Breeder	X	X
American wigeon	*Mareca americana*	Unconfirmed	–	–	–	–
Ash-throated flycatcher	*Myiarchus cinerascens*	Present	Common	Breeder	X	X
Bald eagle	*Haliaeetus leucocephalus*	Present	Rare	Migratory	–	–
Band-tailed pigeon	*Patagioenas fasciata*	Present	Uncommon	Migratory	–	–
Bank swallow	*Riparia riparia*	Present	Rare	Migratory	–	–
Barn owl	*Tyto alba*	Present	Occasional	Resident	–	–
Barn swallow	*Hirundo rustica*	Present	Uncommon	Migratory	–	–
Bell's vireo	*Vireo bellii*	Present	Rare	Breeder	–	–
Belted kingfisher[1]	*Megaceryle alcyon*	Unconfirmed	–	–	X	–
Bewick's wren	*Thryomanes bewickii*	Present	Uncommon	Breeder	X	X
Black phoebe	*Sayornis nigricans*	Present	Uncommon	Breeder	X	–
Black-chinned hummingbird	*Archilochus alexandri*	Present	Common	Breeder	X	–

[1] Observed by NPS staff.

[2] Indicates non-native species.

[3] Species, originally known as the whip-poor-will (*Caprimulgus vociferus*), was split into the eastern whip-poor-will (*Antrostomus vociferous*) and the Mexican whip-poor-will (*Antrostomus arizonae*). Since the latter species is more likely to occur in the monument, the Mexican whip-poor-will was included in the table (Cink et al. 2017a,b).

[4] Formerly known as the western scrub jay (*Aphelocoma californica*) (Curry et al. 2017).

Note: X = species present.

Table B-1 continued. Bird species list for Gila Cliff Dwellings NM.

Common Name	Scientific Name	Occurrence	Abundance	NPSpecies Tags	SODN Riparian Surveys	SODN Upland Surveys
Black-headed grosbeak	*Pheucticus melanocephalus*	Present	Common	Breeder	X	X
Black-throated gray warbler	*Setophaga nigrescens*	Present	Uncommon	Breeder	X	X
Black-throated sparrow	*Amphispiza bilineata*	Present	Uncommon	Breeder	–	–
Blue grosbeak	*Passerina caerulea*	Present	Uncommon	Breeder	X	X
Blue-gray gnatcatcher	*Polioptila caerulea*	Present	Uncommon	Breeder	X	X
Blue-winged teal	*Spatula discors*	Unconfirmed	–	–	–	–
Brewer's blackbird	*Euphagus cyanocephalus*	Present	Uncommon	Migratory	–	X
Brewer's sparrow	*Spizella breweri*	Present	Common	Resident	–	–
Bridled titmouse	*Baeolophus wollweberi*	Present	Uncommon	Breeder	X	X
Broad-tailed hummingbird	*Selasphorus platycercus*	Present	Common	Breeder	X	X
Brown creeper	*Certhia americana*	Present	Uncommon	Resident	X	X
Brown-headed cowbird	*Molothrus ater*	Present	Common	Breeder	X	X
Bufflehead	*Bucephala albeola*	Unconfirmed	–	–	–	–
Bullock's oriole	*Icterus bullockii*	Present	Uncommon	Breeder	X	–
Bushtit	*Psaltriparus minimus*	Present	Uncommon	Breeder	X	X
Calliope hummingbird	*Selasphorus calliope*	Present	Uncommon	Migratory	–	–
Canada goose	*Branta canadensis*	Unconfirmed	–	–	–	–
Canvasback	*Aythya valisineria*	Unconfirmed	–	–	–	–
Canyon towhee	*Melozone fusca*	Present	Common	Breeder	X	X
Canyon wren	*Catherpes mexicanus*	Present	Common	Breeder	X	X
Cassin's finch	*Haemorhous cassinii*	–	–	–	–	X
Cassin's kingbird	*Tyrannus vociferans*	Present	Uncommon	Breeder	X	X
Chipping sparrow	*Spizella passerina*	Present	Common	Breeder	X	X
Cinnamon teal	*Spatula cyanoptera*	Unconfirmed	–	–	–	–
Clark's nutcracker	*Nucifraga columbiana*	Present	Occasional	Migratory	–	–
Cliff swallow	*Petrochelidon pyrrhonota*	Present	Uncommon	Breeder	X	X
Common black hawk	*Buteogallus anthracinus*	Present	Uncommon	Breeder	X	–
Common goldeneye	*Bucephala clangula*	Unconfirmed	–	–	–	–
Common merganser	*Mergus merganser*	Present	Uncommon	Breeder	X	–
Common nighthawk	*Chordeiles minor*	Present	Uncommon	Breeder	–	–
Common poorwill	*Phalaenoptilus nuttallii*	Present	Uncommon	Breeder	–	–

[1] Observed by NPS staff.

[2] Indicates non-native species.

[3] Species, originally known as the whip-poor-will (*Caprimulgus vociferus*), was split into the eastern whip-poor-will (*Antrostomus vociferous*) and the Mexican whip-poor-will (*Antrostomus arizonae*). Since the latter species is more likely to occur in the monument, the Mexican whip-poor-will was included in the table (Cink et al. 2017a,b).

[4] Formerly known as the western scrub jay (*Aphelocoma californica*) (Curry et al. 2017).

Note: X = species present.

Table B-1 continued. Bird species list for Gila Cliff Dwellings NM.

Common Name	Scientific Name	Occurrence	Abundance	NPSpecies Tags	SODN Riparian Surveys	SODN Upland Surveys
Common raven	*Corvus corax*	Present	Common	Breeder	X	X
Common yellowthroat	*Geothlypis trichas*	Present	Uncommon	Breeder	X	X
Cooper's hawk	*Accipiter cooperii*	Present	Uncommon	Breeder	–	X
Cordilleran flycatcher	*Empidonax occidentalis*	Present	Common	Breeder	X	X
Curve-billed thrasher	*Toxostoma curvirostre*	Present	Uncommon	Breeder	–	–
Dark-eyed junco	*Junco hyemalis*	Present	Uncommon	Breeder	X	X
Downy woodpecker	*Picoides pubescens*	Unconfirmed	–	–	–	–
Dusky flycatcher	*Empidonax oberholseri*	Present	Uncommon	Migratory	–	X
Dusky-capped flycatcher	*Myiarchus tuberculifer*	Present	Rare	Migratory	–	–
Eared grebe	*Podiceps nigricollis*	Unconfirmed	–	–	–	–
Elf owl	*Micrathene whitneyi*	Present	Rare	Breeder	–	–
Eurasian collared-dove[2]	*Streptopelia decaocto*	–	–	–	X	X
Flammulated owl	Psiloscops flammeolus	Present	Rare	Migratory	–	–
Franklin's gull	*Leucophaeus pipixcan*	Unconfirmed	–	–	–	–
Gadwall	*Mareca strepera*	Unconfirmed	–	–	–	–
Gambel's quail	*Callipepla gambelii*	Present	Common	Breeder	X	–
Golden eagle	*Aquila chrysaetos*	Present	Uncommon	Resident	–	–
Grace's warbler	*Setophaga graciae*	Present	Uncommon	Breeder	X	X
Gray catbird	*Dumetella carolinensis*	Present	Occasional	Migratory	–	–
Gray flycatcher	*Empidonax wrightii*	Present	Uncommon	Migratory	X	X
Great blue heron	*Ardea herodias*	Present	Uncommon	Breeder	X	X
Great horned owl	*Bubo virginianus*	Present	Uncommon	Breeder	X	X
Greater pewee	*Contopus pertinax*	Present	Rare	Migratory	X	X
Greater roadrunner	*Geococcyx californianus*	Present	Uncommon	Breeder	X	X
Greater yellowlegs	*Tringa melanoleuca*	Unconfirmed	–	–	–	–
Great-tailed grackle	*Quiscalus mexicanus*	–	–	–	X	–
Green heron	*Butorides virescens*	Present	Rare	Migratory	–	–
Green-tailed towhee	*Pipilo chlorurus*	Present	Uncommon	Migratory	X	–
Green-winged teal	*Anas crecca*	Unconfirmed	–	–	–	–
Hairy woodpecker	*Picoides villosus*	Present	Common	Breeder	X	X
Hammond's flycatcher	*Empidonax hammondii*	Present	Uncommon	Migratory	–	–
Hepatic tanager	*Piranga flava*	Present	Uncommon	Breeder	X	X
Hermit thrush	*Catharus guttatus*	Present	Uncommon	Breeder	X	X
Hooded oriole	*Icterus cucullatus*	–	–	–	X	–
Horned lark	*Eremophila alpestris*	Unconfirmed	–	–	–	–
House finch	*Carpodacus mexicanus*	Present	Common	Breeder	X	X

[1] Observed by NPS staff.

[2] Indicates non-native species.

[3] Species, originally known as the whip-poor-will (*Caprimulgus vociferus*), was split into the eastern whip-poor-will (*Antrostomus vociferous*) and the Mexican whip-poor-will (*Antrostomus arizonae*). Since the latter species is more likely to occur in the monument, the Mexican whip-poor-will was included in the table (Cink et al. 2017a,b).

[4] Formerly known as the western scrub jay (*Aphelocoma californica*) (Curry et al. 2017).

Note: X = species present.

Table B-1 continued. Bird species list for Gila Cliff Dwellings NM.

Common Name	Scientific Name	Occurrence	Abundance	NPSpecies Tags	SODN Riparian Surveys	SODN Upland Surveys
House wren	*Troglodytes aedon*	Present	Common	Breeder	X	X
Hutton's vireo	*Vireo huttoni*	Present	Uncommon	Breeder	–	X
Indigo bunting	*Passerina cyanea*	Present	Rare	Migratory	X	–
Juniper titmouse	*Baeolophus ridgwayi*	Present	Uncommon	Breeder	X	X
Killdeer	*Charadrius vociferus*	Present	Uncommon	Migratory	X	X
Ladder-backed woodpecker	*Picoides scalaris*	Present	Rare	Breeder	–	–
Lark bunting	Calamospiza melanocorys	Present	Rare	Migratory	–	–
Lark sparrow	*Chondestes grammacus*	Present	Uncommon	Breeder	X	–
Lazuli bunting	*Passerina amoena*	Present	Uncommon	Migratory	X	–
Least sandpiper	*Calidris minutilla*	Unconfirmed	–	–	–	–
Lesser goldfinch	*Carduelis psaltria*	Present	Common	Breeder	X	X
Lesser scaup	*Aythya affinis*	Unconfirmed	–	–	–	–
Lesser yellowlegs	*Tringa flavipes*	Unconfirmed	–	–	–	–
Lewis's woodpecker	*Melanerpes lewis*	Present	Rare	Migratory	X	–
Lincoln's sparrow	*Melospiza lincolnii*	Present	Uncommon	Migratory	–	–
Long-billed dowitcher	*Limnodromus scolopaceus*	Unconfirmed	–	–	–	–
Long-eared owl	*Asio otus*	Present	Rare	Migratory	–	–
Lucy's warbler	*Oreothlypis luciae*	Present	Uncommon	Breeder	X	–
MacGillivray's warbler	*Geothlypis tolmiei*	Present	Uncommon	Migratory	X	–
Mallard	*Anas platyrhynchos*	Present	Uncommon	Resident	X	–
Marsh wren	*Cistothorus palustris*	Unconfirmed	–	–	–	–
Merlin	*Falco columbarius*	Present	Rare	Migratory	–	–
Mexican jay	*Aphelocoma wollweberi*	Present	Uncommon	Breeder	–	–
Mexican whip-poor-will[3]	*Antrostomus arizonae*	Present	Common	Breeder	–	–
Montezuma quail	*Cyrtonyx montezumae*	Present	Rare	Breeder	X	X
Mountain chickadee	*Poecile gambeli*	Present	Uncommon	Breeder	---	X
Mourning dove	*Zenaida macroura*	Present	Common	Breeder	X	X
Northern flicker	*Colaptes auratus*	Present	Common	Breeder	X	X
Northern goshawk	*Accipiter gentilis*	Present	Rare	Resident	–	–
Northern harrier[1]	*Circus hudsonius*	–	–	–	–	–
Northern mockingbird	*Mimus polyglottos*	Present	Uncommon	Breeder	X	–
Northern pintail	*Anas acuta*	Unconfirmed	–	–	–	–
Northern pygmy-owl	*Glaucidium gnoma*	Present	Uncommon	Breeder	X	X
Northern rough-winged swallow	*Stelgidopteryx serripennis*	Present	Uncommon	Breeder	–	–

[1] Observed by NPS staff.

[2] Indicates non-native species.

[3] Species, originally known as the whip-poor-will (*Caprimulgus vociferus*), was split into the eastern whip-poor-will (*Antrostomus vociferous*) and the Mexican whip-poor-will (*Antrostomus arizonae*). Since the latter species is more likely to occur in the monument, the Mexican whip-poor-will was included in the table (Cink et al. 2017a,b).

[4] Formerly known as the western scrub jay (*Aphelocoma californica*) (Curry et al. 2017).

Note: X = species present.

Table B-1 continued. Bird species list for Gila Cliff Dwellings NM.

Common Name	Scientific Name	Occurrence	Abundance	NPSpecies Tags	SODN Riparian Surveys	SODN Upland Surveys
Northern saw-whet owl	*Aegolius acadicus*	Present	Rare	Breeder	–	–
Northern shoveler	*Spatula clypeata*	Unconfirmed	–	–	X	–
Olive warbler	*Peucedramus taeniatus*	Present	Uncommon	Breeder	–	–
Orange-crowned warbler	*Oreothlypis celata*	Present	Uncommon	Migratory	–	X
Painted redstart	*Myioborus pictus*	Present	Uncommon	Breeder	X	X
Peregrine falcon	*Falco peregrinus*	Present	Rare	Breeder	–	–
Pine siskin	*Spinus pinus*	Present	Uncommon	Breeder	X	X
Pinyon jay	*Gymnorhinus cyanocephalus*	Present	Uncommon	Breeder	–	X
Plumbeous vireo	*Vireo plumbeus*	Present	Uncommon	Breeder	X	X
Prairie falcon	*Falco mexicanus*	Present	Rare	Migratory	–	–
Purple martin	*Progne subis*	Present	Common	Breeder	X	X
Pygmy nuthatch	*Sitta pygmaea*	Present	Uncommon	Breeder	X	X
Red crossbill	*Loxia curvirostra*	Present	Rare	Migratory	–	–
Red-breasted merganser	*Mergus serrator*	Unconfirmed	–	–	–	–
Red-breasted nuthatch	*Sitta canadensis*	Present	Uncommon	Resident	–	–
Red-faced warbler	*Cardellina rubrifrons*	Present	Uncommon	Breeder	X	X
Redhead	*Aythya americana*	Unconfirmed	–	–	–	–
Red-naped sapsucker	*Sphyrapicus nuchalis*	Present	Uncommon	Resident	X	X
Red-tailed hawk	*Buteo jamaicensis*	Present	Common	Breeder	X	–
Ring-billed gull	*Larus delawarensis*	Unconfirmed	–	–	–	–
Ring-necked duck	*Aythya collaris*	Unconfirmed	–	–	–	–
Ring-necked pheasant[2]	*Phasianus colchicus*	Unconfirmed	–	–	–	–
Rock pigeon[2]	*Columba livia*	Unconfirmed	–	–	–	–
Rock wren	*Salpinctes obsoletus*	Present	Uncommon	Breeder	X	X
Ruby-crowned kinglet	Regulus calendula	Present	Uncommon	Breeder	X	X
Ruddy duck	Oxyura jamaicensis	Unconfirmed	–	–	–	–
Rufous hummingbird	*Selasphorus rufus*	Present	Uncommon	Migratory	X	–
Rufous-crowned sparrow	*Aimophila ruficeps*	Present	Common	Breeder	X	X
Sage thrasher	*Oreoscoptes montanus*	Present	Rare	Migratory	–	–
Savannah sparrow	*Passerculus sandwichensis*	Unconfirmed	–	–	–	–
Say's phoebe	*Sayornis saya*	Present	Uncommon	Breeder	X	–

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[2] Indicates non-native species.

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[4] Formerly known as the western scrub jay (*Aphelocoma californica*) (Curry et al. 2017).

Note: X = species present.

Table B-1 continued. ***Bird species list for Gila Cliff Dwellings NM.***

Common Name	Scientific Name	Occurrence	Abundance	NPSpecies Tags	SODN Riparian Surveys	SODN Upland Surveys
Sharp-shinned hawk	*Accipiter striatus*	Present	Uncommon	Resident	X	–
Snowy egret	*Egretta thula*	Unconfirmed	–	–	–	–
Solitary sandpiper	*Tringa solitaria*	Unconfirmed	–	–	–	–
Song sparrow	*Melospiza melodia*	Present	Uncommon	–	X	–
Sora	*Porzana carolina*	Unconfirmed		–	–	–
Spotted owl (Mexican ssp.)	*Strix occidentalis lucida*	Unconfirmed	–	–	–	–
Spotted sandpiper	*Actitis macularius*	Present	Uncommon	Migratory	–	–
Spotted towhee	*Pipilo maculatus*	Present	Common	Breeder	X	X
Steller's jay	*Cyanocitta stelleri*	Present	Uncommon	Breeder	X	X
Summer tanager	*Piranga rubra*	Present	Uncommon	Breeder	X	–
Swainson's hawk	*Buteo swainsoni*	Present	Rare	Migratory	–	–
Swainson's thrush	*Catharus ustulatus*	Present	Rare	Migratory	–	–
Townsend's solitaire	*Myadestes townsendi*	Present	Rare	Resident	–	X
Townsend's warbler	*Setophaga townsendi*	Present	Uncommon	Migratory	–	–
Tree swallow	*Tachycineta bicolor*	Present	Uncommon	Migratory	–	–
Turkey vulture	*Cathartes aura*	Present	Common	Breeder	X	X
Vermilion flycatcher	*Pyrocephalus rubinus*	Present	Uncommon	Breeder	X	–
Vesper sparrow	*Pooecetes gramineus*	Present	Rare	Migratory	–	–
Violet-green swallow	*Tachycineta thalassina*	Present	Common	Breeder	X	X
Virginia rail	*Rallus limicola*	Unconfirmed	–	–	–	–
Virginia's warbler	*Oreothlypis virginiae*	Present	Uncommon	Breeder	X	X
Warbling vireo	*Vireo gilvus*	Present	Uncommon	Breeder	X	X
Western bluebird	*Sialia mexicana*	Present	Uncommon	Breeder	X	X
Western kingbird	*Tyrannus verticalis*	Present	Uncommon	Breeder	X	–
Western sandpiper	*Calidris mauri*	Unconfirmed	–	–	–	–
Western screech-owl	*Megascops kennicottii*	Present	Uncommon	Breeder	–	–
Western tanager	*Piranga ludoviciana*	Present	Uncommon	Breeder	X	X
Western wood-pewee	*Contopus sordidulus*	Present	Common	Breeder	X	X
White ibis	*Eudocimus albus*	Unconfirmed	–	–	–	–
White-breasted nuthatch	*Sitta carolinensis*	Present	Uncommon	Breeder	X	X
White-crowned sparrow	*Zonotrichia leucophrys*	Present	Common	Resident	–	–
White-throated swift	*Aeronautes saxatalis*	Present	Uncommon	Breeder	X	–
White-winged dove	*Zenaida asiatica*	Present	Uncommon	Breeder	X	X
Wild turkey	*Meleagris gallopavo*	Present	Uncommon	Breeder	X	X
Willet	*Tringa semipalmata*	Unconfirmed	–	–	–	–

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[3] Species, originally known as the whip-poor-will (*Caprimulgus vociferus*), was split into the eastern whip-poor-will (*Antrostomus vociferous*) and the Mexican whip-poor-will (*Antrostomus arizonae*). Since the latter species is more likely to occur in the monument, the Mexican whip-poor-will was included in the table (Cink et al. 2017a,b).

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Table B-1 continued. Bird species list for Gila Cliff Dwellings NM.

Common Name	Scientific Name	Occurrence	Abundance	NPSpecies Tags	SODN Riparian Surveys	SODN Upland Surveys
Williamson's sapsucker	*Sphyrapicus thyroideus*	Present	Uncommon	Resident	–	–
Willow flycatcher	*Empidonax traillii*	Present	Rare	Migratory	–	–
Wilson's phalarope	*Phalaropus tricolor*	Unconfirmed	–	–	–	–
Wilson's snipe	*Gallinago delicata*	Unconfirmed	–	–	–	–
Wilson's warbler	*Cardellina pusilla*	Present	Uncommon	Migratory	X	X
Wood duck	*Aix sponsa*	Unconfirmed	–	–	–	–
Woodhouse's scrub-jay[4]	*Aphelocoma woodhouseii*	Present	Uncommon	Breeder	–	X
Yellow warbler	*Setophaga petechia*	Present	Common	Breeder	X	X
Yellow-bellied sapsucker	*Sphyrapicus varius*	Unconfirmed	–	–	–	–
Yellow-billed cuckoo	*Coccyzus americanus*	Present	Rare	Breeder	–	–
Yellow-breasted chat	*Icteria virens*	Present	Common	Breeder	X	X
Yellow-headed blackbird	*Xanthocephalus xanthocephalus*	Present	Rare	Migratory	–	–
Yellow-rumped warbler	*Setophaga coronata*	Present	Uncommon	Breeder	X	X
Zone-tailed hawk	*Buteo albonotatus*	Present	Uncommon	Breeder	–	X

[1] Observed by NPS staff.

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[3] Species, originally known as the whip-poor-will (*Caprimulgus vociferus*), was split into the eastern whip-poor-will (*Antrostomus vociferous*) and the Mexican whip-poor-will (*Antrostomus arizonae*). Since the latter species is more likely to occur in the monument, the Mexican whip-poor-will was included in the table (Cink et al. 2017a,b).

[4] Formerly known as the western scrub jay (*Aphelocoma californica*) (Curry et al. 2017).

Note: X = species present.

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