National Park Service
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Natural Resource Stewardship and Science

Walnut Canyon National Monument

Natural Resource Condition Assessment

Natural Resource Report NPS/SCPN/NRR—2018/1637

ON THIS PAGE
View into Walnut Canyon. Photo Credit: NPS

ON THE COVER
View of the Walnut Creek riparian corridor. Photo Credit: NPS

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Executive Summary

The Natural Resource Condition Assessment (NRCA) Program, administered by the National Park Service's (NPS) Water Resources Division, aims to provide documentation about current conditions of important park natural resources through a spatially explicit, multidisciplinary synthesis of existing scientific data and knowledge. The workshop for the Flagstaff Area National Monuments (NM) NRCAs, which includes Walnut Canyon, Wupatki, and Sunset Crater Volcano, was held from May 17 - 19, 2016. This NRCA report is for Walnut Canyon NM.

Walnut Canyon was established as a national monument in 1915 to preserve the hundreds of archaeological sites along 16.1 km (10 mi) of Walnut Creek (NPS 2015a). The rare water source was a valuable resource for the Northern Sinagua people and rich biological communities (NPS 2015a).

For Walnut Canyon NM's NRCA, park staff selected 10 natural resource topics for condition assessments and an evaluation of habitat connectivity between the three Flagstaff Area NMs. Walnut Canyon NM's resources were grouped into five broad categories: landscapes, air and climate, geology and soils, water, and biological integrity, which included wildlife and vegetation resources. Most of the assessments resulted in a good or moderate concern condition rating. The most significantly impacted resource included the Walnut Creek Riparian Area Creek -one of the park's most biologically rich areas.

The resources at Walnut Canyon NM face many threats due to an ever-increasing human population within and surrounding Flagstaff, Arizona and increasing temperatures and erratic precipitation events due to climate change. The Flagstaff Area NM's proactive science program will become even more important in influencing resource conditions and identifying necessary adaptations in a rapidly changing environment.

Acknowledgements

Natural resources staff in the Flagstaff Area NM's Science and Resource Management Division participated in the development and reviews of this report's condition assessments. Lisa Leap, Division Chief of Resources; Paul Whitefield, Natural Resource Specialist; Mark Szydlo, Biologist; and Michael Jones, GIS Specialist provided their expertise as chapter and assessment reviewers and as information facilitators assisting with the development of indicators, measures, reference conditions, and maps, as needed. Paul Whitefield contributed significantly to the assessment development process, providing an overview of the regional resource-context and significance to the monument's resources.

Joel Wagner, Wetlands Program Leader, and Mike Martin, Hydrologist, both with the National Park Service's Water Resources Division, and Christine Taliga, National Park Service / Natural Resources Conservation Service, Liaison conducted a rapid riparian condition assessment for the purposes of the Walnut Canyon Riparian Area condition assessment. National Park Service's Southern Colorado Plateau Inventory and Monitoring Program's monitoring data for Walnut Canyon NM helped to inform conditions for the Cherry Pools in Cherry Canyon, Ponderosa Pine, and Birds Chapter 4 assessments.

Phyllis Pineda Bovin, National Park Service Intermountain Region Natural Resource Condition Assessment Coordinator, and Donna Shorrock, former National Park Service Intermountain Region Natural Resource Condition Assessment Coordinator, assisted with overall project facilitation and served as peer review managers. Jeff Albright, National Park Service Natural Resource Condition Assessment Program Coordinator, provided programmatic guidance. To all of the additional reviewers listed in Appendix B and contributors who are listed within each Chapter 4 assessment, we thank you. Your contributions have increased the value of Walnut Canyon NM's NRCA report.

View into Walnut Canyon. Photo Credit: NPS.

Chapter 1. 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.

Although the primary objective of NRCAs is to report on current conditions relative to logical forms

[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.

NRCAs Strive to Provide...

- *Credible condition reporting for a subset of important park natural resources and indicators*
- *Useful condition summaries by broader resource categories or topics and by park areas*

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.

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

Important NRCA Success Factors

- *Obtaining good input from park staff and other NPS subject-matter experts at critical points in the project timeline*
- *Using study frameworks that accommodate meaningful condition reporting at multiple levels (measures - indicators - broader resource topics and park areas)*
- *Building credibility by clearly documenting the data and methods used, critical data gaps, and level of confidence for indicator-level condition findings*

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 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/.

NRCA Reporting Products...

Provide a credible, snapshot-in-time evaluation for a subset of important park natural resources and indicators, to help park managers:

- *Direct limited staff and funding resources to park areas and natural resources that represent high need and/or high opportunity situations **(near-term operational planning and management)***
- *Improve understanding and quantification for desired conditions for the park's "fundamental" and "other important" natural resources and values*

[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.

Walnut Canyon NM's Walnut Creek corridor. Photo Credit: NPS.

Chapter 2. Introduction and Resource Setting

2.1. Introduction

2.1.1. Enabling Legislation/Executive Orders

Walnut Canyon National Monument (NM) was established on November 30, 1915 to preserve the hundreds of archaeological sites along 16.1 km (10 mi) of Walnut Creek (NPS 2015a). The availability of water was a valuable and rare resource for the Northern Sinagua people and the rich biological communities (NPS 2015a). The monument's purpose is to "preserve and protect the ancient Northern Sinagua cliff dwellings, pit houses, and other cultural resources found in the canyon's deeply incised and meandering topography" (NPS 2015a). Walnut Canyon NM's additional unique resources and values are further described in its three significance statements as follows (text excerpted from NPS (2015a)):

> ***People in the Environment-*** The Northern Sinagua adapted to varied environmental exposure created by the tight meanders of the canyon, alcoves, and the concentration of available resources and water.
>
> ***Connections from Past to Present-*** Natural and cultural resources within the monument are significant to a number of contemporary American Indian tribes, as evidenced by oral history, archeological study, and continuing traditional practices. Today's visitors experience an intimate connection to communities of the past, both through traditional knowledge shared by contemporary tribes and by visiting ancestral homes in Walnut Canyon.
>
> ***Biodiversity-*** Walnut Canyon and its meandering topography and ecological communities overlap to form ecotones, bringing together plants and wildlife usually separated by elevation. This creates a rare compression of flora/fauna zones.

Additional fundamental and other important resources and values are identified for the monument in its foundation document (NPS 2015a), which further expand on the themes related to its purpose and significance statements.

2.1.2. Geographic Setting

Walnut Canyon NM, which is co-administered with Sunset Crater Volcano and Wupatki NMs, collectively referred to as Flagstaff Area National Monuments, is located in northern Arizona's Coconino County 12 km (7.5 mi) southeast from downtown Flagstaff, Arizona (Figure 2.1.2-1) and encompasses 1,444 ha (3,567 ac) (NPS 2015a). It is located south of Interstate 40, which provides access to the monument. Lands surrounding the national monument consist largely of the Coconino National Forest, managed by the U.S. Forest Service (USFS).

Population

Arizona is the fourth fastest growing state in the U.S. based on projected percent change in population size from 1995 to 2025 (U.S. Census Bureau 2016a). The population estimate for Coconino County was 139,097 in July 2015, with an increase of 3.5% since April 2010, and the population of Flagstaff was an estimated 70,320 in July 2015, with a 6.4% increase since April 2010 (U.S. Census Bureau 2016b).

Climate

The climate of the U.S. Southwest is most influenced by its location between the mid-latitude and subtropical atmospheric circulation regimes. This creates the typical southwestern climate of dry, sunny days, with low annual precipitation. Rain comes in July-September from monsoon storms that originate in the Pacific Ocean and the Gulf of Mexico, and in November-March from winter storms that originate in the Pacific Ocean (Sheppard et al. 2002). The Colorado Plateau, where the monument is situated, is an arid region with irregular rainfall, periods of drought, warm to hot growing seasons, and long winters with freezing temperatures (Davey et al. 2006).

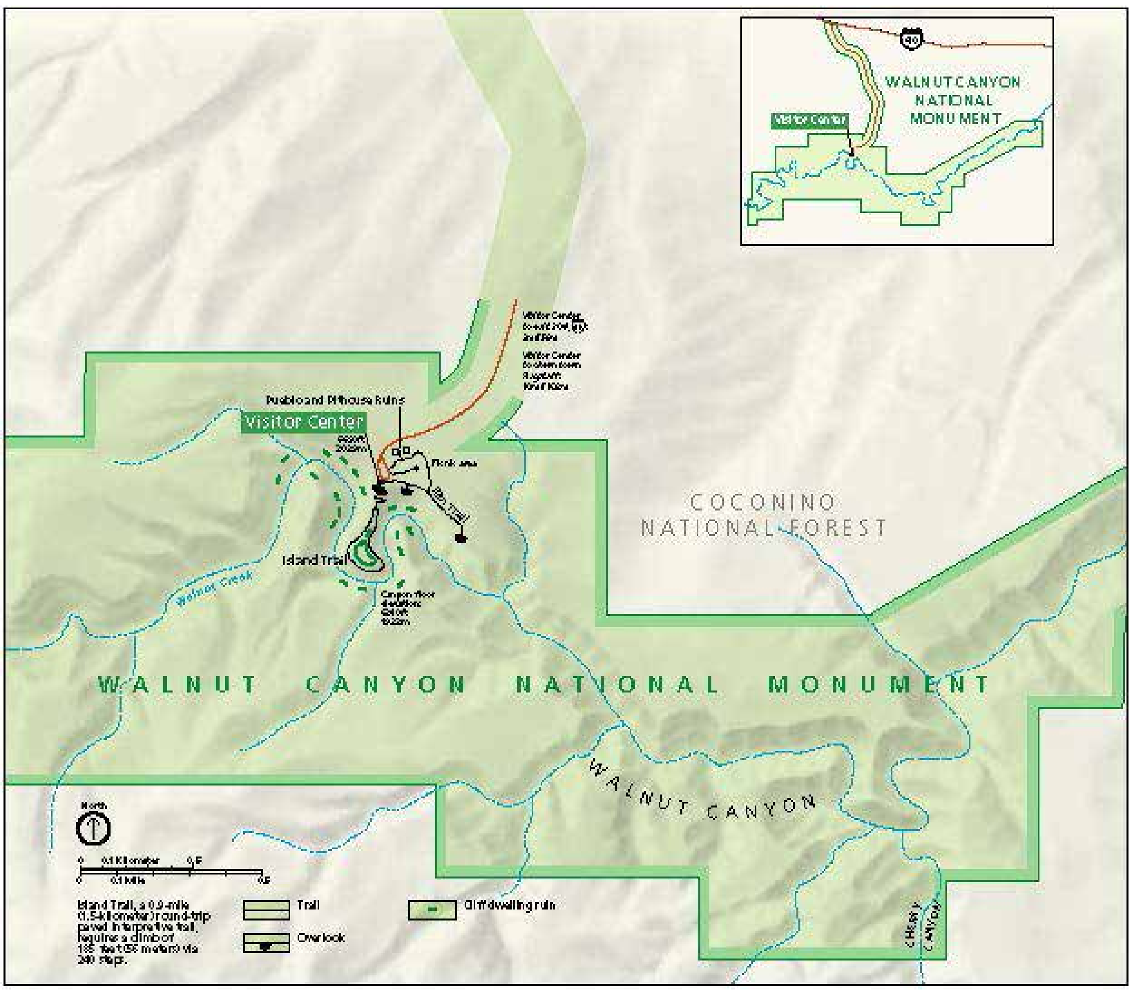


Figure 2.1.2-1. Walnut Canyon NM is located south of Interstate 40, approximately 12 km (7.5 mi) southeast of downtown Flagstaff, Arizona. The entrance road to Walnut Canyon NM is not included within the boundaries of the monument. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction. Figure Credit: NPS.

The National Weather Service Cooperative Observer (COOP) Network station, 29156, is located in the monument and has collected temperature and precipitation data since 1950 at an elevation of 2,040.6 m (6,695 ft), although data are lacking over much of the recording period (Figure 2.1.2-2, Climate Analyzer 2017). Another weather station, located at Flagstaff Airport, Arizona at an elevation of 2,134 m (7,001 ft) has a more comprehensive period of record from 1893-2012 (Figure 2.1.2-3, NPS SCPN 2017a).

In general, the weather at Walnut Canyon NM is quite variable with high winds, frequent summer thunderstorms, and heavy snowfall occurring between fall and spring. The highest average daily high temperatures occur during the months of July and August. The cold season generally occurs from November to March, with the coldest temperatures occurring in December and January. The average temperature is 7.9 ºC (46.1 ºF) (NPS SCPN 2017a).

Walnut Canyon NM receives the majority of its precipitation from July through September then again from December through March in the form of snow. The average precipitation in the monument area is 439 mm (17.2 in), which represents the higher end of the average precipitation throughout the Colorado Plateau, which is 160-540 mm/year (6.3-21.3 in/year) (NPS SCPN 2016).

2.1.3. Visitation Statistics

Monthly visitation data for Walnut Canyon NM are available from 1979-2016 (NPS Public Use Statistics Office 2017). The total number of Walnut Canyon NM visitors each year ranged from a low of 69,729 (in 1979) to a high of 165,223 (in 1993). The months with the highest average number of visitors over the recording period were June-August (Figure 2.1.3-1).

2.2. Natural Resources

A brief summary of the natural resources at Walnut Canyon NM is presented in this section. For additional information, please refer to Chapter 4 assessments and cited reports within the summaries below.

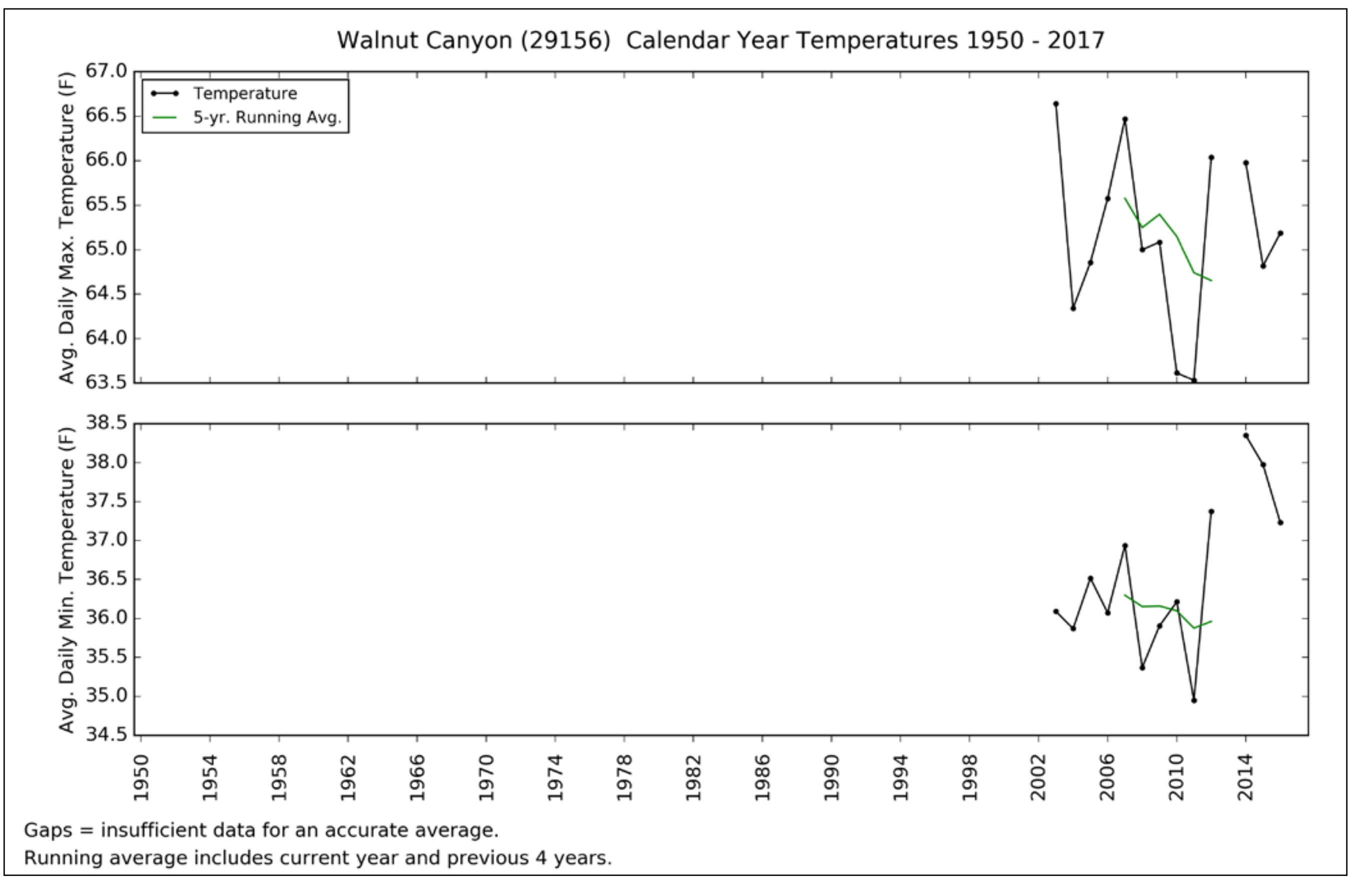


Figure 2.1.2-2. Average daily maximum (top) and minimum (bottom) temperatures (1950-Oct. 2017). Figure Credit: Climate Analyzer (2017).

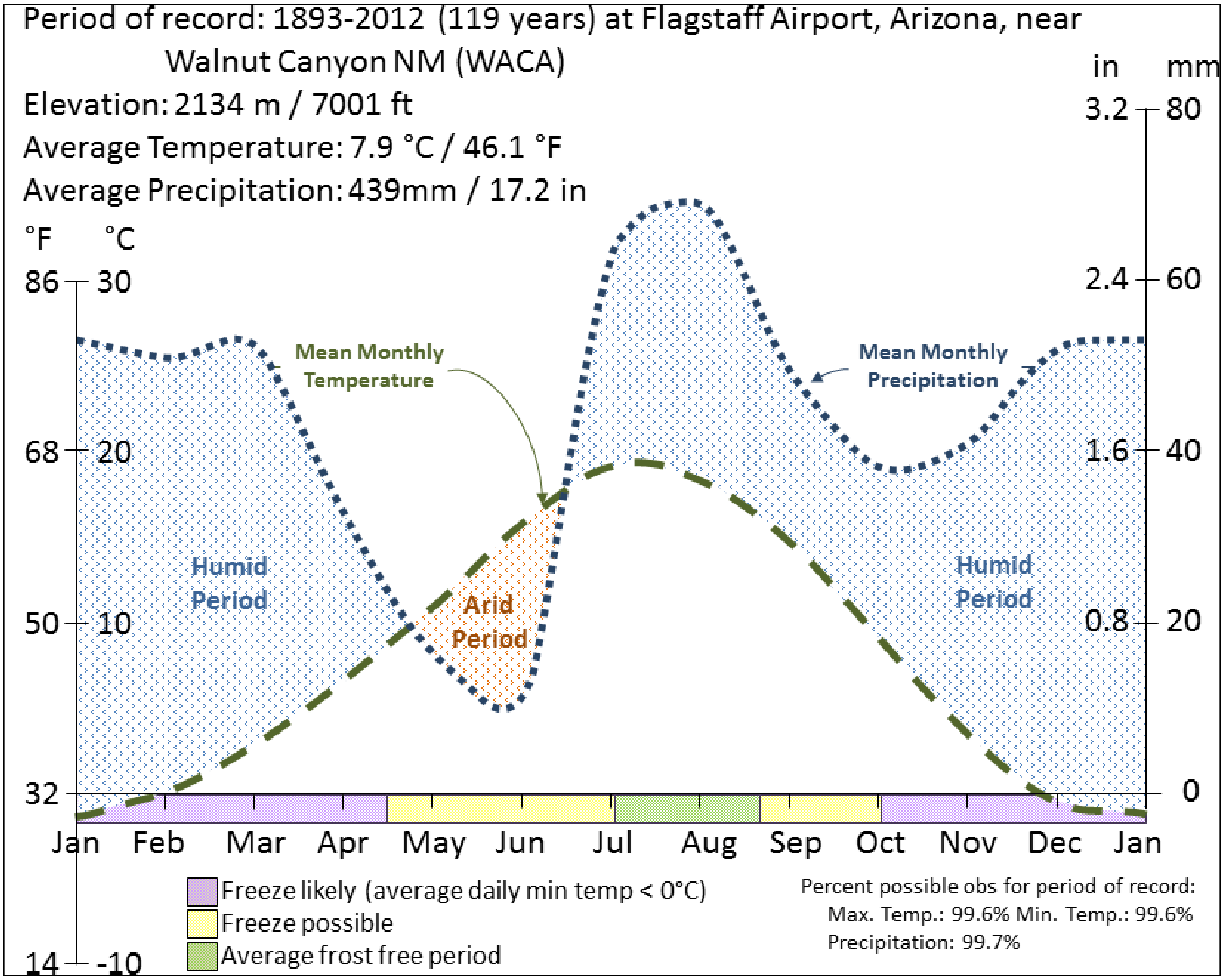


Figure 2.1.2-3. Average precipitation and temperature near Walnut Canyon NM (1893-2012). Figure Credit: NPS SCPN (2017a).

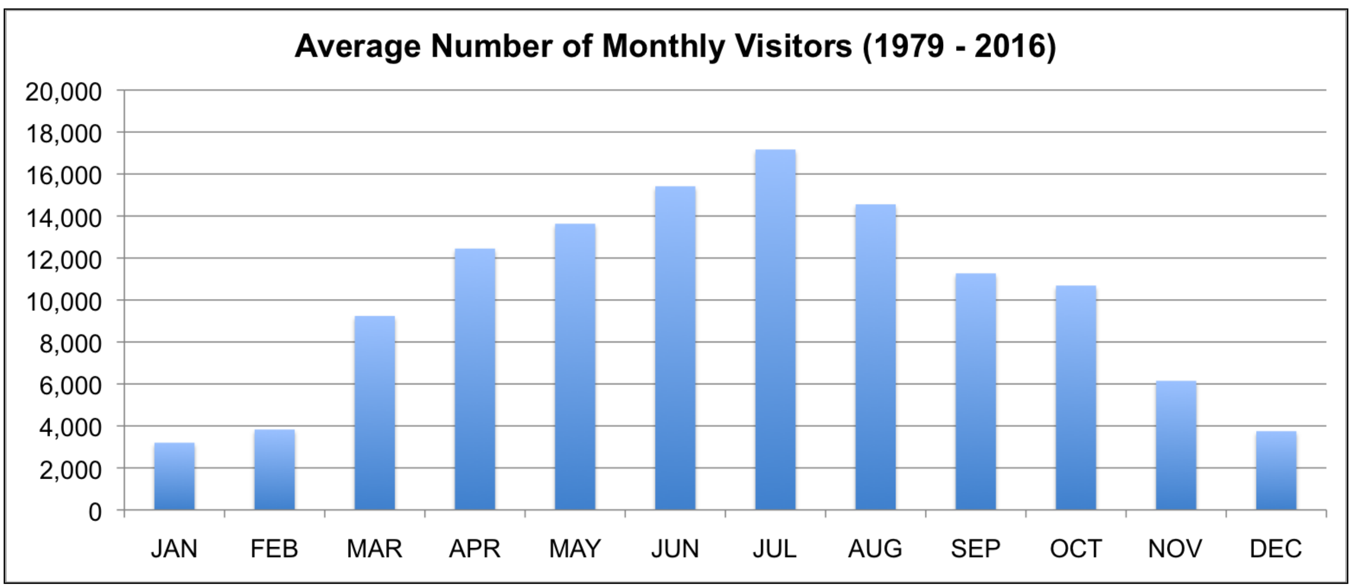


Figure 2.1.3-1. Average number of visitors by month to Walnut Canyon NM from 1979-2016.

2.2.1. Ecological Units, Watersheds, and NPScape Landscape-scale

Ecological Units

Walnut Canyon NM is located in the Colorado Plateau Ecoregion, which includes portions of Arizona, Utah, Colorado, and New Mexico. The entire area encompasses 9.3 million ha (22.9 million ac) and is characterized by desert scrub and shrublands. Elevations reach as high as 2,804 m (9,200 ft) throughout the ecoregion. The elevation at Walnut Canyon NM ranges between 1,896–2,106 m (6,220 to 6,910 ft) and spans the Semi-Desert Grassland/Shrub Steppe, Pinyon-Juniper Woodland and Ponderosa Pine Forest life zones (Figure 2.2.1-1) NPS SCPN 2017b). The canyon, which is the major geologic feature at the monument, is 122 m (400 ft) deep and 0.4 km (0.25 mi) wide (NPS 1996).

Watershed Units

The national monument is located primarily within the Cherry Canyon-Walnut Creek watershed, which covers a total area of 114.6 km² (28,330 ac) (U.S. Geological Survey [USGS 2014]), of which 8% is occupied by the monument. The monument's northeastern boundary occupies 5.4% of the 67.3 km² (16,622 ac) Porcupine Canyon - Walnut Creek watershed, and it's northern extension occupies 1.1% of the 139.2 km² (34,397 ac) Upper San Francisco Wash (Figure 2.2.1-2).

NPScape Landscape-scale

Most of Walnut Canyon NM's natural resources (e.g., viewshed, night sky, water resources, vegetation, wildlife, etc.) are affected by landscape-scale processes, and this broader perspective can provide more comprehensive information to better understand

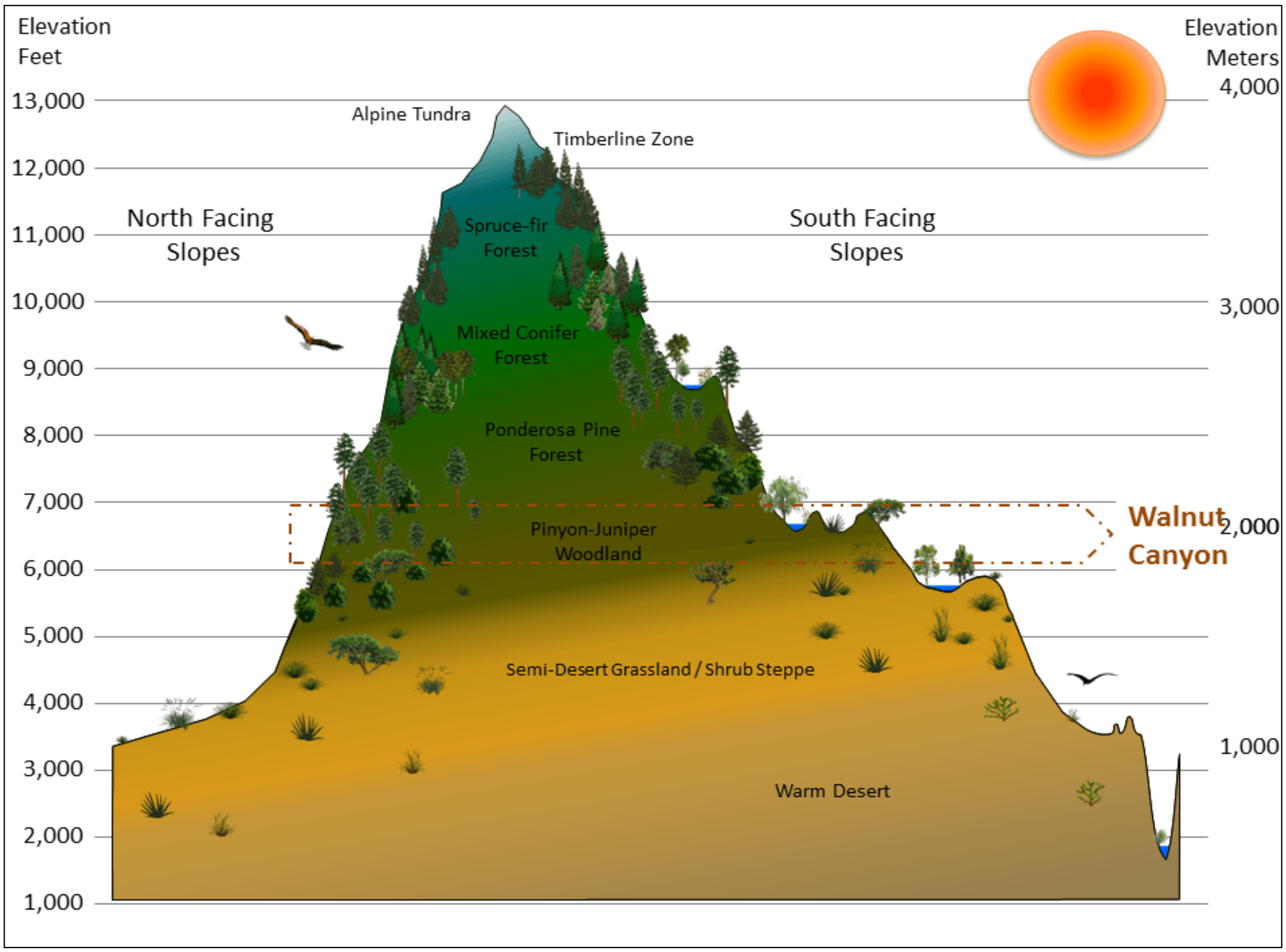


Figure 2.2.1-1. Walnut Canyon NM spans three life zones. Figure Credit: NPS SCPN (2017b).

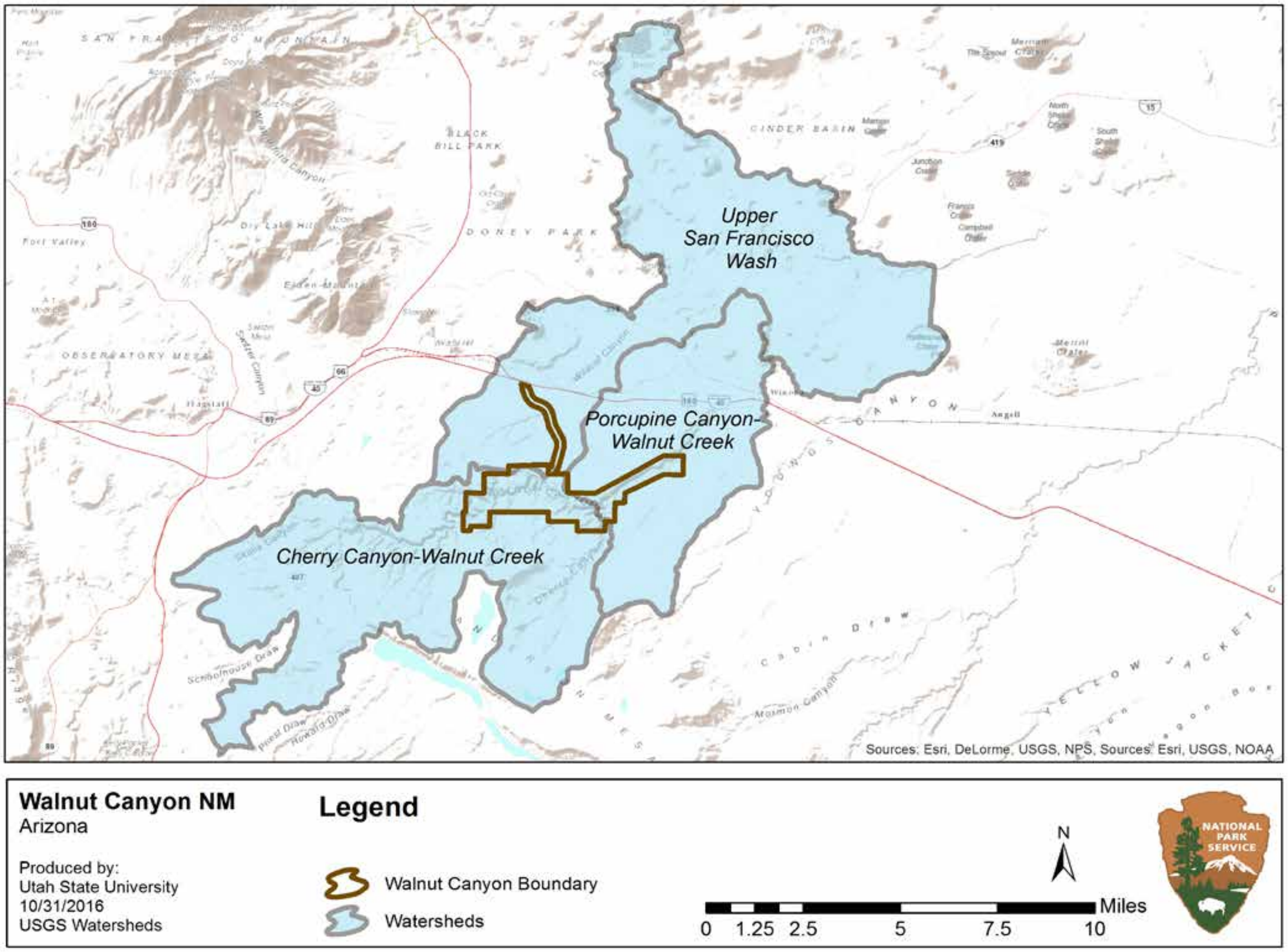


Figure 2.2.1-2. Walnut Canyon NM is located within three watersheds. The entrance road to Walnut Canyon NM is not included within the boundaries of the monument. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction. Figure Credit: NPS.

resource conditions throughout the monument. Studies have shown that natural resources rely upon the larger, surrounding area to support their life cycles (Coggins 1987 as cited in Monahan et al. 2012), and most parks are not large enough to encompass self-contained ecosystems for the resources found within their boundaries. This is especially important to Walnut Canyon's natural resources due to the increasing population and developments surrounding Flagstaff, AZ that continue to fragment what is currently intact natural areas. Where feasible, landscape-scale indicators and measures were included in the condition assessments to provide an ecologically relevant, landscape-scale context for reporting resource conditions. NPS NPScape metrics were used to report on these resource conditions, providing a framework for conceptualizing human effects (e.g., housing densities, road densities, etc.) on landscapes (NPS 2014a,b). A broader perspective of habitat and resource connectivity for selected wildlife species was evaluated and presented in Chapter 5 of this report.

2.2.2. Resource Descriptions

The monument supports high plant and animal diversity, with the steep gradient of the canyon creating an environment for the intermingling of plant species that would not normally occur together. Species such as mountain lions (*Puma concolor*), Mexican spotted owls (*Strix occidentalis lucida*), and black bears (*Ursus americanus*), in addition to many other types of wildlife including reptiles and frogs, inhabit these various plant community types (NPS 2015a). The cultural and natural resources found within the monument coupled with its close proximity to the city of Flagstaff provides an opportunity to link culture and 'sense of place' for local citizens and visitors.

Viewshed

Viewsheds are considered an important part of the visitor experience at national parks and features on the visible landscape influence the enjoyment, appreciation, and understanding of parks. Areas throughout Walnut Canyon NM are closed to visitors but scenic vistas of coniferous forests and cliff dwellings can easily been seen along the Rim Trail, which is open to the public. Since most of Walnut Canyon NM is surrounded by the USFS Coconino National Forest, much of the surrounding landscape is currently undeveloped.

Night Sky

Dark night skies are considered an aesthetic in national parks and offer an experiential quality that is also integral to natural and cultural resources (Moore et al. 2013). Historically, American Indian's observation of the sun, moon and stars was essential for planning festivals and activities such as when to start planting and when to harvest (Aveni 2003). In an estimated 20 national parks, stargazing events are the most popular ranger-led program (NPS 2010a). But the values of night skies go far beyond visitor experience and scenery. The photic environment affects a broad range of species, is integral to ecosystems, and is a natural physical process (Moore et al. 2013). In 2016, Walnut Canyon NM was designated an International Dark Sky Park by the International Dark Sky Association (IDA), a non-profit organization dedicated to preserving dark night skies around the world (IDA 2016). In addition, the city of Flagstaff, AZ was designated as the world's first International Dark Sky Community due to its progressive outdoor lighting policy enacted in 1958— the world's first outdoor lighting ordinance (IDA 2016).

The NPS Natural Sounds and Night Skies Division (NSNSD) scientists conducted an assessment of Walnut Canyon NM's night sky condition from the monument's Rim Trail's east overlook on May 12, 2002, June 18, 2004, October 6, 2004, and March 13, 2012. The results were used to evaluate the night sky condition at Walnut Canyon NM and to support the IDA application (NPS 2016a).

Soundscape

According to a majority of members of the American public surveyed, opportunities to experience natural quiet and the sounds of nature is an important reason for having national parks (Haas and Wakefield 1998). Baseline acoustical monitoring data for Walnut Canyon NM were collected by park natural resource staff. The National Transportation Systems Center (Volpe Center) analyzed the data and produced the report (NPS 2013), which was coordinated as part of a technical assistance request with the NPS NSNSD. These data, along with results from a sound model developed by Mennitt et al. (2013), were used to evaluate the soundscape condition at the monument.

Air Quality

Two categories of air quality areas (Class I and II) have been established through the authority of the Clean Air Act of 1970 (42 U.S.C. §7401 et seq. (1970)). Like most National Park Service areas, Walnut Canyon NM is designated as a Class II airshed. No air quality monitoring stations are located within the required distances to derive trends for ozone or atmospheric deposition within the monument, however, there is a visibility monitor (SYCA1, AZ) nearby from which to derive trend for haze and clear days. To date, 13 plants in the national monument are known to be ozone sensitive species (Bell in review, Kohut 2004).

Water Resources

In Walnut Canyon NM the major riparian corridor of Walnut Creek meanders from west to east through 13 km (8 mi) of Kaibab Limestone and Coconino Sandstone (Graham 2008). The hydrology, vegetation, and erosion/deposition processes have been altered due to the construction of three dams that were built between 1885 and 1941 (Soles and Monroe 2012). Since then regular water flows do not occur to support the natural processes necessary to maintain the vegetation complex, including Arizona walnut (*Juglans major*) and boxelder (*Acer negundo*) as well as the natural floodplain and channel characteristics.

Cherry Creek is a major drainage to Walnut Creek in the monument (Graham 2008). Water flows in Cherry Creek through Cherry Canyon in response to spring snowmelt and summer rainstorms (Soles and Monroe 2012). In wet years, water may flow from fractures or bedding planes in the canyon walls as a result of groundwater recharge from local precipitation. These wet areas often support hanging gardens. The main water resource in Cherry Canyon is a reach approximately 125 m (410 ft) long where pools occur in natural depressions or small basins formed by erosion of the porous Coconino Sandstone (Holton 2007). These naturally occurring pools are a rare but critically important resource for wildlife and plants in the monument

Vegetation

Coniferous forest and woodland vegetation dominate Walnut Canyon NM, with ponderosa pine (*Pinus ponderosa*) forest and pinyon-juniper woodland comprising about half of the monument's acreage (NPS 2009a). Ponderosa pine dominates the canyon rim terraces on the western half of the monument, and towards the eastern portion of the monument, the vegetation transitions into pinyon-juniper woodland and grassland. The south-facing slopes of the canyon are more exposed to the wind and sun, and they are dominated by scattered pinyon pine (*Pinus edulis*) and Utah juniper (*Juniperus osteosperma*) trees with a variety of shrubs, herbaceous species, and succulents in the understory. The more shaded and moist north-facing canyon slopes and tributary canyons are dominated by Douglas-fir-Gambel oak habitat (*Pseudotsuga menziesii-Quercus gambelii*). The canyon bottom and the south-side tributary canyons contain deciduous riparian vegetation. The creek bottom formerly maintained an open riparian area that was dominated by riparian-obligate species, including willow (*Salix spp*.), redosier dogwood (*Cornus sericea*), and narrow-leaf cottonwood (*Populus angustifolia*). Today, stands of box elder and Arizona walnut dominate the riparian corridor.

Wildlife

Birds

Several general bird surveys have been conducted throughout the monument and in targeted habitats in addition to raptor species-specific surveys, including the Mexican spotted owl, northern goshawk (*Accipiter gentilis*), peregrine falcon (*Falco peregrinus*), golden eagle (*Aquila chrysaetos*), and great horned owl (*Bubo virginianus*). A total of 121 bird species have been recorded at Walnut Canyon NM or otherwise appear on the NPSpecies list for the monument (NPS 2016b). The high number of bird species is due to the diversity of plant communities and the variety of geological and physical features present (Haldeman and Clark 1969). Ledges, holes, and recesses in and on the canyon walls provide nesting sites for some of these species (Haldeman and Clark 1969). Most of the monument occurs within federally-designated critical habitat for the Mexican spotted owl, providing the necessary protection for its recovery.

Amphibians and Reptiles

A total of 14 amphibians and reptiles have been recorded at Walnut Canyon NM. Species listed by Persons and Nowak (2006) were those recorded by

Garter snakes in Walnut Canyon's Cherry pool. Photo Credit: NPS.

their field sampling efforts (in 2001-2003) and others' past, reliable observations or specimens (refer to Appendix A for a species list). No non-native species have been observed. The list of amphibian and reptile species was compared with lists of federally threatened and endangered species and those of Greatest Conservation Need in Arizona (Arizona Game and Fish Department [AGFD] 2012), but no species were identified.

Mammals
The most recently conducted survey of mammals in the national monument was that by Drost (2009) during field work in 2002-2004 and based on his review of museum data and other sources. In addition, Walnut Canyon's NPSpecies (2016b) list of mammals along with Drost's (2009) recordings documented a total of 58 species, with two representing non-natives (refer to Appendix A for a species list). The monument's list of mammal species was compared with lists of federally threatened and endangered species and those of Greatest Conservation Need in Arizona (AGFD 2012). Eight species are on the SGCN list, although none of the species are federally-listed as endangered or threatened.

2.2.3. Resource Issues Overview

Climate Change

Like many places, the Southwest is already experiencing the impacts of climate change, and the Southern Colorado Plateau is vulnerable to the impacts of climate change due to its semi-arid climate. The predictions are that the Southwest will likely continue to become warmer and drier with continued climate change (Garfin et al. 2014, Monahan and Fisichelli 2014). According to Kunkel et al. (2013), the historical climate trends (1895-2011) for the southwest (including the states of Arizona, California, Colorado, Nevada, New Mexico, and Utah) have already experienced an average annual temperature increase of 0.9°C (greatest in winter months) and more than double the number of four-day periods of extreme heat. Future climate predictions (Kunkel et al. 2013) for 2070-2099 (based on climate patterns from 1971-1999) estimate temperatures could rise between 2.5°C and 4.7°C.

In addition, Monahan and Fisichelli (2014) assessed the magnitude and direction of changes in climate for Walnut Canyon for 25 variables including temperature and precipitation between 1901-2012 (historical range of variability (HRV)). Results for extreme climate were defined as experiencing either <5th percentile or >95th percentile relative to the HRV. The results for the extreme climate variables at Walnut Canyon NM were as follows:

- Three temperature variables were "extreme warm" (annual mean temperature, mean temperature of the warmest quarter, and mean temperature of the coldest quarter).
- No temperature variables were "extreme cold."
- Three precipitation variables were "extreme dry" (annual precipitation, precipitation of the driest month, precipitation of the driest quarter).
- No precipitation variables were "extreme wet"(brief can be accessed at (http://science.nature.nps.gov/climatechange/?tab=0&CEtab=3&PanelBrief3=open#PanelBrief).

The 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 2.2.3-1. 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 decade on record. Garfin et al. (2014) expects more sustained extreme heat and fewer and less extreme cold periods. Overall, it's likely that future climate change will increasingly affect all aspects of the monument's resources and operations (Monahan and Fisichelli 2014).

Prein et al. (2016) report that the western U.S., and especially the Southwest, has experienced increasing temperatures and decreasing rainfall. Since 1974 there has been a 25% decrease in precipitation; however, this is a trend that is partially counteracted by increasing precipitation intensity (Prein et al. 2016). Streams in semiarid regions, such as Walnut Creek, are especially sensitive to changes in precipitation and runoff (Cooper et al. 2012), and climate change may influence the amount of water available for stream flow.

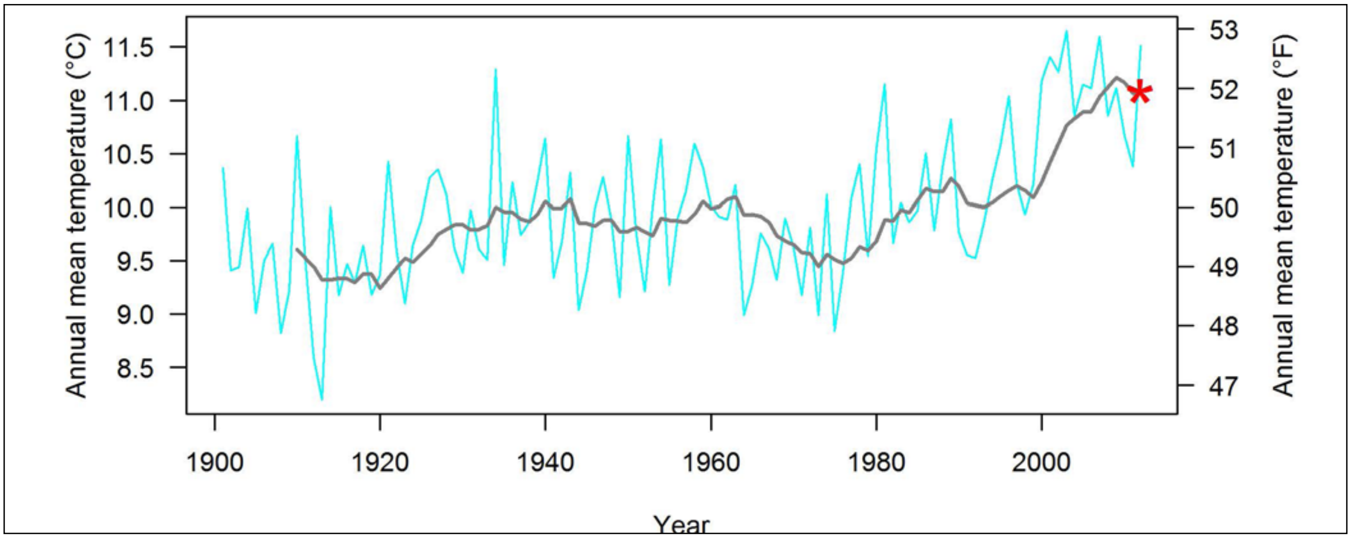


Figure 2.2.3-1. Time series used to characterize the historical range of variability and most recent percentile for annual mean temperature at Walnut Canyon NM (including areas within 30-km [18.6-mi] of the park's boundary). Figure Credit: Monahan and Fisichelli (2014).

Much damage to Walnut Creek has already occurred and is a direct result of diversion of 90% of the water flowing within Walnut Creek upstream of the monument (Rowlands et al. 1995). Stream flow is rare and the plant community has transitioned from one that was historically dominated by riparian obligate species to one that is now dominated by upland species. Furthermore, several non-native species have invaded the riparian corridor, and stream channel pools that once provided habitat for aquatic invertebrates and amphibians have been filled in by sediments and vegetation in the absence of scouring floods (Holton 2007, Soles and Monroe 2012).

In addition to the effects of decreased precipitation on water availability, climate change also has the potential to alter fire regimes, which in turn, can affect water health through increased sedimentation, changes in water chemistry due to ash inputs, and loss of overhead vegetation (Earl and Blinn 2003, Moody and Martin 2009, Scott et al. 2005). In the southwest, fire frequency and severity has increased after decades of fire suppression (Abatzoglou and Williams 2016). An increase in severe-fire events in the southwest may result in increased runoff of sediment (Moody and Martin 2009), which has the potential to fill in pools and eliminate the macroinvertebrate community and canyon treefrog (*Hyla arenicolor*) population. Ash deposition can also affect water quality, at least temporarily (Scott et al. 2005).

Uncontrolled or severe wildfire is also one of the main threats to ponderosa pine forests within Walnut Canyon NM and the region. Additional threats include drought, bark beetle infestations, and an overarching threat from climate change. These are threats to all trees and ecosystem components within the forest, but they may be of particular concern for older, larger ponderosa pine trees. Of all the stressors on native vegetation, climate change has the most potential to influence community composition, vegetation structure, and species richness (Schweiger et al. 2010). Climate change can also influence the spread of invasive plants (Hellmann et al. 2008). While access in much of Walnut Canyon is restricted, the monument is a small, highly linear park, which increases the monument's susceptibility to invasion by non-native species (Hiebert and Hudson 2010), especially since introductions and spreading of invasive plants is known to occur along road corridors, trails, and other types of disturbances. Currently, the highest number and cover of non-native species is found in Walnut Canyon NM's high use areas compared to the Resource Preservation Zone (Hiebert and Hudson 2010).

Walnut Canyon NM's visitation has been increasing, and it is also transitioning into an exurban park due to the population growth and associated developments surrounding the monument. Noise from Interstate 40 is nearly constant and can be heard from anywhere in the monument (NPS 1996). Currently, an estimated 1,866 to 5,215 vehicles travel along Interstate 40 corridor every hour (NPS 2013), and traffic volume is likely to increase as the population of Flagstaff, AZ rises. Approximately 70,320 people live in Flagstaff as of July 1, 2015 (U.S. Census Bureau 2016b), and the population is expected to continue to increase (U.S. Census Bureau 2016b). One of the more recent developments near the monument is the Northern Arizona Shooting Range. At present, noise form the range is considered to be one of the greatest threats to the Mexican spotted owl. Hearing is a critical sense for birds and other wildlife, and their ability to hear is vital in activities such as courtship, predation, predator avoidance, and effective use of habitat. Studies have found that wildlife can be adversely affected by intrusive sounds, although the extent to which impacts occur varies depending on the species and other factors. However, as development continues to expand around Walnut Canyon NM, its likely that currently intact habitat for many species will become increasingly fragmented, possibly isolating or extirpating populations.

2.3. Resource Stewardship

2.3.1. Management Directives and Planning Guidance

In addition to NPS staff input based on the park'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 Southern Colorado Plateau Inventory and Monitoring (I&M) Network (SCPN) Program, I&M NPScape Program for landscape-scale measures, Air Resources Division for air quality, and the Natural Sounds and Night Skies Program for the soundscape and night sky sections.

SCPN I&M Program

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 2011a). 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 2011a).

To facilitate this effort, 270 parks with significant natural resources were organized into 32 regional networks. Walnut Canyon NM is part of the SCPN, which includes 18 additional parks. Through a rigorous multi-year, interdisciplinary scoping process, SCPN 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. Walnut Canyon integrated upland ecosystems, integrated riparian, and land surface phenology were selected for monitoring by SCPN (NPS SCPN 2014).

Park Planning Reports

Natural Resource Condition Assessments

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 2.3.1-1).

Foundation Document

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 Walnut Canyon NM in 2015 and was used to identify some of the primary natural features for the development of the NRCA.

Figure 2.3.1-1. The relationship of NRCAs to other National Park Service planning reports.

State of the Park
A State of the Park (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 Chapter 4 assessment includes a SotP condition summary.

Resource Stewardship Strategy
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.

2.3.2. Status of Supporting Science
Available data and reports varied depending upon the resource topic. The existing data used to assess condition of each indicator and/or to develop reference conditions are described in each of the Chapter 4 assessments. In addition to the data obtained from the SCPN I&M and research conducted by other scientists and programs, subject matter experts, Joel Wagner and Mike Martin, with the NPS Water Resources Division, and Christine Taliga, NPS/Natural Resources Conservation Service liaison, provided technical assistance for the Walnut Creek riparian area during a September 2016 field assessment. Additional Washington level programs, including I&M NPScape, Climate Change Response Program, Natural Sounds and Night Skies, and Air Resources, Divisions provided information to assess the monument's resource conditions.

Flagstaff Area National Monuments' NRCA scoping meeting was held on May 17-19, 2016. Photo Credit: NPS.

Chapter 3. Study Scoping and Design

Walnut Canyon National Monument (NM) Natural Resource Condition Assessment (NRCA) was coordinated by the National Park Service (NPS) Intermountain Region Office, Utah State University, and the Colorado Plateau Cooperative Ecosystem Studies Unit through task agreements, P14AC00749 and P15AC01212.

The NRCA process was a collaborative effort between the Flagstaff Area NMs' (Walnut Canyon, Wupatki, and Sunset Crater Volcano) staff, Southern Colorado Plateau Inventory and Monitoring Network staff, Intermountain Region NRCA Coordinator, and the NRCA team from Utah State University. Michael Martin and Joel Wagner, with the NPS Water Resources Division, were selected as subject matter experts for a rapid field assessment of Walnut Creek riparian corridor, which will be conducted in September 2016.

3.1. Preliminary Scoping

Preliminary scoping for Walnut Canyon NM's NRCA project began in March 2015. Paul Whitefield, submitted a draft list of natural resource topics based on the 'key [natural] resources and values identified in the park's Foundation document (NPS 2015a) and General Management Plan (NPS 2002). Paul Whitefield and Michael Jones, Flagstaff Area NMs' GIS Specialist, compiled reports and data sets pertaining to the preliminary list of natural resources, and Donna Shorrock, NPS IMR NRCA Coordinator (former) facilitated the process of uploading the park's information to USU's ftp site. Science writers from USU reviewed these reports and data sets and developed draft indicators, measures, and reference conditions, which served as the primary discussion guide during the on-site NRCA scoping workshop.

The workshop was held over a three day period from May 17-19, 2016 at the Flagstaff Area NMs' headquarters in Flagstaff, Arizona. The initial list of natural resource topics submitted by the park were reviewed, discussed, and refined by scoping workshop attendees (listed in Appendix B). Through discussions, meeting participants reviewed and refined the draft indicators, measures, and reference conditions for each resource topic. Some topics were omitted and some key resources were identified and selected as focal resources for the condition assessment. Additional data sets and reports were identified and were incorporated into the revised assessment approach. Park staff also identified important concerns, issues/stressors, and data gaps for each natural resource topic.

The final list of selected natural resources and their associated indicators, measures, threats/stressors, and data gaps are discussed in each Chapter 4 assessment.

3.2. Study Design

3.2.1. Indicator Framework, Focal Study Resources and Indicators

Walnut Canyon NM's NRCA utilizes the NPS Inventory & Monitoring (I&M) Program's "NPS Ecological Monitoring Framework" (NPS 2005). This framework was endorsed by the National NRCA Program as an appropriate framework for listing resource components, indicators/measures, and resource conditions. Additionally, Flagstaff Area National Monuments' natural resource files, Southern Colorado Plateau Inventory and Monitoring Network's (SCPN) Vital Signs Plan (Thomas et al. 2006), and the RM-77 NPS Natural Resource Management Guideline (NPS 2004a) are all organized similarly to the I&M framework.

Each NRCA report represents a unique assessment of key natural resource topics that are important to each park. For the purposes of Walnut Canyon NM's NRCA, 10 focal resources were selected for assessment, which are listed in Tables 3.2.1-1 -3.2.1-4. This list of resources does not include every natural resource at the park, but represents the natural resources and processes that were of greatest significance to park staff at the time of this effort. Each resource's threats and stressors were discussed and are presented in Table 3.2.1-5. Additional resources considered important, but listed as data gaps, are presented in Table 3.2.1-6.

Staff gave thought to identifying focal resource topics which have been consistently identified in legacy planning documents and literature, possess knowledge bases that are sufficient for establishing baseline condition, are indicative of overall ecologic and biotic integrity, have also been identified by stakeholders as focal resources on adjacent lands, or where resource trend may be increasingly understood as the NPS SCPN progresses with vital signs monitoring (Thomas et al. 2006). Staff were also interested in including some focal resources which may be vulnerable to degradation and possible loss due to climate change.

Reference conditions were identified with the intent of providing a benchmark to which the current condition of each indicator/measure could be compared using existing research and documentation. When a quantifiable reference for a given measure was not feasible, an attempt was made to include a qualitative reference to provide some context for interpreting current resource condition.

Table 3.2-1-1. Walnut Canyon NM natural resource condition assessment framework based on the NPS Inventory & Monitoring Program's Ecological Monitoring Framework for landscapes patterns and processes.

Resource	Indicators	Measures
Viewshed	Scenic and Historic Integrity	Conspicuousness of Non-contributing Features
	Scenic and Historic Integrity	Extent of Development
Night Sky	Sky Brightness	All-sky Light Pollution Ratio
	Sky Brightness	Vertical Maximum Illuminance
	Sky Brightness	Horizontal Illuminance
	Sky Brightness	Zenith Sky Brightness
	Sky Quality	Bortle Dark Sky Scale
Soundscape	Sound Level	% Time Above Reference Sound Levels
	Sound Level	% Reduction in Listening Area
	Audibility of Anthropogenic Sounds	% Time Audible
	Geospatial Model	L_{50} Impact

Table 3.2.1-2. Walnut Canyon NM natural resource condition assessment framework based on the NPS Inventory & Monitoring Program's Ecological Monitoring Framework for air and climate.

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

3.2.2. Reporting Areas

The primary focus of the reporting area was within the national monument's legislative boundary; however,

Table 3.2.1-3. Walnut Canyon NM natural resource condition assessment framework based on the NPS Inventory & Monitoring Program's Ecological Monitoring Framework for water.

Resource	Indicators	Measures
Cherry Pools in Cherry Canyon	Water Quantity & Availability	Stream Flow
	Water Quantity & Availability	Persistence of Pooled Water
	Water Quality	Core Water Parameters, Inorganic Chemicals, and Uranium
	Biodiversity	Plants
	Biodiversity	Invertebrates
	Biodiversity	Birds
	Biodiversity	Mammals
	Biodiversity	Herpetofauna
Walnut Creek Riparian Area	Water Quantity and Availability	Stream Flow (timing, duration, and magnitude)
	Vegetation Change	Importance Value for Herbaceous/Shrub Layer
	Vegetation Change	Boxelder Age-class Structure
	Vegetation Change	Narrowleaf Cottonwood Age-class Structure
	Vegetation Change	Arizona Walnut Age-class Structure
	Status of Arizona Walnut	Population Size and Extent
	Status of Arizona Walnut	Age-Class Distribution
	Status of Arizona Walnut	Vigor
	Status of Arizona Walnut	Genetic Diversity
	Hydrology	Floodplain
	Hydrology	Sinuosity, Width/Depth Ratio, and Gradient
	Hydrology	Riparian-Wetland Area
	Hydrology	Upland Watershed Contribution
	Vegetation	Age-Class Distribution
	Vegetation	Overall Community Composition
	Vegetation	Wetland Plant Status
	Vegetation	Streambank Community Composition
	Vegetation	Vigor
	Vegetation	Cover

Table 3.2.1-3 continued. Walnut Canyon NM natural resource condition assessment framework based on the NPS Inventory & Monitoring Program's Ecological Monitoring Framework for water.

Resource	Indicators	Measures
Walnut Creek Riparian Area *continued*	Erosion/Deposition	Floodplain and Channel Characteristics
	Erosion/Deposition	Point Bar Vegetation
	Erosion/Deposition	Lateral Stream Movement
	Erosion/Deposition	Vertical Stability of Stream Channel
	Erosion/Deposition	Water/Sediment Balance

Table 3.2.1-4. Walnut Canyon NM natural resource condition assessment framework based on the NPS Inventory & Monitoring Program's Ecological Monitoring Framework for biological integrity.

Resource	Indicators	Measures
Ponderosa Pine Forest	Fire Regime	Departure from Natural Historical Fire Regime
	Stand Structure	Stem Densities by Size Class
	Stand Structure	Presence and Persistence of Large Trees
	Status / Health of Trees	Extent/Proportion of Conifer Mortality
	Presence & Composition of Understory Vegetation & Soil Surface Features	Functional Group Cover
	Presence & Composition of Understory Vegetation & Soil Surface Features	Species Cover & Frequency
	Presence & Composition of Understory Vegetation & Soil Surface Features	Soil Surface Features Cover
Non-native Invasive Plants	Potential to Alter Native Plant Communities	NatureServe Invasive Species Impact Rank
	Potential to Alter Native Plant Communities	AZ-WIPWG Ecological Impact Rank
	Prevalence	Overall Frequency
	Prevalence	Overall Cover
	Prevalence	Frequency by Habitat Type and Area

Table 3.2.1-4 continued. Walnut Canyon NM natural resource condition assessment framework based on the NPS Inventory & Monitoring Program's Ecological Monitoring Framework for biological integrity.

Resource	Indicators	Measures
Non-native Plants *continued*	Prevalence	Cover by Habitat Type and Area
	Control Effort	Non-native Plants Removed
Birds	Species Occurrence	Presence/Absence
	Species Occurrence	Presence of Species of Conservation Concern
	Status of Selected Species	Northern Goshawk
	Status of Selected Species	Peregrine Falcon
	Status of Selected Species	Golden Eagle
Mexican Spotted Owl and Inner Canyon Environment	Species Occurrence	Number of Adult MSO Pairs Exhibiting Territorial Occupancy
	Status/Condition of MSO Habitat: Douglas-fir-Gambel oak	Total Area/Cover of Douglas fir-Gambel Oak Forest
	Status/Condition of MSO Habitat: Douglas-fir-Gambel oak	Minimum Tree Basal Area
	Status/Condition of MSO Habitat: Douglas-fir-Gambel oak	Minimum Density of Large Trees
	Level of Human Disturbance	Occurrence/level of Potentially-disturbing Activities and Noise in MSO Habitat

some of the analyses encompassed areas beyond the park's boundary. For example, the entrance road to Walnut Canyon NM is not included within the boundaries of the monument. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction.

Natural resources assessed at the landscape level included viewshed, night sky, soundscape, and habitat connectivity. Data and reports for the night sky and soundscape assessments were provided by the NPS Natural Sounds and Night Skies Division. USU completed both the viewshed and habitat connectivity analyses, augmenting condition reporting using the NPS NPScape Program data sets and Area of Analysis for the viewshed and 30-km boundaries (NPS 2015b). The Cherry Canyon - Walnut Creek watershed was the focus area for the watershed condition assessment for Cherry and Walnut Creeks. It encompasses a total area of 11,486 hectares/28,382.1 acres, 87% of which is located within Forest Service land and 8% (922 hectares/2,279 acres) is located within Walnut Canyon NM.

3.2.3. General Approach and Methods

The general approach to developing the condition assessments included reviewing literature and data and/or speaking to subject matter expert(s) for each of the focal resource topics, and when applicable, analyzing existing data to provide new interpretations for condition reporting. Following the NPS NRCA guidelines (NPS 2010b), each Chapter 4 assessment included six sections briefly described below.

The background and importance section of the NRCA report provided information regarding the relevance of the resource to the national monument using existing project proposals or descriptions previously developed by park staff for various planning documents.

The data and methods section of the assessment described the existing data sets and methodologies used for evaluating the indicators/measures for current condition.

The reference conditions section lists the good, moderate concern, and significant concern definitions used to evaluate the condition of each measure.

The condition and trend section provided a discussion of the condition and trend, if available, for each indicator/measure based on the reference condition(s). Condition icons were presented in a standard format consistent with *State of the Park* reporting (NPS 2012a) and serve as visual representations of condition/trend/level of confidence for each measure that was evaluated. Table 3.2.3-1 shows the condition/trend/confidence level scorecard used to describe the condition for each assessment, and Table 3.2.3-2 provides examples of conditions and associated interpretations.

Circle colors convey condition. Red circles signify that a resource is of significant concern; yellow circles

Table 3.2.1-5. Resource condition assessment topic threats and stressors.

Resource	Threats / Stressors / Data Gaps
Viewshed	• Regional development, associated light pollution - effects on most nocturnal species are not well understood
Night Sky	• New visitor activities (e.g., casinos)
	• Increasing dust and smog due to climate change
Soundscape	• Regional development and anthropogenic noises, including military airspace, with air traffic representing the most significant current threat
	• Effects of noise on most species are not well understood
Air Quality	• Increasing dust from various sources (e.g., local industry, USFS Forest-wide Materials Quarry, climate change, etc.)
	• USFS prescribed burns and increasing frequency of wildfires in the southwest
	• The Navajo Generating Station, Cholla Power Plant, and Coronado Generating Station are potential sources for air quality impacts.
	• Lack of vegetation monitoring for potential ozone impact
Cherry Pools in Cherry Canyon	• Climate change: reduced precipitation within the watershed will lower the amount of water available to recharge pools, and warmer temperatures will alter the timing of snowmelt.
	• Invertebrates sampled at Cherry Canyon pools were considered terrestrial but to date not all specimens have been identified to species
	• Unknown influence from groundwater
	• Impact from potential increased wildfires and associated sedimentation/ash pollution
	• Reduction or elimination of surface waters for wildlife and plants
Walnut Creek Riparian Area	• Climate change
	• Elimination of stream flow due to water manipulation (e.g., Lake Mary Dam)
	• Riparian area is dominated by upland species
	• Non-native species
	• Lack of scouring floods and wild leading to sedimentation and vegetation
	• Severe fires within the monument's watershed may impact erosion, patterns of sedimentation, and rill and gully formation
	• Exurban development within the Flagstaff city limit in the watershed below Lower Lake Mary may increase storm water run-off floods and non-point source pollution
	• Lack of geomorphic monitoring of the canyon bottom
Ponderosa Pine Forest	• Drought due to climate change
	• Bark beetle infestations
	• Uncontrolled or severe wildfire
Non-native and Invasive Plants	• Climate change has the most potential to influence community composition, vegetation structure, and species richness and to influence spread of invasive plants.
	• Spread via road corridors, trails, and disturbances
	• Disruption of natural processes including fire and periodic floods
	• Little is known about how or if fire suppression has influenced the occurrence and spread of non-native plants in the monument.
Birds	• Disturbance from shooting range
	• Loss of large, old trees due to pests/drought
	• Last group-wide surveys in 2009-2010 cover ponderosa pine and canyon riparian habitats only
	• Have data from nesting surveys for 2006-2016 but goshawk not surveyed in some years

Table 3.2.1-5 continued. Resource condition assessment topic threats and stressors.

Resource	Threats / Stressors / Data Gaps
Mexican Spotted Owl and Inner Canyon Environment	• Growth/development of nearby communities
	• Conifer mortality due to pests/drought
	• Risk of crown fire
	• Changes in riparian vegetation
	• Increases in outdoor recreation and associated anthropogenic noises (e.g., shooting range, visitors/ recreational activities, management activities). Park is conducting sound studies, but no results until 2017
	• Information on prey base
	• Currently, no data available on canopy cover change in MSO habitat (but it is being collected)

Table 3.2.1-6. Additional resource data gaps identified during scoping workshop.

Resource	Notes
Mammals	• Overpopulation of elk and impacts to mule deer; common issue region-wide, but no park specific information; Bandelier included it (example); could become an issue; include as a data gap rather than a threat; • Coati record from the 1960s and also caught on camera trap at Cherry Canyon more recently. • Mammal connectivity – data gap; Connectivity as a separate assessment
Herpetofauna	• Limited information for park

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

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

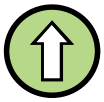
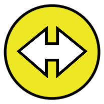
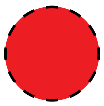
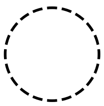
The level of confidence in the assessment ranges from high-low and is symbolized by the border around the condition circle. Key uncertainties and resource threats are also discussed in the condition and trend section for each resource topic.

The sources of expertise are individuals who were consulted and/or provided a review are listed in this

Table 3.2.3-1. 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 3.2.3-2. 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.

section, along with the writer(s) who drafted the assessment.

The literature cited section lists all of the referenced sources for the assessment. A DVD is included in the final report with copies of all literature cited unless the citation was from a book.

Chapter 4. Natural Resource Condition Assessments

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

Bottom of Walnut Canyon. Photo Credit: NPS.

4.1. Viewshed

4.1.1. Background and Importance

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

Visitor Experience

Viewsheds are considered an important part of the visitor experience at Walnut Canyon NM, and features on the visible landscape influence a visitor's enjoyment, appreciation, and understanding of the monument. These views represent much more than just scenery; they represent a way to better understand the connection between self and nature and between past and present cultures.

Inherent in virtually every aspect of this assessment is how features on the visible landscape influence the enjoyment, appreciation, and understanding of the monument by visitors. The indicators we use for condition of the viewshed are based on studies related to perceptions people hold toward various features and attributes of the viewsheds. We also focus on how the cultural integrity of the viewshed enhances the opportunity for visitors to better understand past cultures and their connection to modern Native American cultures in the region.

4.1.2. Data and Methods

The indicator and measures used in this assessment are based on studies related to perceptions people hold toward various features and attributes of scenic landscapes. In general, there is a wealth of research demonstrating that people tend to prefer natural landscapes over human-modified landscapes (Zube et al. 1982, Kaplan and Kaplan 1989, Sheppard 2001, Kearny et al. 2008, Han 2010). Human-altered components of the landscape (e.g., roads, buildings, power lines, and other features) that do not contribute to the natural scene are often perceived as detracting from the scenic character of a viewshed. Despite this

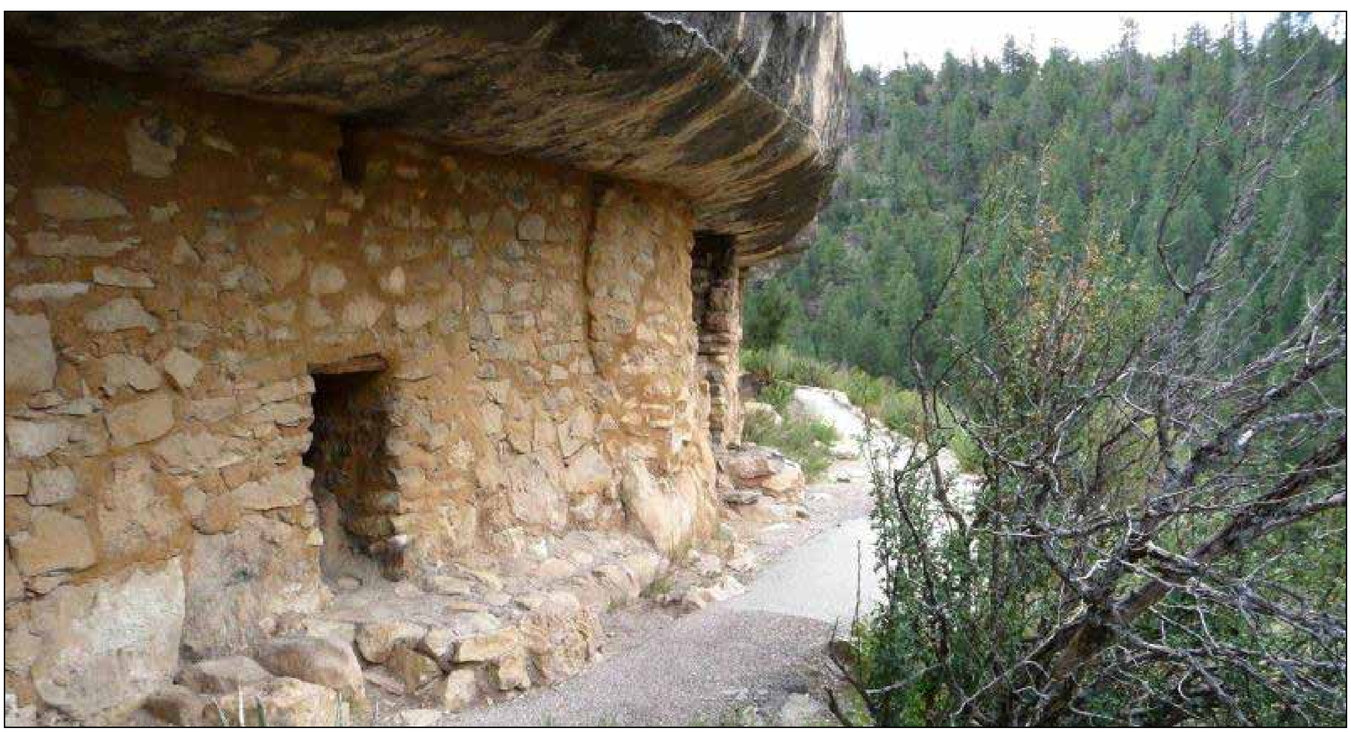


Figure 4.1.1-1. View of cliff dwellings in Walnut Canyon NM. Photo Credit: NPS.

generalization for natural landscape preferences, studies have also shown that not all human-made structures or features have the same impact on visitor preferences. Ancient cliff dwellings in Walnut Canyon NM for example, are considered to contribute to, rather than detract from, the monument's viewshed. Visitor preferences can be influenced by a variety of factors including cultural background, familiarity with the landscape, and their environmental values (Kaplan and Kaplan 1989, Virden and Walker 1999, Kaltenborn and Bjerke 2002, Kearney et al. 2008).

While we recognize that visitor perceptions of an altered landscape are highly subjective, and that there is no completely objective way to measure these perceptions, research has shown that there are certain landscape types and characteristics that people tend to prefer over others. Substantial research has demonstrated that human-made features on a landscape are perceived more positively when they are considered in harmony with the landscape (e.g., Kaplan and Kaplan 1989, Gobster 1999, Kearney et al. 2008).

Kearney et al. (2008) showed that survey respondents tended to prefer development that blended with the natural setting through use of colors, smaller scale, and vegetative screening. For example, cliff dwellings constructed during the 12th and 13th centuries, were constructed in alcoves eroded into the soft sandstone layers of the canyon walls (Graham 2008). These structures blend well with the natural environment and their presence is an integral part of the visitor experience in Walnut Canyon NM. These characteristics, along with distance from non-contributing features, and movement and noise associated with observable features on the landscape, are discussed below.

The indicator, scenic and historic integrity, is defined as the state of naturalness or, conversely, the state of disturbance created by human activities or alteration (U.S. Forest Service (USFS 1995). This aspect of the assessment focuses on the features of the landscape related to non-contributing human alteration/development. Because of the importance of Northern Sinagua culture to the establishment of the monument, we consider these landscape features to be contributing features.

Key Observation Points

Four key observation points were selected by park staff (Table 4.1.2-1, Figure 4.1.2-1) and were used to qualitatively evaluate viewshed condition using GigaPan panoramas and to quantitatively evaluate condition using viewshed analysis overlaid with NPScape housing and road densities. All of these locations include scenic views, but only one location is accessible to the public (Rim Trail). The remaining three locations (Breezy, Ranger Canyon, and Walnut East) are located within the Resource Preservation Zone. The Resource Preservation Zone is a 1,248 ha (3,085 ac) area that is closed to general public access in order to protect sensitive habitat and cultural resources (NPS 2007aa). This zone comprises 93% of the monument.

Conspicuousness of Non-Contributing Features

GigaPan Images

We used a series of panoramic images to portray the viewshed from an observer's perspective. These images were taken from each key observation point using a Canon PowerShot digital camera and the GigaPan Epic 100 system, a robotic camera mount coupled with stitching software (Figure 4.1.2-2).

A series of images were automatically captured and the individual photographs are stitched into a single high-resolution panoramic image using GigaPan Stitch software (http://www.omegabrandess.com/Gigapan). The GigaPan images provided a means of assessing the non-contributing features on the landscape and qualitatively evaluating the viewshed condition based on groups of characteristics of man-made features as follows: (1) distance from a given key observation point, (2) size, (3) color and shape, and (4) movement and noise. A general relationship between these characteristics and their influence on conspicuousness is presented in Table 4.1.2-2.

Table 4.1.2-1. Key observation points used to assess Walnut Canyon NM's viewshed condition.

Site Location	Image Date	Coordinates - Easting, Northing (UTM NAD83 12N)
Breezy	12/19/2016	451944/3892050
Ranger Canyon	12/19/2016	453164/3892341
Rim Trail	12/20/2016	453692/3892180
Walnut East	12/19/2016	458182/3892772

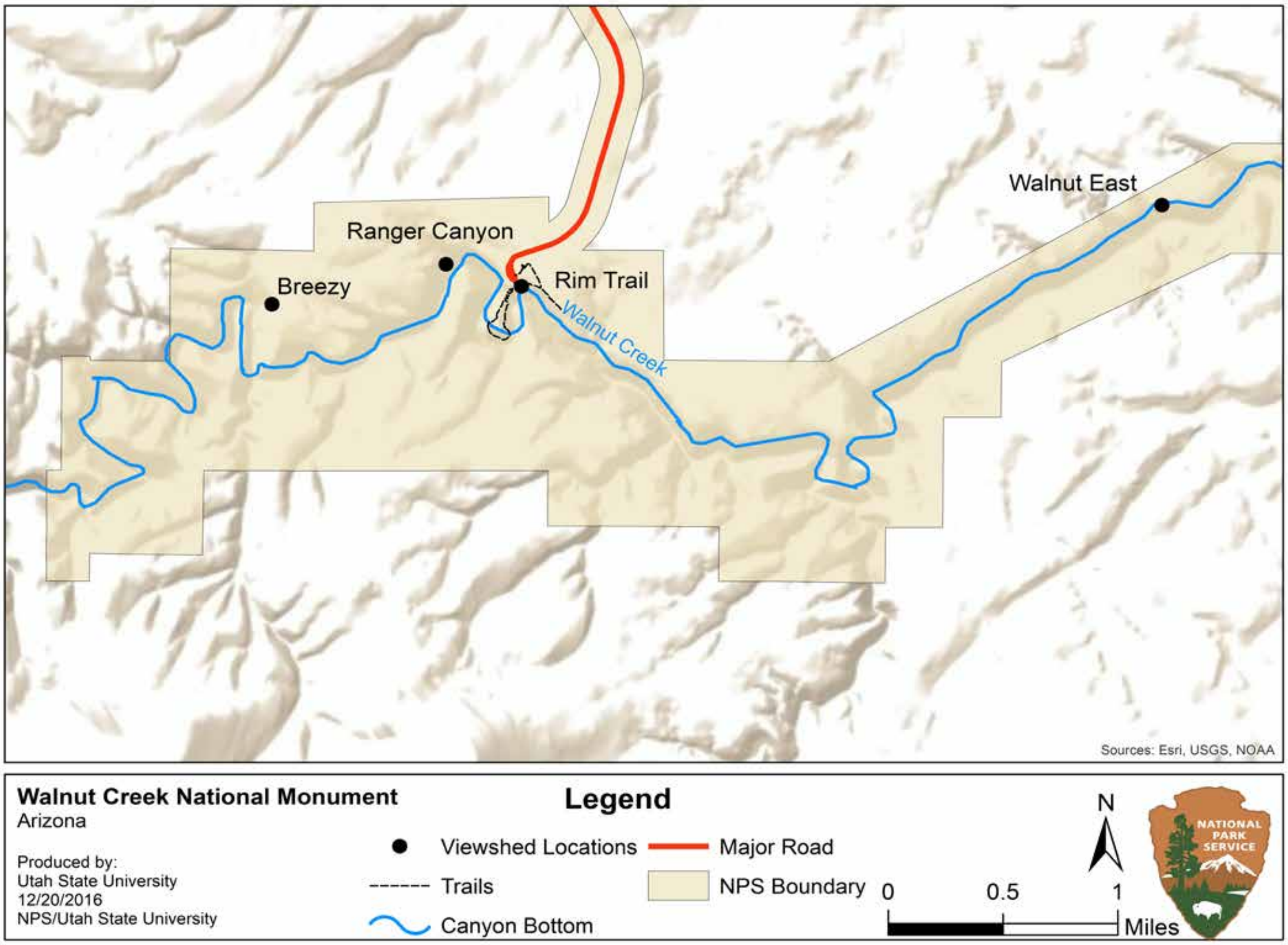


Figure 4.1.2-1. Locations of 2016 viewshed observation points at Walnut Canyon NM. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction.

Figure 4.1.2-2. The GigaPan system takes a series of images that are stitched together using software to create a single panoramic image.

Distance. The impact that individual human-made features have on perception is substantially influenced by the distance from the observer to the feature(s). Viewshed assessments using distance zones or classes often define three classes: foreground, middle ground, and background (Figure 4.1.2-3). For this assessment, we have used the distance classes that have been recently used by the NPS:

- *Foreground* = 0-½ mile from key observation point

Table 4.1.2-2. Characteristics that influence conspicuousness of human-made features.

Characteristic	Less Conspicuous	More Conspicuous
Distance	Distant from the observation point	Close to the observation point
Size	Small relative to the landscape	Large relative to the landscape
Color and Shape	Colors and shapes that blend into the landscape	Colors and shapes that contrast with the landscape
Movement and Noise	Lacking movement or noise	Exhibits obvious movement or noise

- *Middle ground* = ½-3 miles from key observation point
- *Background* = 3-60 miles from key observation point.

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

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

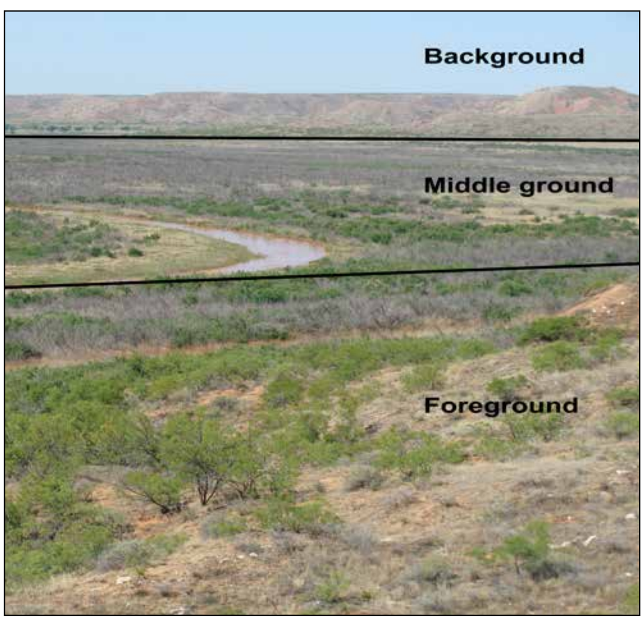


Figure 4.1.2-3. An example of foreground, middle ground, and background distance classes.

Size

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

We considered the features on the landscape surrounding Walnut Canyon NM as belonging to one of six size classes (Table 4.1.2-3), which reflect the

Table 4.1.2-3. Six size classes used for conspicuousness of human-made features.

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

preference groups reported by studies. Using some categories of perhaps mixed measures, we considered size classes within the context of height, volume, and length.

Color and Shape

Studies have shown that how people perceive a human-made feature in a rural scene depends greatly on how well it seems to fit or blend in with the environment (Kearney et al. 2008, Ryan 2006). For example, Kearney et al. (2008) found preferences for homes that exhibit lower contrast with their surroundings as a result of color, screening vegetation, or other blending factors (see Figure 4.1.2-4). It has been shown that colors lighter in tone or higher in saturation relative to their surroundings have a tendency to attract attention (contrast with their surroundings), whereas darker colors (relative to their surroundings) tend to fade into the background (Ratcliff 1972, O'Connor 2008). This is consistent with the findings of Kearney et al. (2008) who found that darker color was one of the factors contributing to a feature blending in with its environment and therefore preferred. Some research has indicated that color can be used to offset other factors, such as size, that may evoke a more negative perception (O'Connor 2009). Similarly, shapes of features that contrast sharply with their surroundings may also have an influence on how they are perceived.

This has been a dominant focus within visual resource programs of land management agencies (Ribe 2005). The Visual Resource Management Program of the BLM (BLM 2016), for example, places considerable focus on design techniques that minimize visual conflicts with features such as roads and power lines by aligning them with the natural contours of the landscape. Based on these characteristics of contrast, we considered the color of a feature in relative harmony with the landscape if it closely matched the surrounding environment, or if the color tended to be darker relative to the environment. We considered the shape of a feature in relative harmony with the landscape if it was not in marked contrast to the environment.

Movement and Noise

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

Hierarchical Relationship among Conspicuousness Measures

The above-described characteristics do not act independently with respect to their influence on the conspicuousness of features; rather, they tend to have a hierarchical effect. For example, the color and shape of a house would not be important to the integrity of the park's viewshed if the house was located too far away from the key observation point. Thus, distance becomes the primary characteristic that affects the potential conspicuousness. Therefore, we considered potential influences on conspicuousness in the context of a hierarchy based on the distance characteristics having the most impact on the integrity of the viewshed, followed by the size characteristic, then both the color and shape, and movement and noise characteristic (Figure 4.1.2-5).

Extent of Development

The extent of development provides a measure of the degree to which the viewshed is altered from its natural (reference) state, particularly the extent to which intrusive or disruptive elements such as structures and roads may diminish the "naturalness" of the view (USFS 1995, Johnson et al. 2008).

We assessed the extent of development using Geographic Information System (GIS) analysis. The analysis provides a spatial and quantitative assessment of the housing and road developments within the monument's Area of Analysis (AOA), which we identified as a 97 km (60 mi) area surrounding the monument.

Viewshed Analysis

Viewshed analyses were conducted to evaluate areas that were visible and non-visible from a given

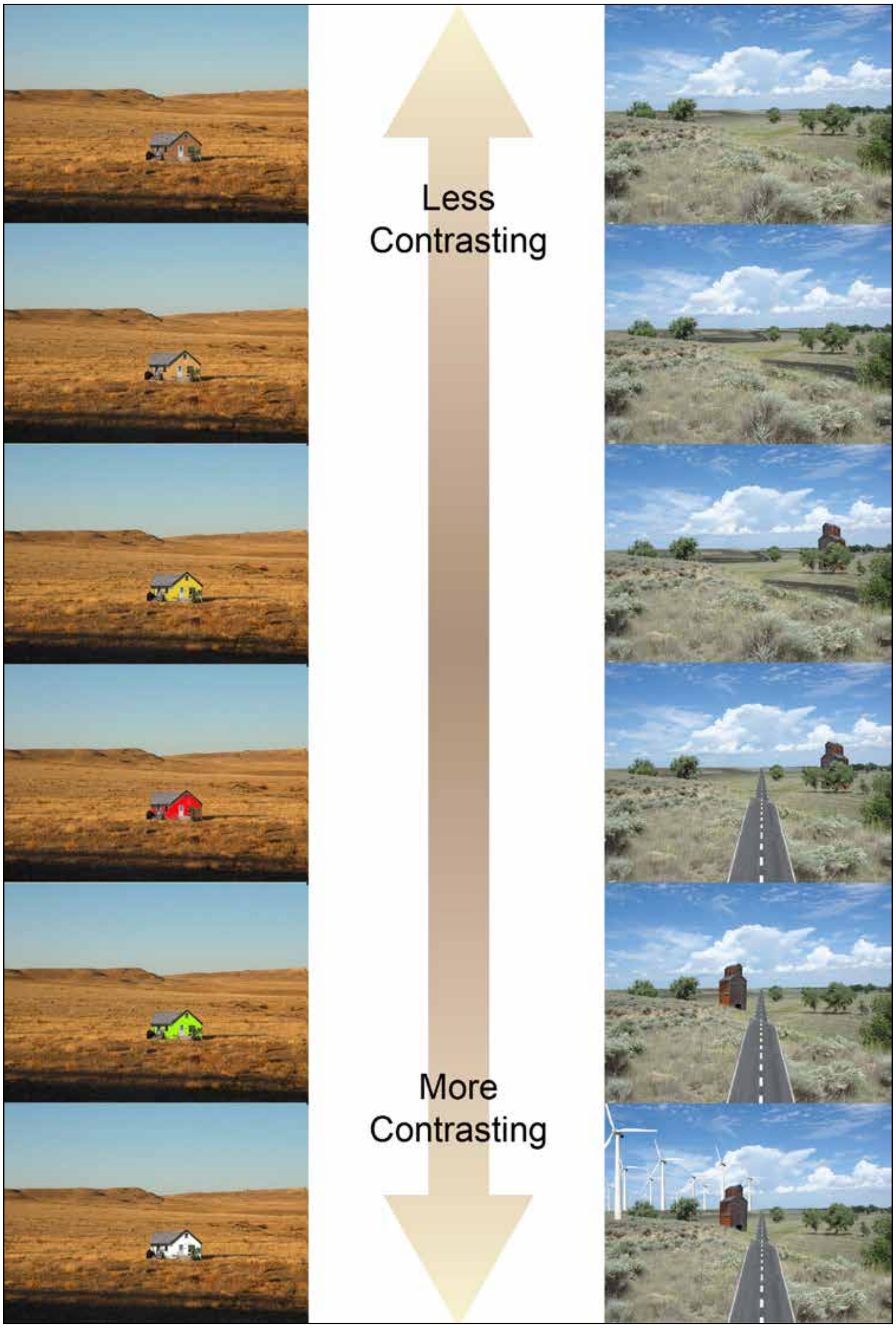


Figure 4.1.2-4. Graphic illustration of how color (left) and shape (right) can influence whether features are in harmony with the environment, or are in contrast.

observation point using ArcGIS Spatial Analyst Viewshed tool. USGS' National Elevation Datasets (NED) at 1/3 arc-second resolution (approximately 10 m / 32.8 ft resolution) (USGS 2016a) were used to create the viewshed AOA from each of the four key observation points; these AOAs were subsequently combined to create composite viewsheds based on all four points. Composite viewsheds are a way to show multiple viewsheds as one, providing an overview of the visible/non-visible areas across all observation points used as the input. The analysis assumed that the viewsheds were not hindered by non-topographic features such as vegetation; the observer was at ground level viewing from a height of 1.68 m (5.5 ft), which is

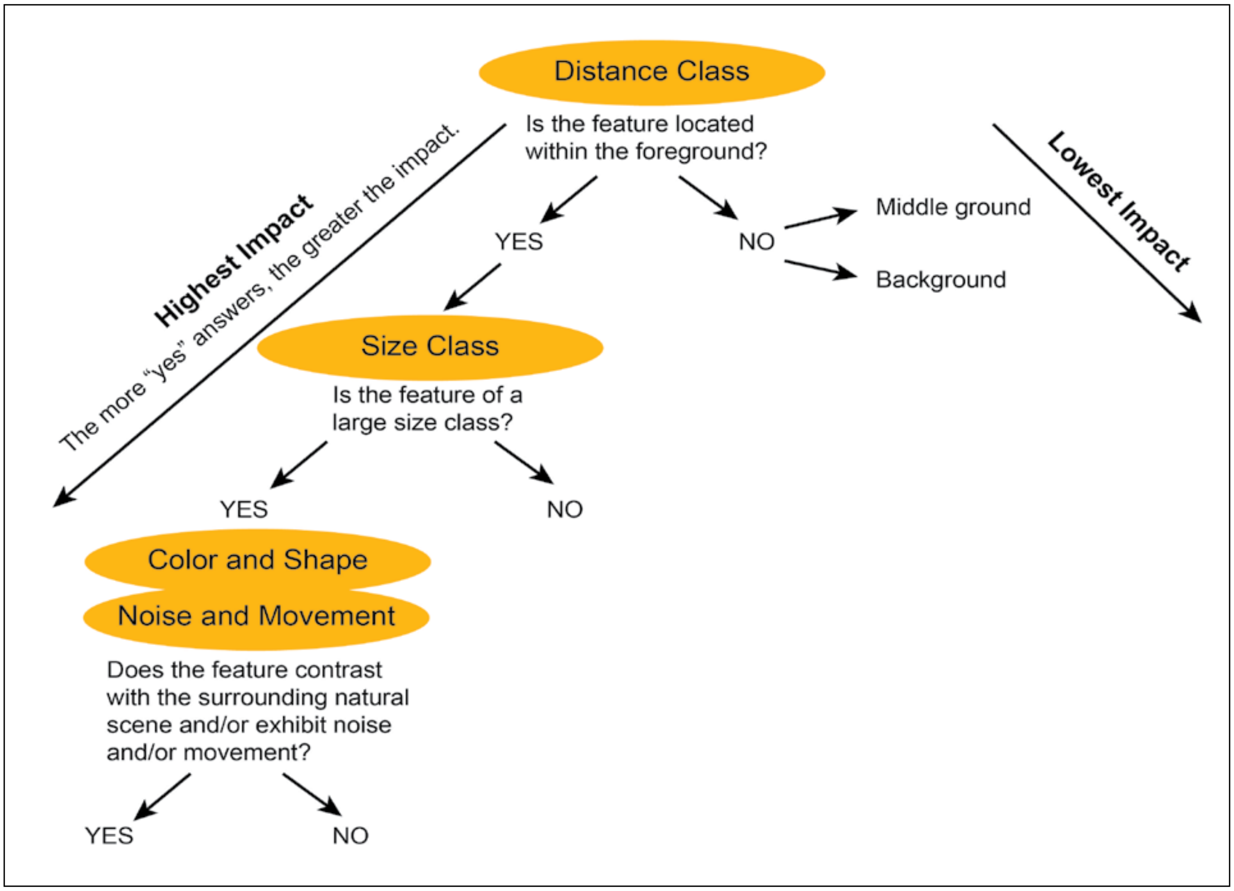


Figure 4.1.2-5. Conceptual framework for hierarchical relationship of characteristics that influence the conspicuousness of features within a viewshed.

the average height of a human; and visibility did not decay due to poor air quality. Additional details are listed in Appendix C. The composite viewshed was overlaid with the housing density and road density output to determine the areas with houses or roads most likely to be visible from the monument.

NPScape Data

NPScape is a landscape dynamics monitoring program that produces and delivers GIS data, maps, and statistics that are integral to understanding natural resource conservation and conditions within a landscape context (NPS 2016c, Monahan et al. 2012). NPScape data include seven major categories (measures), two of which will be used in the viewshed condition assessment: housing and roads. These metrics were used to evaluate resource conditions from a landscape-scale perspective.

NPScape data are consistent, standardized, and collected in a repeatable fashion over time, and yet are flexible enough to provide analyses at many spatial and temporal scales. Data are further described in the sections that follow.

Housing Density

The NPScape 2010 housing density metrics are derived from Theobald's (2005) Spatially Explicit Regional Growth Model, SERGoM 100 m (328 ft) resolution housing density rasters. SERGoM forecasts changes on a decadal basis using county specific population estimates and variable growth rates that are location-specific. The SERGoM housing densities are grouped into six classes as shown in Table 4.1.2-4. NPScape's housing density standard operating procedure (NPS 2014a) and toolset were used to clip the raster to the monument's AOA then to recalculate the housing densities.

Road Density

ESRI's North America Detailed Streets road features (2014) were used to calculate the road density within the monument's AOA. The Feature Class Code values in the dataset are used to identify road types. According to NPScape's road density standard operating

Table 4.1.2-4. Housing density classes.

Grouped Housing Density Class	Housing Density Class (units / km^2)
Urban-Regional Park	Urban-Regional Park
Commercial / Industrial	Commercial / Industrial
Urban	>2,470
	1,235 - 2,470
Suburban	495 - 1,235
	146 - 495
Exurban	50 - 145
	25 - 49
	13 - 24
	7 - 12
Rural	4 - 6
	1.5 - 3
	<1.5
	Private undeveloped

procedure (NPS 2014b), "highways are defined as interstates (FCC: A10-A19) or major roads (FCC: A20-A38, excluding ferry routes). All roads include all road features from the source data regardless of FCC value (excluding ferry routes). New road density rasters, feature classes, and statistics were generated from these data.

4.1.3. Reference Conditions

We used qualitative reference conditions to assess the scenic and historic integrity of Walnut Canyon NM's viewshed, which are as presented in Table 4.1.3-1. Measures are described for resources in good condition, warranting moderate concern or significant concern.

4.1.4. Condition and Trend

<u>Conspicuousness of Non-contributing Features</u>

GigaPan images were collected from the four key observation locations in August 2016. The stitched images are shown in Figures 4.1.4-1, -2, -3, and -4. From the Breezy observation point, there are no visible non-contributing features, although the panoramic images from north to east and east to south are mostly of the ground (Figure 4.1.4-1). Coniferous forests dominate the viewshed in all directions and the meandering canyon is also visible. The viewshed is generally short in distance but the San Francisco Peaks are visible to the northwest. The Breezy observation point is located in the Resource Preservation Zone and is therefore, unlikely to be viewed by visitors. Furthermore, the point is not located along public roads or trails. The viewshed from this location is considered good since there no visible non-contributing features.

From the Ranger Canyon observation location, cliff dwellings are visible in the middle ground of the northern viewshed (Figure 4.1.4-2). The visitor center atop the canyon rim is also visible in the background of the eastern viewshed but the building's low roof line and color allow it to blend well with its surroundings. Furthermore, the building is part of the Walnut Canyon NM Headquarters Area Historic District (NPS 2011b). The district is a combination of NPS Rustic style architecture constructed by the Civilian Conservation Corps and NPS Modern style architecture constructed as part of the Mission 66 program (NPS 2007aa). Therefore, the visitor center, along with the cliff dwellings, are considered contributing features. The eastern viewshed is the largest, while the western viewshed is minimal

Table 4.1.3-1. Reference conditions used to assess the viewshed at Walnut Canyon NM.

Indicator	Measure	Good	Moderate Concern	Significant Concern
Scenic and Historic Integrity	Conspicuousness of Non-contributing Features	The distance, size, color and shape, and movement and noise of the noncontributing features blend into the landscape.	The distance, size, color and shape, and movement and noise of some of the noncontributing features are conspicuous and detract from the natural and cultural aspects of the landscape.	The distance, size, color and shape, and movement and noise of the noncontributing features dominate the landscape and significantly detract from the natural and cultural aspects of the landscape.
	Extent of Development	Lack of or inconspicuous noncontributing features; road and housing densities are low.	Noncontributing features exist in some areas of the viewshed, with some conspicuousness; road and housing densities are moderate, with minor intrusion on the viewshed.	Noncontributing features intrude prominently on the landscape and are highly conspicuous; road and housing densities are high.

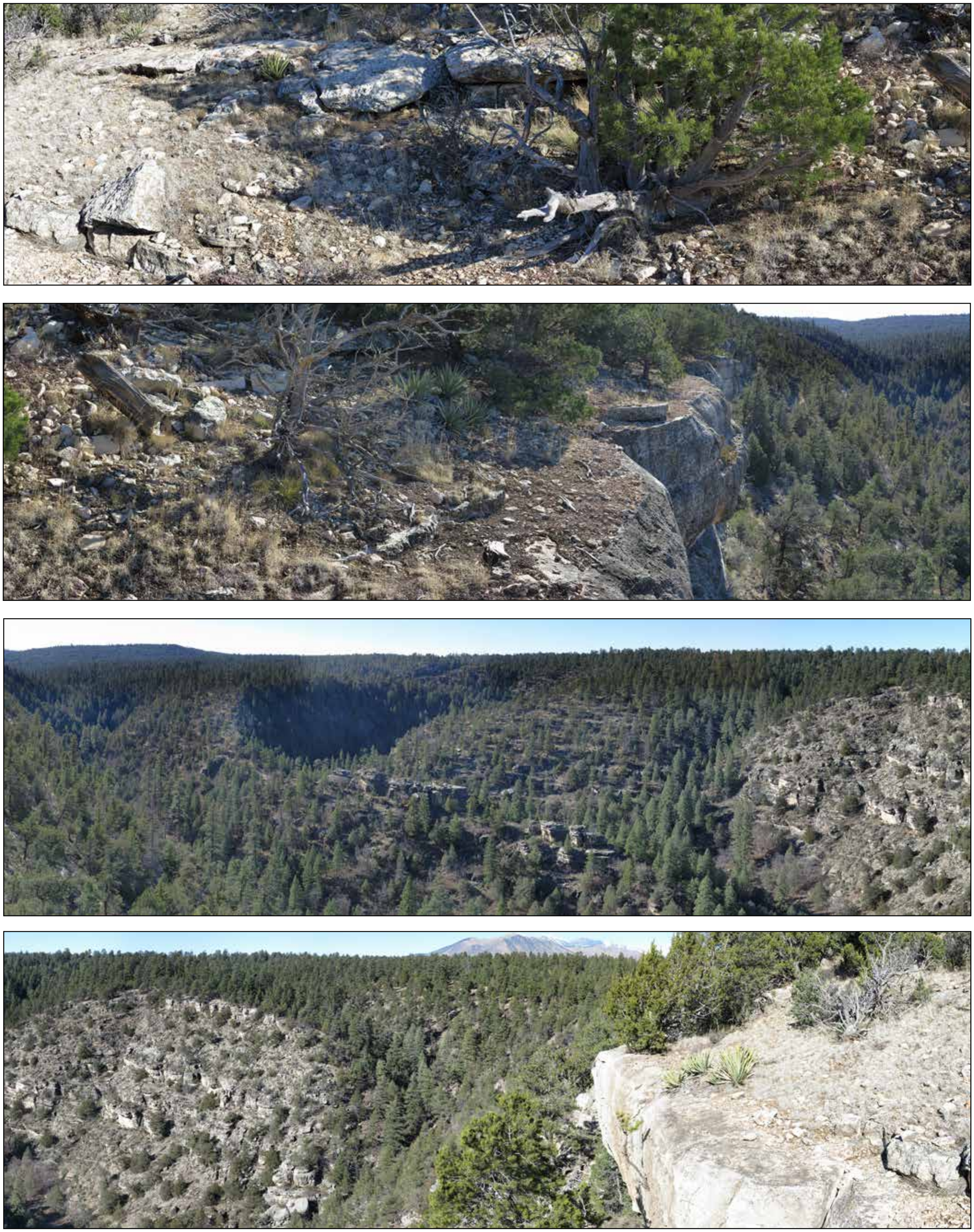


Figure 4.1.4-1. Panoramic views in each direction from the Breezy key observation point in Walnut Canyon NM (from top: north to east, east to south, south to west, and west to north).

Figure 4.1.4-2. Panoramic views in each direction from the Ranger Canyon key observation point in Walnut Canyon NM (from top: north to east, east to south, south to west, and west to north).

with natural topographic features obscuring the middle ground and background. As with the Breezy observation point, the Ranger Canyon point is located within the Resource Preservation Zone. The viewshed from this location is considered good since there are no visible non-contributing features.

The Rim Trail observation point was the only location chosen that is accessible to the public. From this location the visitor center and parts of the Island Trail are visible to the south (Figure 4.1.4-3). As with the Visitor Center, the Island Trail is part of the historic district and is considered a contributing feature. Cliff dwellings are also located along the Island Trail and contribute positively to the overall viewshed. As with the previous two observation points, native coniferous forests dominate the viewshed. The viewshed from this location is good since there are no visible non-contributing features.

From the Walnut East observation point, an old road bed is visible to the east and south (Figure 4.1.4-4). However, the road is not open to the public, it follows the natural contours of the landscape, is not paved, and vegetation is encroaching over it, which minimizes this non-contributing feature's impact on the viewshed. The viewshed to the north and west is of the foreground vegetation so we could not assess quality for these areas. The Walnut East observation point is located within the Resource Preservation Zone and is unlikely to be viewed by visitors. Overall, the viewshed is good from this location.

The viewshed analyses showed that visible areas were limited from each of the observation points (Figure 4.1.4-5). This is consistent with the GigaPan images. Natural landscape features such as canyon walls, rock, and vegetation blocked views for more than a few kilometers and views were often much shorter. The analysis reveals that, although still narrow, the Walnut East observation point has the largest viewshed, while Ranger Canyon has the smallest viewshed. Native vegetation dominated these viewsheds along with historic cliff dwellings and other historic structures, which contribute to the scenic and historic integrity of these locations. Therefore, we consider the condition for this measure to be good.

<u>Extent of Development</u>

The composite viewshed based on the four key observation points overlaid with housing density and road density is shown in blue in Figures 4.1.4-6 and 4.1.4-7. Walnut Canyon NM's viewshed is limited by the naturally variable terrain. Based on data compiled in NPScape (Budde et al. 2009 and Monahan et al. 2012), housing densities surrounding the monument are low (Table 4.1.4-1). The majority (66%) of all housing consists of private undeveloped lands and densities less than 1.5 units/km^2 (23%). Furthermore, most of this rural development occurs outside of Walnut Canyon NM's viewshed (Figure 4.1.4-6). The viewshed analysis was calculated out to 97 km (60 mi) since this is the area most likely visible to the average observer (USFWS 1995). The white spaces within this boundary indicate no census data; thus, housing densities could not be calculated for these areas. However, these data originate with the U.S. Census Bureau and units with unknown densities were probably not reported, which likely indicates undeveloped areas. Total road density within the 97 km (60 mi) AOA surrounding the monument was 0.74 km/km^2. Figure 4.1.4-7 shows road density by various classes. Road density within the monument's viewshed is less dense than it is elsewhere in the AOA and is representative of a relatively rural landscape since there are few areas with a high density of roads.

<u>Overall Condition, Trend, Confidence, and Key Uncertainties</u>

Based on this assessment, the viewshed condition at Walnut Canyon NM is good (Table 4.1.4-2). There were few visible non-contributing features as observed from the four key observation points, and those that were present blended relatively well with the natural landscape. The composite viewshed (blue area in Figures 4.1.4-6 and 4.1.4-7) show that views are limited to the immediate surroundings, but this was a result of natural features of the landscape. The housing and road density analyses show that the region surrounding the monument is mostly rural. This assessment represents baseline condition for Walnut Canyon NM's viewshed; therefore, we could not report on trend. Both measures were assigned medium confidence. Factors that influence confidence level include age of the data (<5 yrs unless the data are part of a long-term monitoring effort), repeatability, field data vs. modeled data, and whether data can be extrapolated to other areas in the monument. We assigned medium confidence to the condition ratings because they were largely based on modeled data. Furthermore, the digital elevation model we used to determine visible areas from each vantage point was

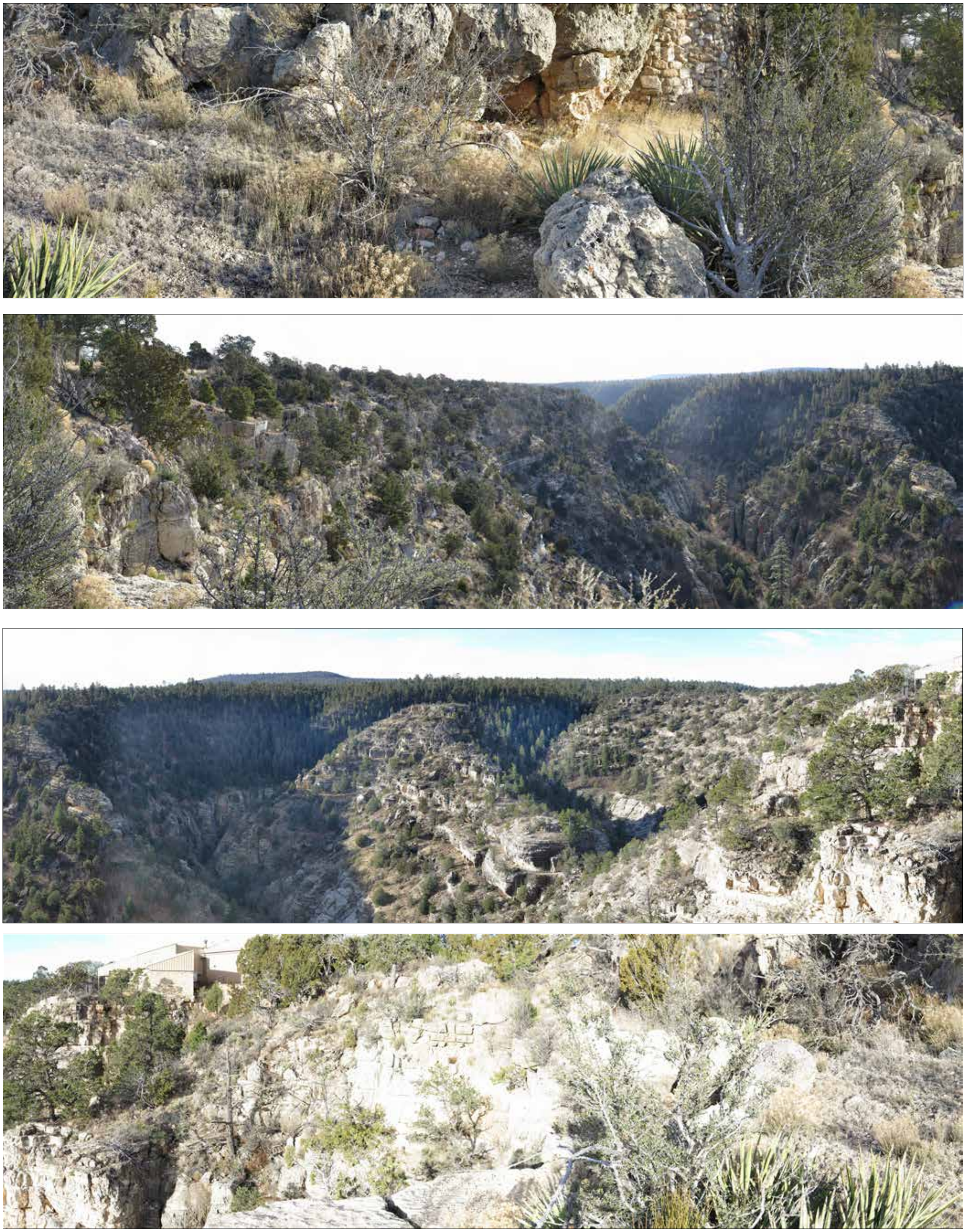


Figure 4.1.4-3. Panoramic views in each direction from the Rim Trail key observation point in Walnut Canyon NM (from top: north to east, east to south, south to west, and west to north).

Figure 4.1.4-4. Panoramic views in each direction from the Walnut East key observation point in Walnut Canyon NM (from top: north to east, east to south, south to west, and west to north).

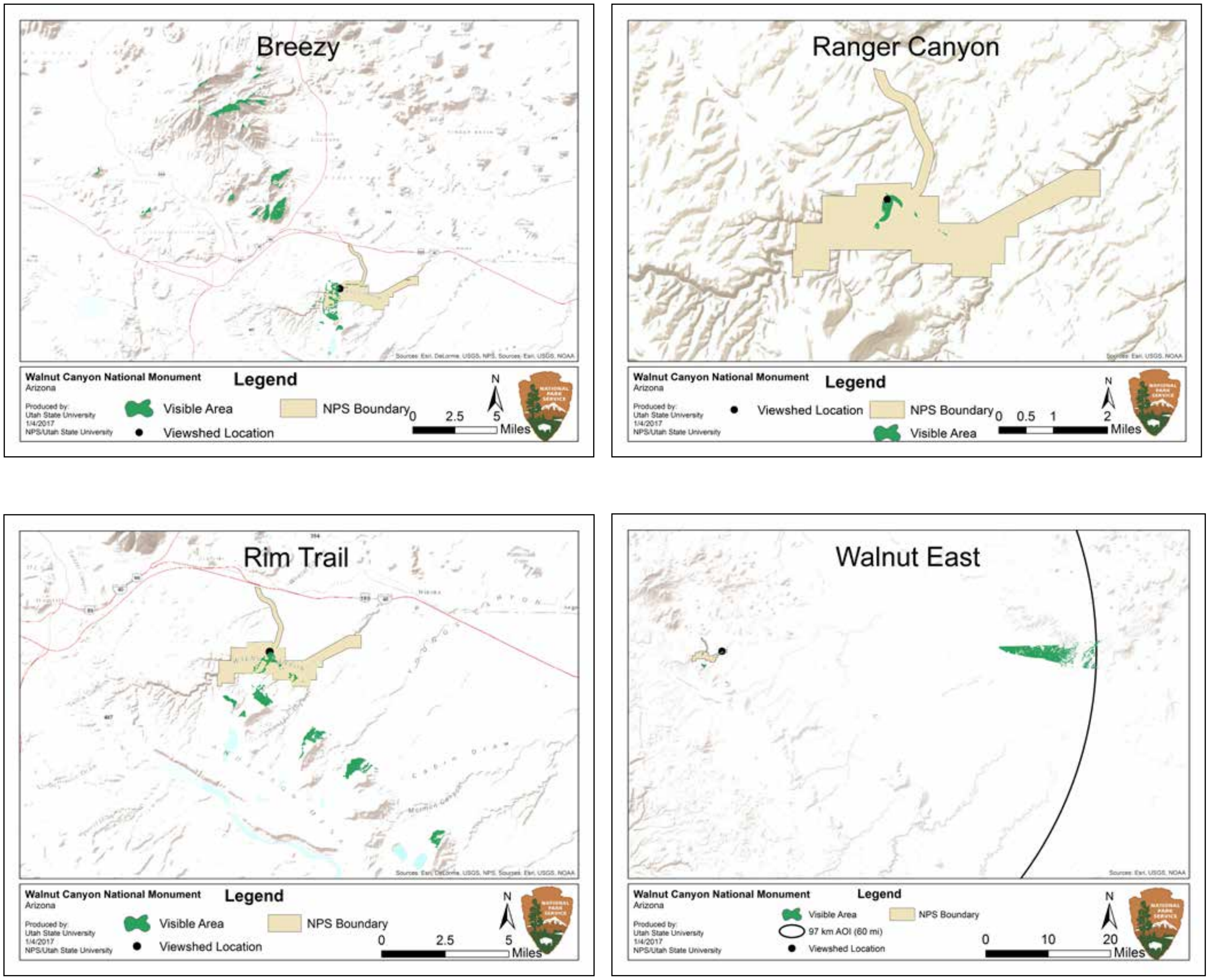


Figure 4.1.4-5. Visible areas from each of the four key observation locations in Walnut Canyon NM. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction.

at 10 m (32.8 ft) resolution. Finer scale data would probably give a better indication of the areas visible. Lastly, we did not account for vegetation height in the viewshed analysis. The monument is densely vegetated by tall coniferous trees, which limited the viewshed.

The consistency between the GigaPan images and the corresponding viewshed analysis displayed in Figure 4.1.4-5 is somewhat difficult to see and would be best viewed digitally (e.g., GIS) to determine the visibility of specific geographic features. When zooming in using GIS the landscape features that block the viewshed or allow for a broad viewshed are more obvious and can be easily compared with the GigaPan images. The viewshed analysis should not be used for planning purposes until groundtruthed.

Table 4.1.4-1. Housing densities within a 97 km (60 mi) buffer around Walnut Canyon NM.

Density Class	Area (km^2)	Percent
Private Undeveloped	9326	66
< 1.5 units	3207	23
1.5 - 6 units	596	4
> 6 units	861	6
Commercial/Industrial	52	< 1
Urban-Regional Park	2	< 1
Total Area	14044	100

Threats, Issues, and Data Gaps

Potential threats to Walnut Canyon NM's viewshed include development within the AOA, increased visitation to the monument, atmospheric dust and smog as a result of climate change, and a potential

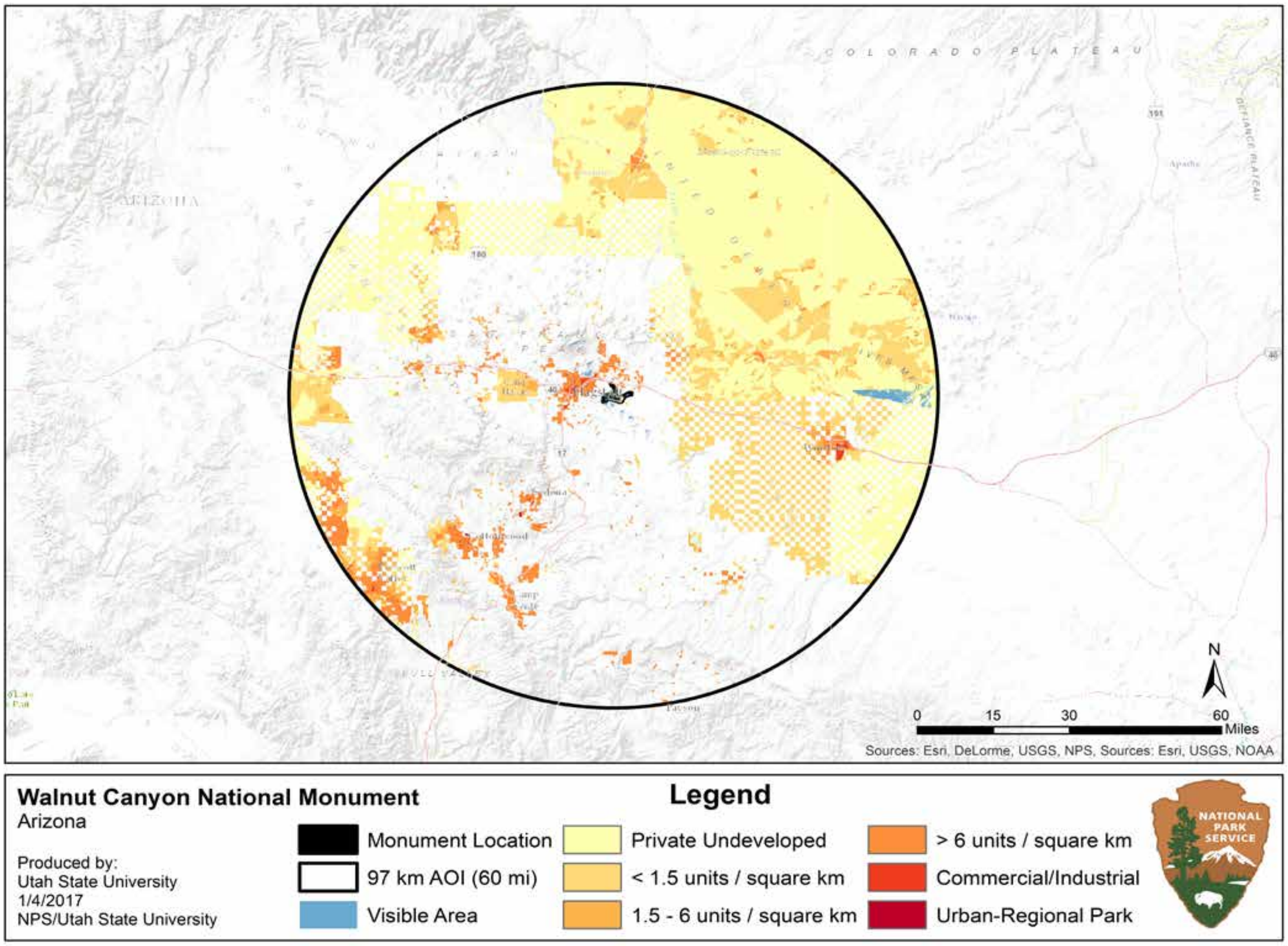


Figure 4.1.4-6. Housing density and visible areas in and around Walnut Canyon NM.

increase in wildfire activity. According to the housing density analysis however, development within the monument's viewshed is not expected to change substantially over the next 50 to 60 years. Even by 2100, the analysis showed only a slight increase in development. It is important to keep in mind, however, that this prediction based on past development and may not reflect actual future development. Road density is also relatively low. Roads are usually associated with development. Since housing density is predicted to remain relatively stable, road density is also likely to remain stable. Even if housing and road density were expected to increase, they are unlikely to substantially affect the monument's viewshed.

Increased visitation could impact viewshed to some extent, but backcountry use is not permitted in the monument (NPS 1996). The majority of visitors are concentrated along the limited road corridors, pullouts, visitor centers, trails, and interpretive exhibits rather than dispersed across the backcountry.

Although the viewshed is not expected to be negatively affected by an increase in development, atmospheric dust and mineral aerosols have increased in the interior western U.S. by 500% over the late Holocene average (Neff et al. 2008). This increase is directly related to increased western settlement and livestock grazing during the 19th century (Neff et al. 2008). Atmospheric dust can impact viewshed quality (refer to the Air Quality assessment for more details). Finally, as the southwestern U.S. has transitioned to a warmer and drier climate in recent decades, wildfire activity has also increased (Abatzoglou and Williams 2016). Wildfires in and around the monument would not only temporarily alter the viewshed as a result of smoke but may also alter the viewshed in the long-term as trees that normally provide a screen to surrounding developments are burned.

4.1.5. Sources of Expertise

Assessment author is Lisa Baril, wildlife biologist and science writer, Utah State University.

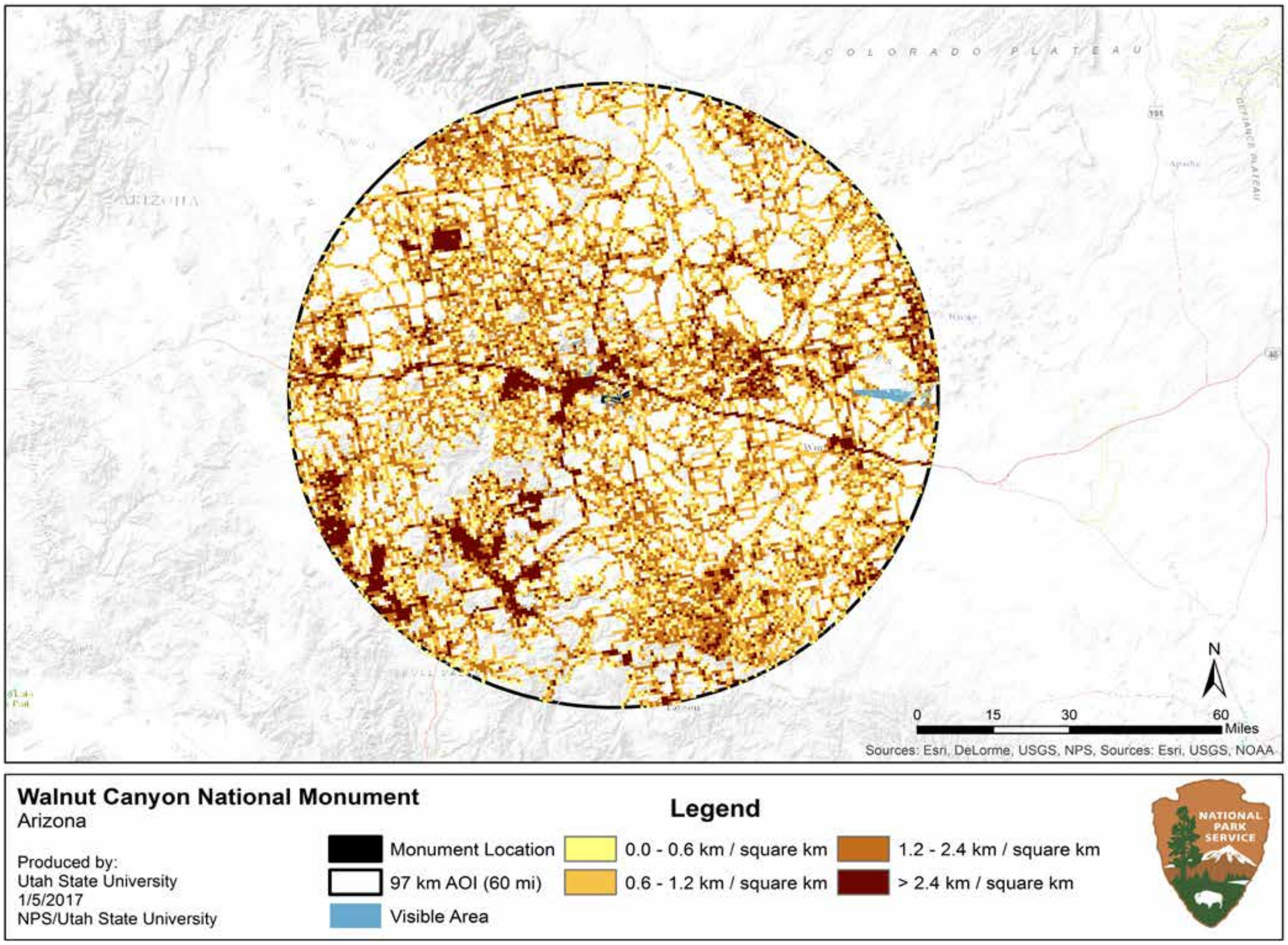


Figure 4.1.4-7. **Road density and visible areas in around Walnut Canyon NM.**

Table 4.1.4-2. **Summary of the viewshed indicators, measures, and condition rationale.**

Indicators of Condition	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Scenic and Historic Integrity	Conspicuousness of Non-contributing Features		Native vegetation dominated the viewshed along with cliff dwellings and other historic structures, which contribute to the overall visitor experience in the monument. Therefore, we consider the condition for this measure to be good. There were no data available to determine trend for this measure. Confidence in this condition rating is medium.
	Extent of Development		The housing and road density analyses show that the region surrounding the monument is mostly rural. Therefore, we consider the condition for this measure to be good. There were no data available to determine trend for this measure. Confidence in this condition rating is medium.
Overall Condition			There were few non-contributing features in the monument's viewshed as observed from the four key observation locations. Housing density indicates the region is mostly rural, and road density is low. There were no data available to determine overall trend. Instead, these data serve as a baseline for which to make future comparisons. Confidence in this condition rating is medium since the majority of data used were based on models.

4.2. Night Sky

4.2.1. Background and Importance

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

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

The value of night skies goes far beyond visitor experience and scenery (Figure 4.2.1-1). The photic environment affects a broad range of species, is integral to ecosystems, and is a natural physical process (Longcore and Rich 2004). Natural light intensity varies during the day-night (diurnal) cycle, the lunar cycle, and the seasonal cycle. Organisms have evolved to respond to these periodic changes in light levels in ways that control or influence movement, feeding, mating, emergence, seasonal breeding, migration, hibernation, and dormancy. Plants also respond to light levels by flowering, vegetative growth, and their direction of growth (Royal Commission on Environmental Pollution 2009). Given the effects of light on living organisms, it is likely that the introduction of artificial light into the natural light/darkness regime will disturb the normal routines of many plants and animals (Royal Commission on Environmental Pollution 2009), as well as diminish stargazing recreational opportunities offered to national park visitors.

Maintaining a dark night sky was identified in Walnut Canyon National Monument's (NM) Foundation Document as fundamental to protecting the natural setting and biological diversity of the park (NPS 2015). The park also protects a dense concentration of archaeological sites important to American Indian cultural traditions (NPS 2015). Historically, American Indian's observation of the sun, moon, and stars was essential for planning festivals and activities such as when to start planting and when to harvest (Aveni 2003). Protecting the night sky resources at Walnut

Figure 4.2.1-1. The monument includes important habitat for many nocturnal species including canyon tree frog. Photo Credit: NPS.

Canyon NM benefits the natural resources, enriches the visitor experience, and has cultural significance.

In 2016, Walnut Canyon NM was designated an International Dark Sky Park by the International Dark Sky Association (IDA), a non-profit organization dedicated to preserving dark night skies around the world (IDA 2016). Walnut Canyon NM was designated along with Sunset Crater Volcano and Wupatki National Monuments since all three monuments are managed jointly by the NPS as one unit. Thus the Dark Sky Park designation was applied to all three simultaneously (IDA 2016).

Walnut Canyon NM lies 11 km (7 mi) east of the city of Flagstaff, Arizona, which in 2001, was designated as the world's first International Dark Sky Community owing to its progressive outdoor lighting policy enacted in 1958— the world's first outdoor lighting ordinance (IDA 2016). The city is also home to Lowell Observatory and the U.S. Naval Observatory Flagstaff Station, both of which are active astronomical research facilities. In addition, the Lowell Observatory regularly hosts interpretive star gazing events that highlight the region's nocturnal lightscape.

4.2.2. Data and Methods

The NPS NSNSD goals of measuring night sky brightness are to describe the quality of the lightscape, quantify how much it deviates from natural conditions, and how it changes with time due to changes in natural conditions, as well as artificial lighting in areas within and outside of the national parks (Duriscoe et al. 2007). In this assessment, we characterize the night sky environment in Walnut Canyon NM using four measures that quantify sky brightness and one measure that describes overall sky quality. The quantitative measures are all-sky light pollution ratio, vertical maximum illuminance, horizontal illuminance, and zenith sky brightness. These measures, which are described in detail below, provide information on various aspects of the observed photic environment and proportion of light pollution attributed to anthropogenic sources. We also include the Bortle dark sky scale, which is a measure of sky quality as perceived by a human observer trained to determine the visibility of various celestial bodies and night sky features. Together, these five measures were used to assess the condition of this important park resource (Table 4.2.2-1).

NSNSD scientists conducted an assessment of Walnut Canyon NM's night sky condition from the Rim Trail's east overlook on May 12, 2002, June 18, 2004, October 6, 2004, and March 13, 2012 (Figure 4.2.2-1). Data collected during the assessment were used to support the IDA application. Ground-based measurements were collected under clear and moonless conditions. A CCD camera was used to assess the all-sky light pollution ratio, zenith sky brightness, maximum vertical illuminance, and horizontal illuminance. The Bortle dark sky scale, which is commonly used by amateur astronomers to assess the night sky for star gazing, was used to evaluate night sky quality. In addition to these field-based data, the all-sky light pollution ratio was also modeled using satellite imagery from October 2015.

<u>All-sky Light Pollution Ratio</u>

The all-sky light pollution ratio (ALR) is the average anthropogenic sky luminance presented as a ratio over natural conditions. It is a useful metric to average the light flux over the entire sky (measuring all that is above the horizon and omitting the terrain). Recent advances in modeling the natural components of the night sky allow separation of anthropogenic light from

Table 4.2.2-1. Indicators and measures of the night sky and why they are important to resource condition.

Indicator	Measure	Description
Sky Brightness	All-sky Light Pollution Ratio, Vertical Maximum and Horizontal Illuminances, and Zenith Sky Brightness	The all-sky light pollution ratio describes light due to man-made sources compared to light from a natural dark sky. Vector measures of illuminance (horizontal and vertical) are important in describing the appearance of objects on the landscape and their relative visibility. Understanding the lightscape and sources of light is helpful to managers to maintain dark skies for the benefit of wildlife and people alike.
Sky Quality	Bortle Dark Sky Scale	The Bortle Dark Sky Scale classification system describes the quality of the dark night sky by the celestial bodies and night sky features an observer can see. Observing the stars has been an enjoyable human pastime for centuries.

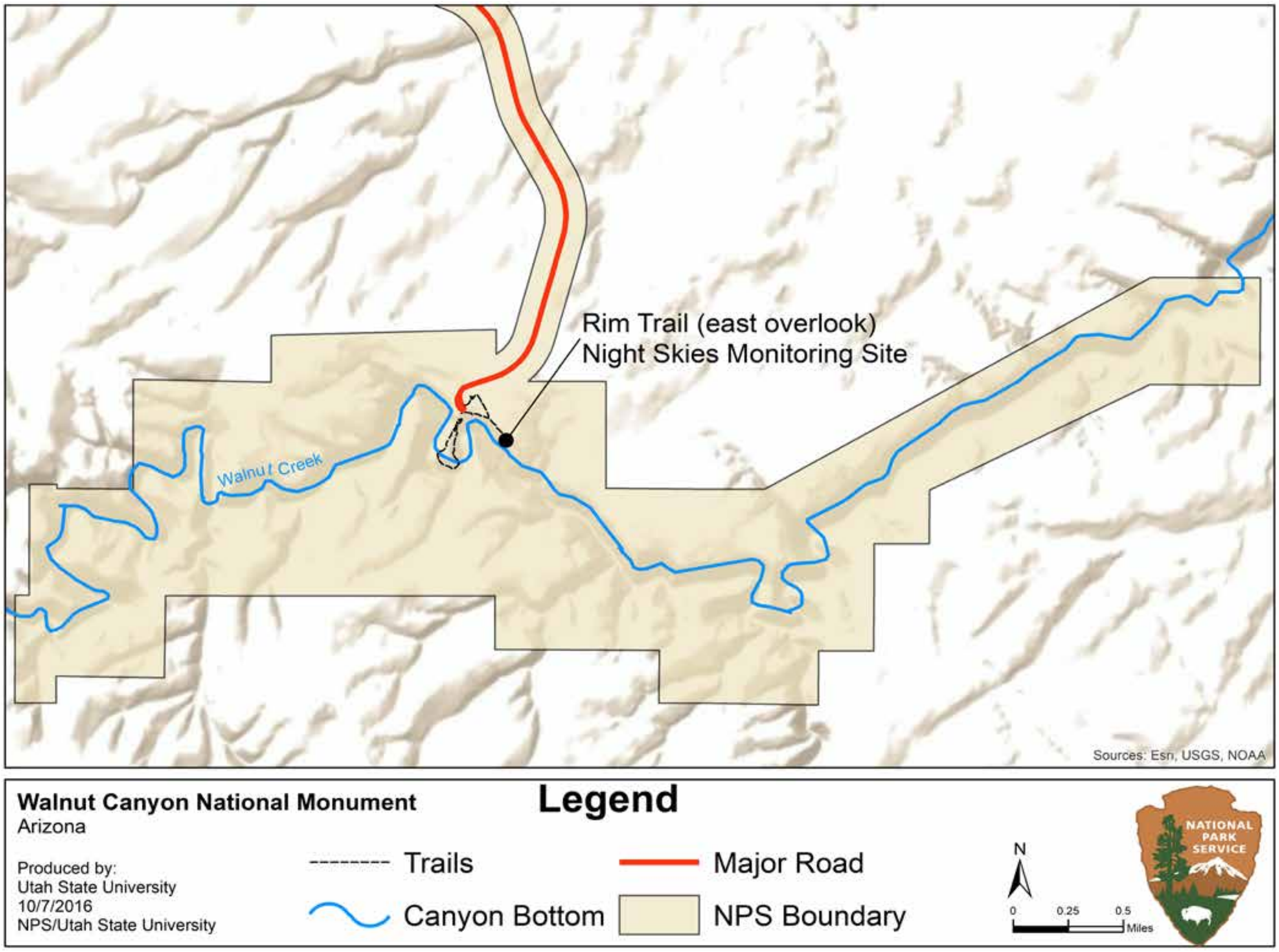


Figure 4.2.2-1. Location of the Rim Trail (east overlook) night sky monitoring site in Walnut Canyon NM. The entrance road to Walnut Canyon NM is not included within the boundaries of the monument. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction.

natural features, such as the Milky Way. This metric is a convenient and robust measure. It is most accurately obtained from ground-based measurements with the NPS Night Skies Program's photometric system, however, it can also be modeled with moderate confidence when such measurements are not available.

Modeled ALR data were based on 2015 National Aeronautics and Space Administration (NASA) Day/Night Band data collected by the Visible Infrared Imaging Radiometer Suite instrument located on the Suomi National Polar Orbiting Partnership satellite (NASA 2016). While modeled data provide useful overall measurements, especially when site visits cannot be made, they are less accurate than ground-based measurements.

A natural night sky has an average brightness across the entire sky of 78 nL (nanolamberts, a measure of luminance), and includes features such as the Milky Way, Zodiacal light, airglow, and other starlight. This is figured into the ratio, so that an ALR reading of 0.0 would indicate pristine natural conditions where the anthropogenic component was 0 nL. A ratio of 1.0 would indicate that anthropogenic light was 100% as bright as the natural light from the night sky.

<u>Maximum Vertical and Horizontal Illuminance</u>
The maximum sky brightness is typically found in the core of urban light domes (i.e., the semicircular-shaped light along the horizon caused by the scattering of urban light). The minimum sky brightness is typically found at or near the zenith (i.e., straight overhead). The integrated night sky brightness is calculated from both the entire celestial hemisphere as well as a measure of the integrated brightness masked at the apparent horizon to avoid site-to-site variations introduced by terrain and vegetation blocking. Vector measures of

illuminance (horizontal and vertical) are important in describing the appearance of three-dimensional objects on the landscape and their relative visibility.

Vertical illuminance is the integration of all light striking a vertical plane from the point of the observer. In light-polluted areas, maximum sky brightness and maximum vertical illuminance will often measure the same area of sky, typically at the core of urban light domes. Vertical illuminance is an important metric when discussing night sky quality as it is easily noticeable to park visitors (since humans are oriented vertically). Even with dark conditions overhead, high vertical illuminance can hinder or inhibit dark adaptation of the eyes and cast visible shadows on the landscape. This is also an important ecological indicator, as many wildlife species base behavior on visual cues along the horizon. Horizontal illuminance is the amount of light striking a horizontal surface and is an important indicator of sky brightness (Cinzano and Falchi 2014). It is less sensitive in slightly impacted areas. This is because, even though the entire sky is considered, there is a rapid falloff in response to photons near the horizon, owing to Lambert's cosine law. At sites remote from cities, most of the anthropogenic sky glow occurs near the horizon.

For these two measures of illuminance we report the observed (artificial + natural) maximum vertical and horizontal illuminance. We also report the corresponding light pollution ratio (LPR) (i.e., proportion of light attributed to anthropogenic sources) (Duriscoe 2016).The light pollution ratio is useful since it is unit-less, allowing for comparison between measures (Duriscoe 2016). The LPR is also a more intuitive approach to understanding the contribution of artificial light sources for a particular area.

Zenith Sky Brightness

Sky brightness describes the amount of light observed in the night sky. This measure was calculated from the median pixel value of an approximately one degree diameter circle centered on the zenith and was collected using the CCD camera (NPS 2016a). As with maximum vertical and horizontal illuminance, we report the observed zenith sky brightness in addition to its corresponding LPR.

Bortle Dark Sky Scale

The Bortle dark sky scale was proposed by John Bortle (Bortle 2001) based on 50 years of astronomical observations. Bortle's qualitative approach uses a nine-class scale that requires a basic knowledge of the night sky and no special equipment (Bortle 2001, Moore 2001, White et al. 2012, Table 4.2.2-2). The Bortle scale uses both stellar objects and familiar descriptors to distinguish among the different classes. Another advantage of the Bortle scale is that it is suitable for conditions ranging from the darkest skies to the brightest urban areas (Moore 2001, Figure 4.2.2-2).

4.2.3. Reference Conditions

Table 4.2.3-1 summarizes the condition thresholds for measures in good condition, those warranting moderate concern, and those warranting significant concern. The ideal night sky reference condition, regardless of how it's measured, is one devoid of any light pollution. However, results from night sky data collection throughout more than 90 national parks suggest that a pristine night sky is very rare (NPS 2010a).

Walnut Canyon NM is considered a non-urban NPS unit, or area with at least 90% of its property located outside an urban area (Moore et al. 2013). For non-urban NPS units and those containing wilderness areas, the thresholds separating reference conditions of good condition, moderate concern, and significant concern are more stringent than those for urban NPS units because these areas are generally more sensitive to the effects of light pollution.

Anthropogenic Light Ratio (ALR)

The threshold for night skies in good condition is an ALR <0.33 and the threshold for warranting moderate concern is ALR 0.33-2.00. An ALR >2.00 would warrant significant concern (Moore et al. 2013).

Maximum Vertical Illuminance

Although no thresholds for maximum vertical illuminance have been set at this time, the NPS Night Skies Programrecommends a reference condition of 0.4 milli-Lux, since the average vertical illuminance experienced under the natural night sky on a moonless night is 0.4 milli-Lux (derived from Jensen et al. 2006, Garstang 1986, and unpublished NPS Night Skies Program data). Vertical illuminance can also be

Table 4.2.2-2. Bortle Dark Sky Scale.

Bortle Scale	Milky Way (MW)	Astronomical Objects	Zodiacal Constellations	Airglow and Clouds	Nighttime Scene
Class 1 Excellent Dark Sky Site	MW shows great detail, and appears 40° wide in some parts; Scorpio-Sagittarius region casts an obvious shadow	Spiral galaxies (M33 and M81) are obvious objects; the Helix nebula is visible with the naked eye	Zodiacal light is striking as a complete band, and can stretch across entire sky	The horizon is completely free of light domes, very low airglow	Jupiter and Venus annoy night vision, ground objects are barely lit, trees and hills are dark
Class 2 Typical Dark Site	MW shows great detail and cast barely visible shadows	The rift in Cygnus star cloud is visible; the Prancing Horse in Sagittarius and Fingers of Ophiuchus dark nebulae are visible, extending to Antares	Zodiacal band and gegenschein are visible	Very few light domes are visible, with none above 5° and fainter than the MW; airglow may be weakly apparent, and clouds still appear as dark voids	Ground is mostly dark, but object projecting into the sky are discernible
Class 3 Rural Sky	MW still appears complex; dark voids and bright patches and a meandering outline are visible	Brightest globular clusters are distinct, pinwheel galaxy visible with averted vision	Zodiacal light is easily seen, but band of gegenschein is difficult to see or absent	Airglow is not visible, and clouds are faintly illuminated except at zenith	Some light domes evident along horizon, ground objects are vaguely apparent
Class 4 Rural-Suburban Transition	MW is evident from horizon to horizon, but fine details are lost	Pinwheel galaxy is a difficult object to see; deep sky objects such as M13 globular cluster, Northern Coalsack dark nebula, and Andromeda galaxy are visible	Zodiacal light is evident, but extends less than 45° after dusk	Clouds are just brighter than the sky, but appear dark at zenith	Light domes are evident in several directions (up to 15° above the horizon), sky is noticeably brighter than terrain
Class 5 Suburban Sky	MW is faintly present, but may have gaps	The oval of Andromeda galaxy is detectable, as is the glow in the Orion nebula, Great rift in Cygnus	Only hints of zodiacal light may be glimpsed	Clouds are noticeably brighter than sky	Light domes are obvious to casual observers, ground objects are easily seen
Class 6 Bright Suburban Sky	MW only apparent overhead, and appears broken as fainter parts are lost to sky glow	Cygnus, Scutum, and Sagittarius star fields just visible	Zodiacal light is not visible; constellations are seen, and not lost against a starry sky	Clouds appear illuminated and reflect light	Sky from horizon to 35° glows with grayish color, ground is well lit
Class 7 Suburban-Urban Transition	MW may be just barely seen near the zenith	Andromeda galaxy (M31) and Beehive cluster (M44) are rarely glimpsed	Zodiacal light is not visible, and brighter constellations are easily seen	Clouds are brilliantly lit	Entire sky background appears washed out, with a grayish or yellowish color
Class 8 City Sky	MW not visible	Pleiades are easily seen, but few other objects are visible	Zodiacal light not visible, constellations are visible but lack key stars	Clouds are brilliantly lit	Entire sky background has uniform washed out glow, with light domes reaching 60° above the horizon
Class 9 Inner City Sky	MW not visible	Only the Pleiades are visible to all but the most experienced observers	Only the brightest constellations are discernible	Clouds are brilliantly lit	Entire sky background has a bright glow, ground is illuminated

Source: White et al. (2012).

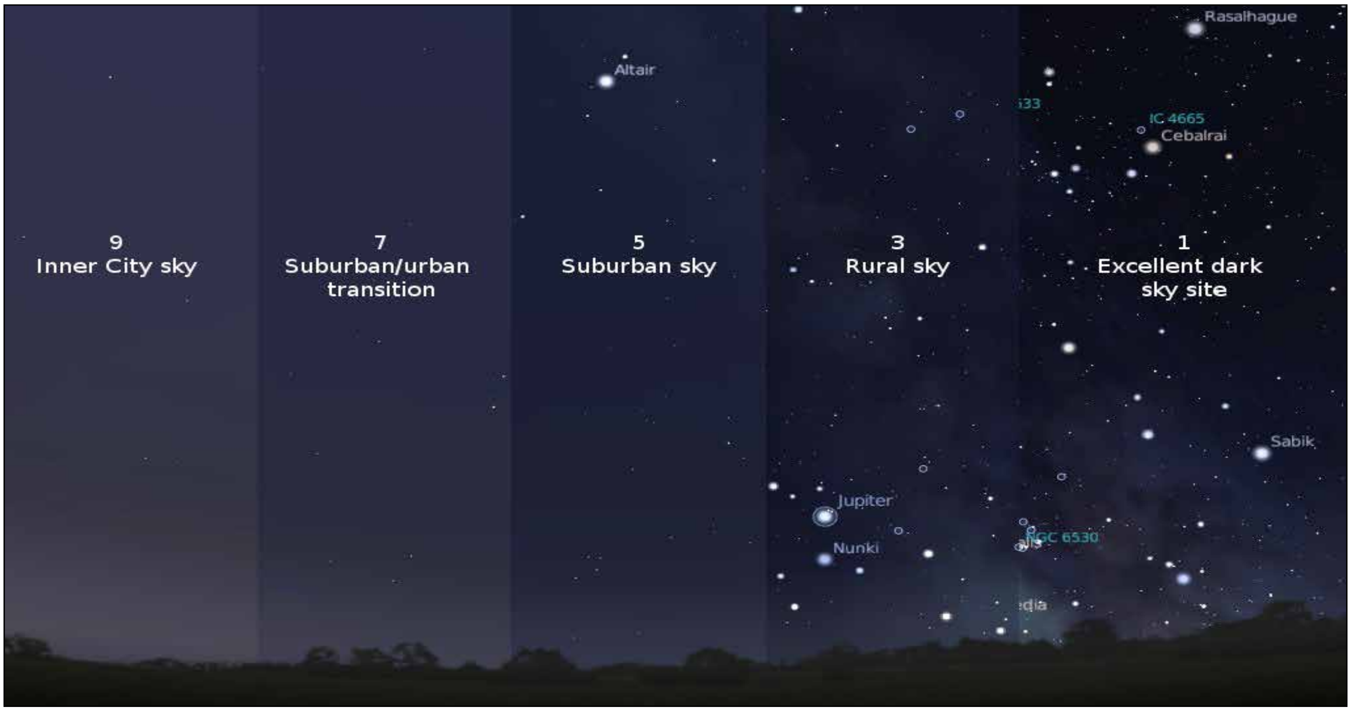


Figure 4.2.2-2. A graphic representation of the Bortle Dark Sky Scale (Bortle 2001). Figure Credit: NPS Natural Sounds and Night Skies Division.

expressed as a ratio to natural conditions, similar to ALR.

Horizontal Illuminance

As with maximum vertical illuminance, no thresholds for horizontal illuminance have been set at this time. The NPS Night Skies Programrecommends a reference condition of 0.8 milli-Lux, since the average horizontal illuminance experienced under the natural night sky on a moonless night is 0.8 milli-Lux (Duriscoe 2016). Horizontal illuminance can also be expressed as a ratio to natural conditions, similar to ALR.

Zenith Sky Brightness

Reference conditions for night sky brightness can vary moderately based on the time of night (time after sunset), time of the month (phase of the moon), time of the year (the position of the Milky Way), and the activity of the sun, which can increase "airglow"—a kind of faint aurora. For the minimum night sky brightness measure, the darkest part of a natural night

Table 4.2.3-1. Reference conditions used to assess the night sky.

Indicator	Measure	Good	Moderate Concern	Significant Concern
Sky Brightness	All-sky Light Pollution Ratio (ALR)*	ALR <0.33 (<26 nL average anthropogenic light in sky)	ALR 0.33-2.00 (26-156 nL average anthropogenic light in sky)	ALR >2.00 (>156 nL average anthropogenic light in sky)
	Maximum Vertical Illuminance	Thresholds have not been developed. A recommended reference is 0.4 milli-Lux.	Thresholds have not been developed. A recommended reference is 0.4 milli-Lux.	Thresholds have not been developed. A recommended reference is 0.4 milli-Lux.
	Horizontal Brightness	Thresholds have not been developed. A recommended reference is 0.8 milli-Lux.	Thresholds have not been developed. A recommended reference is 0.8 milli-Lux.	Thresholds have not been developed. A recommended reference is 0.8 milli-Lux.
	Zenith Sky Brightness (msa)*	≥21.60	21.20-21.59	<21.20
Sky Quality	Bortle Dark Sky Scale Class*	1-3	4	5-9

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

sky is generally found near the zenith. A value of 22.0 magnitudes per square arc second (msa) is considered to represent a pristine sky, though it may vary naturally by more than +0.2 to -0.5 depending on natural conditions (Duriscoe 2013). Lower (brighter) values indicate increased light pollution and a departure from natural conditions. The astronomical magnitude scale is logarithmic, so a change of 2.50 magnitudes corresponds to a difference of l0x; thus a 19.5 msa sky would be 10x brighter than natural conditions. Minimum night sky brightness values of 21.4 to 22.0 msa, are generally considered to represent natural (unpolluted) conditions (Duriscoe et al. 2007).

Bortle Dark Sky Scale

A night sky with a Bortle Dark Sky Scale class 1 is considered in the best possible condition (Bortle 2001); unfortunately, a sky that dark is so rare that few observers have ever witnessed it (Moore 2001). Non-urban park skies with a Bortle class 3 or darker are considered to be in good condition, class 4 warrants moderate concern, and class 5 warrants significant concern. At class 4 and higher, many night-sky features are obscured from view due to artificial lights (either within or outside the park). Skies class 7 and higher have a significantly degraded aesthetic quality that may introduce ecological disruption (Moore et al. 2013).

4.2.4. Condition and Trend

All-sky Light Pollution Ratio

Modeling data by the NPS Night Skies Program shows a median ALR of 0.80 for the entire monument (Table 4.2.4-1). This is 80% brighter than average natural conditions. Figure 4.2.4-1 shows the modeled ALR for the region surrounding Walnut Canyon NM and the extent of the light domes cast by cities located in the region. The light domes from Flagstaff, Arizona located 11 km (7 mi) to the west and Phoenix, Arizona located approximately 185 km (115 mi) to the south of the monument are visible from Walnut Canyon NM. The light dome of Phoenix, Arizona is the largest contributor of artificial sky glow in the monument.

The modeled ALR value was higher than ground-based measurements (Table 4.2.4-1). Ground-based ALRs varied from 0.39 to 0.71, which corresponds to a range of 39% to 71% brighter than average natural conditions. Figures 4.2.4-2, -3, -4, and -5 show the natural and anthropogenic light sources on the four monitoring dates. These data images are shown in false color with yellow, red, and white corresponding to brighter sky and blue, purple, and black corresponding to darker sky. Since all ALR measurements, modeled and ground-based, were greater than 0.33 but less than 2.00, we consider this measure of sky brightness to warrant moderate concern. All ALR values were toward the lower end of the moderate concern range. Confidence in this condition rating is high since it was based on four ground-based measurements and a modeled estimate. We could not determine trend based on the four nights during which data were collected. The apparently improving condition in ALR does not necessarily reflect an improvement in night sky quality. Rather, the difference is likely due to variability in natural airglow, which can influence the ALR measurements.

Maximum Vertical Illuminance (milli-Lux)

Observed maximum vertical illuminance ranged from 0.38 to 0.62 milli-Lux. The corresponding LPR was estimated as 95% to 155% brighter than average natural conditions. Two of the four monitoring dates exceeded the NSNSD recommendation of 0.4 milli-Lux, however, since there are no thresholds for good condition, moderate concern, or significant concern, we did not assign a condition for this measure. Confidence is low due to lack of reference

Table 4.2.4-1. Night sky measurements collected at the Rim Trail (east overlook) monitoring site in Walnut Canyon NM.

Date	All-sky Light Pollution Ratio	Observed Maximum Vertical Illuminance (milli-Lux)	Observed Horizontal Illuminance (milli-Lux)	Observed Zenith Sky Brightness (msa)	Bortle Class
10/2015*	0.80	–	–	–	---
05/12/2002	0.46	0.39	1.10	21.76	4
06/18/2004	0.71	0.62	1.14	21.73	4
10/06/2004	0.60	0.47	1.07	21.02	4
03/13/2012	0.39	0.38	1.03	21.68	4

* Modeled median ALR data park-wide.

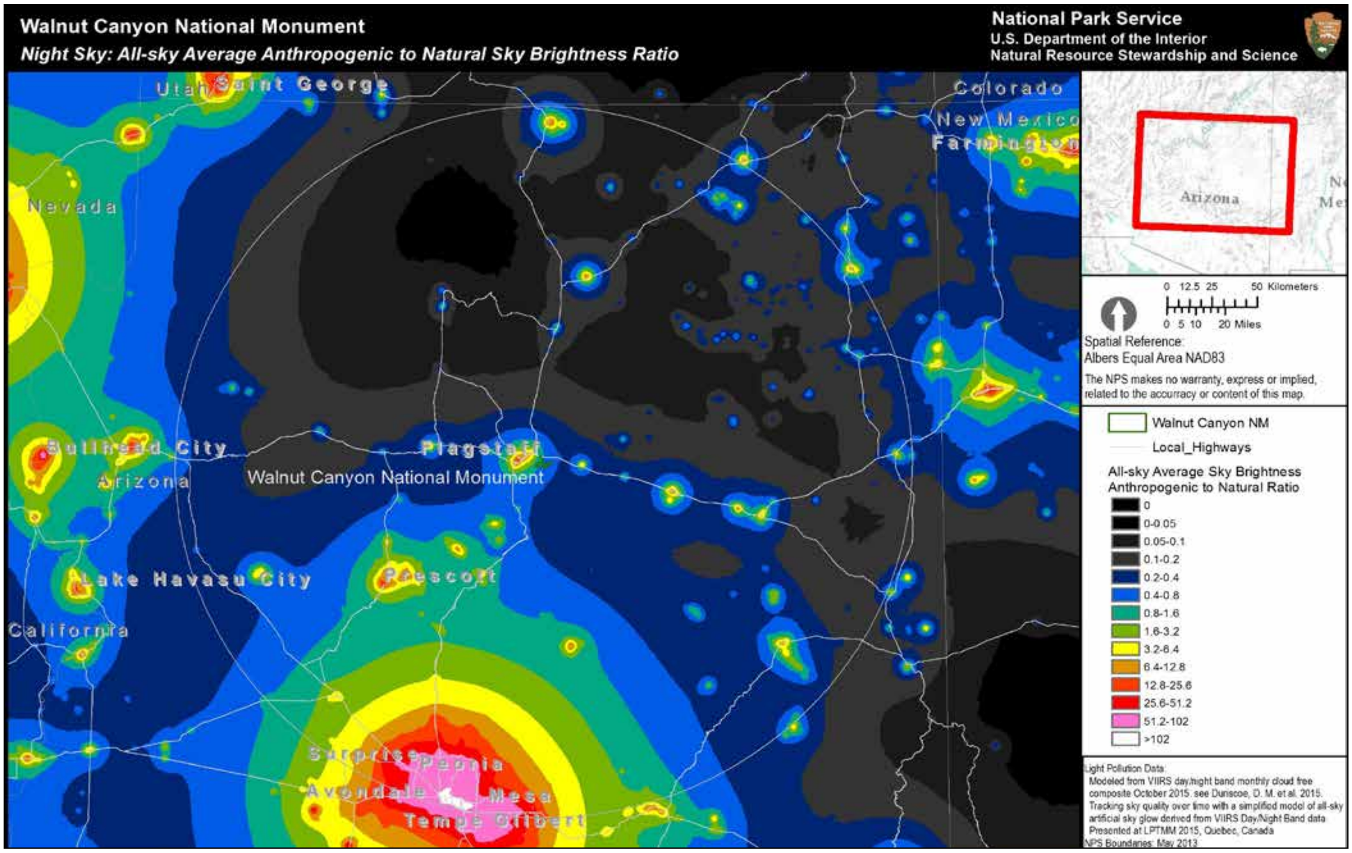


Figure 4.2.4-1. Modeled ALR map for Walnut Canyon National Monument. A 200 km ring around the park illustrates the distance at which anthropogenic light can impact night sky quality within the monument. Figure Credit: NPS Natural Sounds and Night Skies Division.

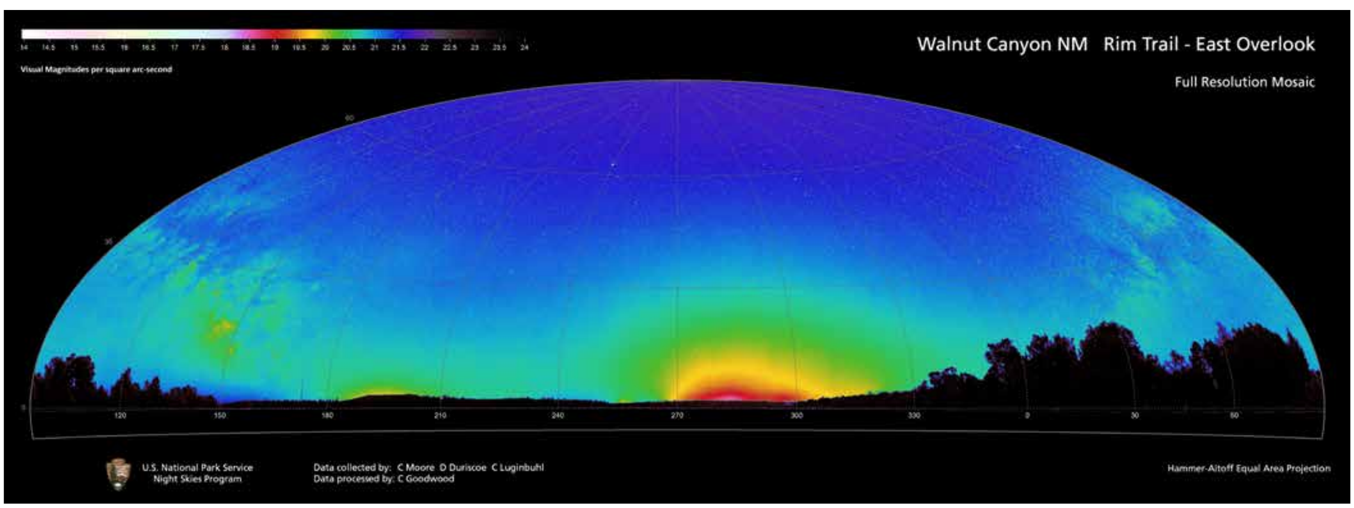


Figure 4.2.4-2. Panoramic all-sky mosaic of all light sources on May 12, 2002 in Walnut Canyon National Monument. Light sources include natural and anthropogenic. Figure Credit: NPS Natural Sounds and Night Skies Division.

conditions. We could not determine trend based on the four sampling dates.

Horizontal Illuminance (milli-Lux)

Observed horizontal illuminance ranged from 1.03 to 1.14 milli-Lux, which corresponds to an LPR of 19% to 34% brighter than average natural conditions. The NSNSD recommends a threshold of 0.8 milli-Lux, which was exceeded during all four monitoring dates. However, since there are no thresholds for good condition, moderate concern, or significant concern, we did not assign a condition for this measure.

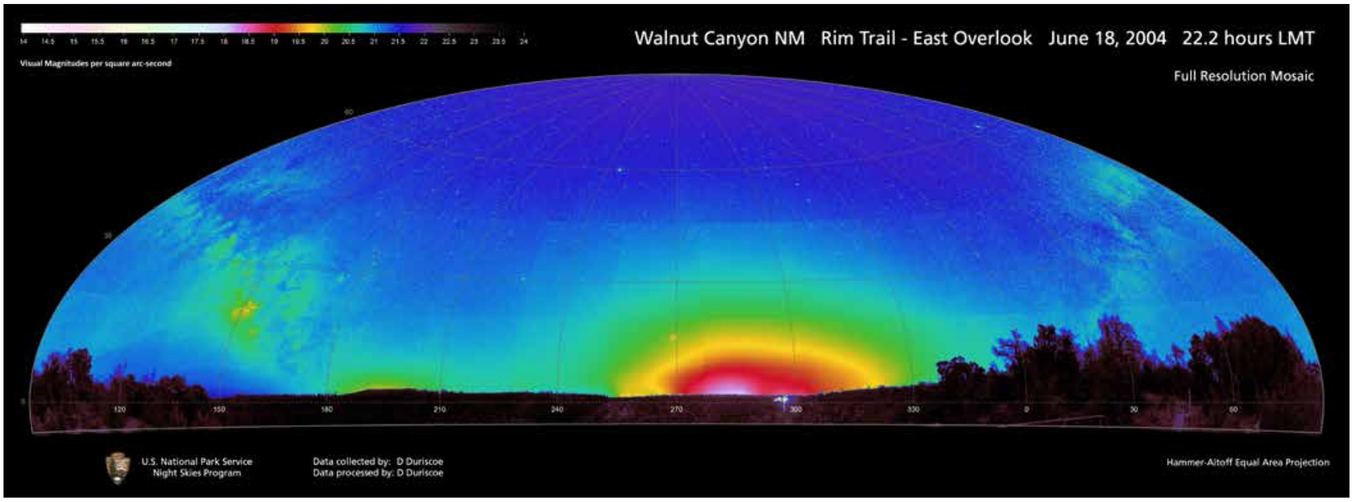


Figure 4.2.4-3. Panoramic all-sky mosaic of all light sources on June 18, 2004 in Walnut Canyon National Monument. Light sources include natural and anthropogenic. Figure Credit: NPS Natural Sounds and Night Skies Division.

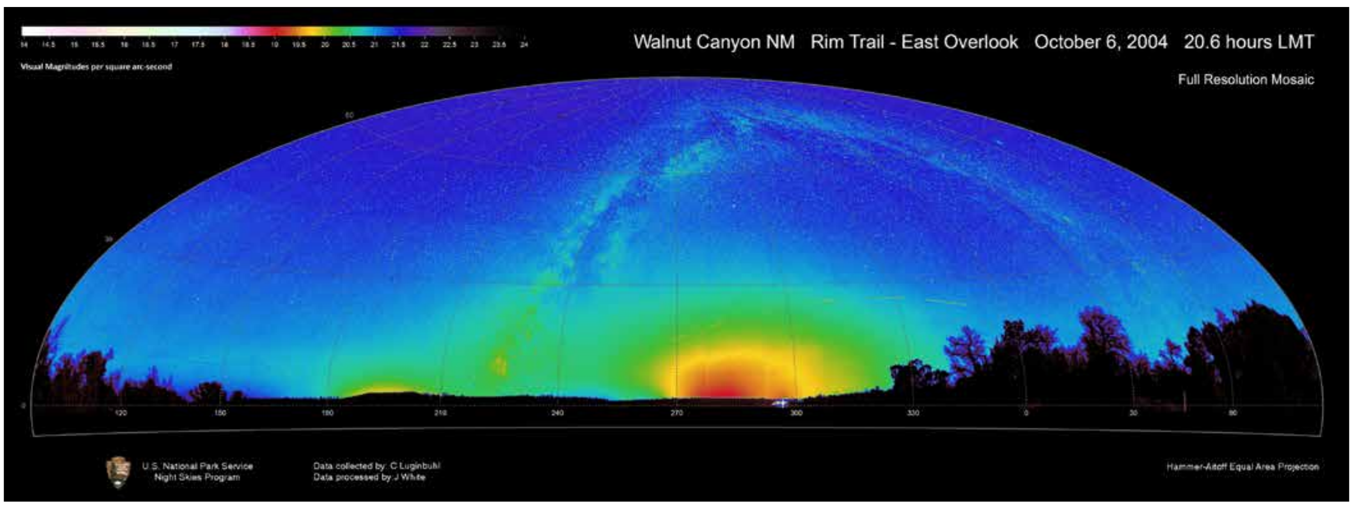


Figure 4.2.4-4. Panoramic all-sky mosaic of all light sources on October 6, 2004 in Walnut Canyon National Monument. Light sources include natural and anthropogenic. Figure Credit: NPS Natural Sounds and Night Skies Division.

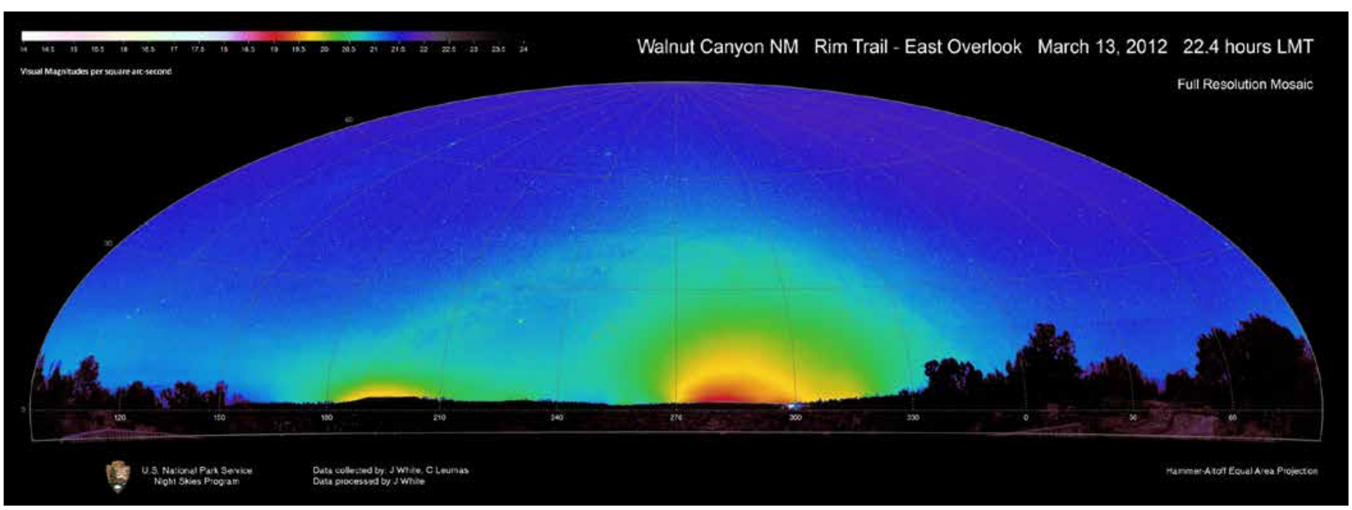


Figure 4.2.4-5. Panoramic all-sky mosaic of all light sources on March 13, 2012 in Walnut Canyon National Monument. Light sources include natural and anthropogenic. Figure Credit: NPS Natural Sounds and Night Skies Division.

Confidence is low due to lack of reference conditions. We could not determine trend based on the four sampling dates.

Zenith Sky Brightness (msa)
Zenith sky brightness varied from 21.02 to 21.76 msa. All but one of these values were above the threshold of 21.60 msa, which indicates good condition for this measure. Although the value for October 6, 2004 warrants significant concern, we consider this measure of illuminance to be in good condition since this values appears to be an outlier. The corresponding LPR measurements for zenith sky brightness ranged from 10% to 29% brighter than average natural conditions. We assigned high confidence to this condition rating since the data were collected in the field and as recently as March 2012. We could not determine trend based on the four sampling dates.

Bortle Dark Sky Scale
NSNSD observers estimated the night sky quality to class 4 on all four monitoring dates, which corresponds to a rural to suburban transition. While the Milky Way was still evident, its finer details were lost. Under a Bortle class 4, light domes are obvious and the sky appears brighter than the terrain. The Bortle class designation is somewhat subjective depending on the observer, but was consistent on all nights of data collection. A Bortle class 4 designation warrants moderate concern for this measure of sky quality. We assigned medium confidence to this condition rating since this measure is subjective and observer dependent. We could not determine trend based on the four sampling dates.

Overall Condition, Trend, Confidence, and Key Uncertainties
Overall, we consider the night sky at Walnut Canyon NM warrant moderate concern with an unknown trend and high overall confidence level in the condition rating. For a summary of indicators, measures, and their condition see Table 4.2.4-2. The overall condition rating and confidence level were based on the three measures for which condition thresholds have been developed. These measures were all-sky light pollution ratio, zenith sky brightness, and the Bortle dark sky class designation.

Those measures for which confidence in the condition rating was high were weighted more heavily in the overall condition rating than measures with medium confidence. None of the measures were assigned low confidence. Factors that influence confidence level include age of the data (<5 yrs unless the data are part of a long-term monitoring effort), repeatability, field data vs. modeled data, and whether data can be extrapolated to other areas in the monument. Two of the three measures were given a high confidence level since the majority of data were collected in the field with data acquired as recently as 2012. The Bortle dark sky scale, which is based on qualitative observations of the night sky, is somewhat subjective and was therefore, assigned medium confidence. Although the data used in this assessment spans an 11-year period, data collection occurred on only four nights, which is insufficient to determine trend. However, over time, and in conjunction with other measurements, these data will provide a robust dataset with which to monitor and assess the night sky environment at Walnut Canyon NM.

Regional and Local Context
Walnut Canyon NM preserves a dark night sky rarely found in park's so close to urban centers, an attribute acknowledged by its designation as an International Dark Sky Park in 2016. Criteria for this designation are stringent and require a plan to preserve dark night skies (IDA 2016). To this end, monument staff are committed to long-term monitoring of night skies in addition to continuing outreach and education programs highlighting the monument's nocturnal landscape (NPS 2016a). In 2016, NPS staff purchased three basic Unihedron Sky Quality Meter devices to be shared among the three Flagstaff area monuments and has created a data collection form to support long-term sky quality monitoring (NPS 2016a).

Although the city of Flagstaff, Arizona (population 65,870) is located only 11 km (7 mi) west of the monument, its light dome is only faintly visible and does not significantly interfere with the monument's dark sky environment (NPS 2016a). The city of Flagstaff, Arizona is a leader in preserving dark night skies and was the first community to receive the Dark Sky designation by the IDA in 2001 (IDA 2016). Lowell Observatory located within the city limits provides numerous educational opportunities for the local community to participate in star gazing events and learn about the importance of dark night skies for aesthetics, wildlife, human health, and as a cultural resource. Although the population of Flagstaff, Arizona is expected to grow, city lighting ordinances will limit

Table 4.2.4-2. Summary of night sky indicators, measures, and condition rationale.

Indicators of Condition	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Sky Brightness	All-sky Light Pollution Ratio (ALR)		The modeled ALR (0.80) was higher than ground-based measurements. Ground-based ALR varied from 0.39 to 0.71, which corresponds to a range of 39% to 71% brighter than average natural conditions. Since all ALR measurements, modeled and ground-based, were greater than 0.33 but less than 2.00, we consider this measure to warrant moderate concern. We could not determine trend based on the four nights of sampling. Confidence in this condition rating is high since it was based on four ground-based measurements and a modeled estimate.
	Vertical Maximum Illuminance (milli-Lux)		The condition for this measure is indeterminate since condition class thresholds have not been developed by the NSNSD; however, measurements exceeded the recommended threshold of 0.4 milli-Lux developed by the NSNSD on two of the four nights data were collected. There were insufficient data to determine trend since measurements were collected on only four nights. Confidence in this condition rating is low due to lack of reference values.
	Horizontal Illuminance (milli-Lux)		The condition for this measure is indeterminate since condition class thresholds have not been developed by the NSNSD; however, data from all four monitoring dates exceeded the recommended threshold of 0.8 milli-Lux. There were insufficient data to determine trend since measurements were collected on only four nights. Confidence in this condition rating is low due to lack of reference values.
	Zenith Sky Brightness (MSA)		Zenith sky brightness varied from 21.02 to 21.76 MSA. All but one of these values were above the threshold of 21.60 msa, which indicates good condition for this measure. The measure from October 6, 2004 warrants significant concern, but may be an outlier. There were insufficient data to determine trend since measurements were collected on only four nights. Confidence in this condition rating is high since it was based on four ground-based measurements.
Sky Quality	Bortle Dark Sky Scale		NSNSD observers estimated the night sky quality to class 4 on all monitoring dates, which corresponds to a rural to suburban transition. While the Milky Way was still evident, its finer details were lost. Under a Bortle class 4, light domes are obvious and the sky appears brighter than the terrain. The Bortle class designation warrants moderate concern for this measure of sky quality. Trend could not be determined based on these four measurements. Since several factors influence Bortle classification, including observer variability and airglow, confidence in this condition rating is medium.
Overall Condition			Walnut Canyon NM nocturnal landscape warrants moderate concern. Two of the three measures for which thresholds have been developed were met the threshold for moderate concern. Although field data were collected over a 11-year period (2002-2012), there were only four data points. Therefore, trend could not be determined. Confidence in these data is high.

light pollution in the area, thereby contributing to the preservation of dark night skies in Walnut Canyon NM.

Threats, Issues, and Data Gaps

Although Flagstaff, Arizona and Walnut Canyon NM have implemented plans to preserve dark night skies, light pollution from the city and surrounding area may have unwanted effects on the monument's nocturnal landscape, especially if the Flagstaff area grows in population. Arizona is the fourth fastest growing state in the U.S. (NPS 2016a, U.S. Census Bureau 2016). Continued growth of urban centers such as Phoenix, Arizona (population 1,445,632) may degrade Walnut Canyon NM's dark night sky despite being 185 km (115 mi) away (NPS 2016a). The modeled ALR map shown in The Condition And Trend Section shows the influence of the Phoenix, Arizona metropolitan area light dome on the monument.

Effects of Artificial Lighting on Wildlife

Studies show that artificial lighting reduces nocturnal foraging by rodents, modifies patterns of communication among coyotes, stimulates nocturnal activity in birds that are normally diurnal, disorients insects and birds that migrate at night, and alters patterns of pollination by nocturnal moths (Longcore and Rich 2004). Despite these studies, the effects of artificial lighting are not well understood for most species. Walnut Canyon NM protects an unique ecosystem with varied topography that brings together many plants and animals that would not normally occur together (NPS 2015). The monument includes important habitat for many nocturnal species including canyon tree frog (*Hyla arenicolor*) (Figure 4.2.4-6) and Mexican spotted owl (*Strix occidentalis lucida*) (NPS 2015). Given the monument's designation as an International Dark Sky Park, the region has the potential to protect species that depend on the nocturnal landscape.

Figure 4.2.4-6. Canyon tree frog in Walnut Canyon NM.

4.2.5. Sources of Expertise

The NPS Natural Sounds and Night Skies Division (NSNSD) helps parks manage the night sky in a way that protects park resources and the visitor experience. They provide technical assistance to parks in the form of monitoring, data collection and analysis, and in developing baselines for planning and reporting purposes. For more information, see http://nps.gov/nsnsd.

Jeremy White and Li-Wei Hung, Natural Sounds and Night Skies Division, part of the NPS Natural Resource Stewardship and Science Directorate, provided information pertaining to night sky data collection methodology, interpretation of results, and comments on earlier drafts of this assessment.

Assessment author is Lisa Baril, science writer, Utah State University.

4.3. Soundscape

4.3.1. Background and Importance

Our ability to see is a powerful tool for experiencing our world, but sound adds a richness that sight alone cannot provide. In many cases, hearing is the only option for experiencing certain aspects of our environment, and an unimpaired acoustical environment is an important part of overall National Park Service (NPS) visitor experience and enjoyment, as well as vitally important to overall ecosystem health.

In a 1998 survey of the American public, 72% of respondents identified opportunities to experience natural quiet and the sounds of nature as an important reason for having national parks (Haas and Wakefield 1998). Additionally, 91% of NPS visitors "consider enjoyment of natural quiet and the sounds of nature as compelling reasons for visiting national parks" (McDonald et al. 1995) (Figure 4.3.1-1). Despite this desire for quiet environments, noise continues to intrude upon natural areas and has become a source of concern in national parks (Lynch et al. 2011).

A park's natural soundscape is an inherent component of "the scenery and the natural and historic objects and the wildlife" protected by the Organic Act of 1916. NPS Management Policies (§ 4.9) (2006) require preservation of parks' natural soundscapes and restoration of degraded soundscapes to natural conditions wherever possible. Additionally, NPS is required to prevent or minimize degradation of natural soundscapes from noise (i.e., any unwanted sound). Although the management policies currently refer to the term soundscape as the aggregate of all natural sounds that occur in a park, differences exist between the physical sound sources and human perceptions of those sound sources. Physical sound resources (e.g., wildlife, waterfalls, wind, rain, and cultural or historical sounds), regardless of their audibility, at a particular location, are referred to as the acoustical environment, while the human perception of that acoustical environment is defined as the soundscape. Clarifying this distinction will allow managers to create objectives for safeguarding both the acoustical environment and the visitor experience.

In addition, sound plays a critical role for wildlife communication. Activities such as courtship, predation, predator avoidance, and effective use of habitat rely on the ability to hear with studies showing that wildlife can be adversely affected by intrusive sounds. While the severity of impacts vary depending on the species and other conditions, documented responses of wildlife to noise include increased heart rate, startle responses, flight, disruption of behavior, separation of mothers and young, and interference with communication (Selye 1956, Clough 1982, USFS 1992, Anderssen et al. 1993, NPS 1994, Dooling

Figure 4.3.1-1. Winter in Walnut Canyon NM provides solitude for park visitors. Photo Credit: NPS.

and Popper 2007, Kaseloo 2006). Researchers have also documented wildlife avoidance behaviors due to increased noise levels (Shannon et al. 2015, McLaughlin and Kunc 2013). An interesting recent publication showed that even plant communities can be adversely affected by noise because key dispersal species avoid certain areas (Francis et al. 2012).

Walnut Canyon National Monument (NM) provides an increasingly rare opportunity for visitors to experience a natural soundscape. The monument's proximity to Flagstaff, Arizona provides a unique opportunity for park staff to engage visitors in appreciating and preserving the monument's natural soundscape through interpretive programs and guided hikes (NPS 2015). Furthermore, the monument's cliff dwellings provide visitors opportunities to contemplate previous cultures and experience a soundscape similar to the past.

Sound Characteristics

Humans and wildlife perceive sound as an auditory sensation created by pressure variations that move through a medium such as water or air. Sound is measured in terms of frequency (pitch) and amplitude (loudness) (Templeton and Sacre 1997, Harris 1998).

Frequency, measured in Hertz (Hz), describes the cycles per second of a sound wave and is perceived by the ear as pitch. Humans with normal hearing can hear sounds between 20 Hz and 20,000 Hz, but most people are sensitive to frequencies between 1,000 Hz and 6,000 Hz. High frequency sounds are more readily absorbed by the atmosphere or scattered by obstructions than low frequency sounds. Low frequency sounds diffract more effectively around obstructions, therefore, travel farther.

The amplitude (or loudness) of a sound, measured in decibels (dB), is logarithmic, which means that every 10 dB increase in sound pressure level (SPL) represents a tenfold increase in sound energy. This also means that small variations in SPL can have significant effects on the acoustical environment. For instance, a 6 dB reduction in background noise level would produce a 4x increase in listening area (Figure 4.3.1-2). Changes in background noise level cause changes in listening opportunity. These lost opportunities will approach a halving of alerting distance and a 75% reduction of listening area for each 6 dB increase in affected band level (Barber et al. 2010).

SPL is commonly summarized in terms of dBA (A-weighted SPL). This metric significantly discounts sounds below 1,000 Hz and above 6,000 Hz to approximate the variation in human hearing sensitivity.

4.3.2. Data and Methods

Baseline acoustical monitoring data for Walnut Canyon NM were collected by park natural resource staff. Acoustical monitoring systems were deployed at two locations within the national monument during the months of July and August 2010: Northeast Rim and Southeast Rim (Figure 4.3.2-1). The characteristics of both monitoring locations are summarized in Table 4.3.2-1.

Northeast Rim was located approximately 24 m (80 ft) from the canyon rim and was monitored for 30 days. The National Transportation Systems Center (Volpe Center) analyzed the data and produced a report (NPS 2013), which was coordinated as part of a technical assistance request with the NPS Natural Sounds and Night Skies Division (NSNSD). The objectives were to characterize existing sound levels, establish a baseline for future monitoring, and estimate natural ambient sound levels in support of the potential development of an air tour management plan (NPS 2013); however, the monument was exempted from producing an air tour management plan since fewer than 50 air tours are reported annually (NPS 2013).

Figure 4.3.1-2. A 6 dB reduction in background noise level would produce a 4x increase in listening area. Figure Credit: © Ted E. Dunn.

The Southeast Rim site was located at a remote location in the southeastern portion of the monument that was closest to the Northern Arizona Shooting Range. The objective was to determine noise levels associated with the shooting range, which is located approximately 1.2 km (0.75 mi) from the boundary of the monument. NPS staff became concerned about the effects of gunshot noise on wildlife and visitor enjoyment of the monument in addition to the effects of increased traffic along the unimproved access road through the Coconino National Forest, which comes within 0.8 km (0.5 mi) of the monument's southeast rim (NPS 2011c). This site was monitored for 22 days and the data were analyzed by the NSNSD.

Table 4.3.2-1. Location characteristics of acoustical monitoring sites at Walnut Canyon NM.

Location	Dates Deployed	Vegetation	Elevation
Northeast Rim	7/7/2010-8/5/2010 (30 days)	Shrubland	1,982 m (6,503 ft)
Southeast Rim	8/5/2010-8/27/2010 (22 days)	Evergreen Forest	2,029 m (6,657 ft)

% Time Above Reference Sound Levels

The percent time above reference sound levels is a measure of the amount of time that the sound level exceeds specified decibel values (NPS 2013). Research into the effects of noise on wildlife is rapidly developing, and observed responses to noise sources and sound levels have been found across a variety of species. In a literature review of the effects of noise on wildlife, Shannon et al. (2015) found that responses to noise can include "altered vocal behavior to mitigate masking, reduced abundance in noisy habitats, changes in vigilance and foraging behavior, and impacts on individual fitness and the structure of ecological communities." Of the organisms studied, wildlife responses were observed at noise levels as low as 40 dBA, and further, 20% of studies documented impacts below 50 dBA. Human responses to sound levels can serve as a proxy for potential impacts to

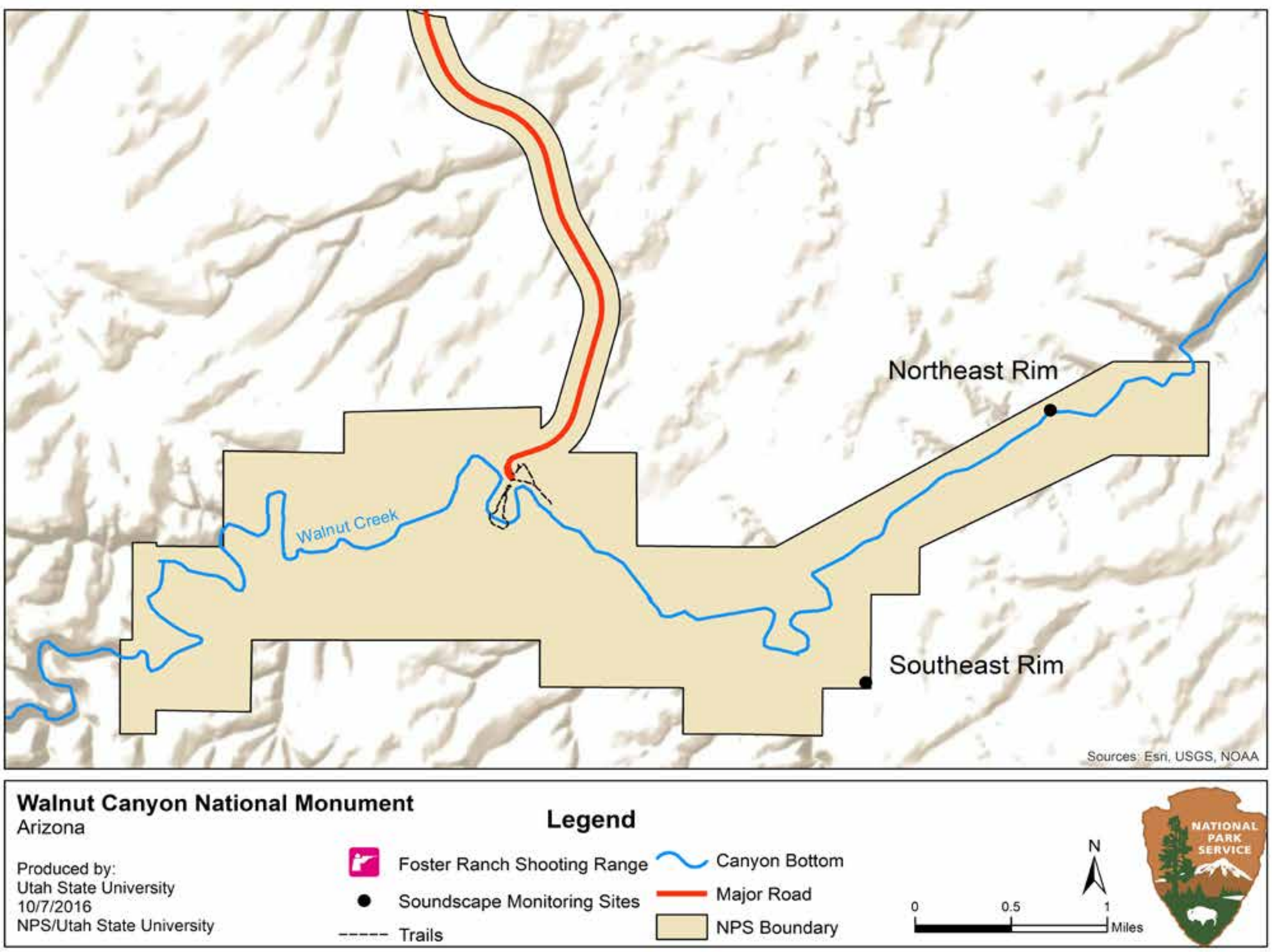


Figure 4.3.2-1. Locations of 2010 acoustical monitoring sites at Walnut Canyon NM. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction.

other vertebrates because humans have more sensitive hearing at low frequencies than most species (Dooling and Popper 2007). Table 4.3.2-2 summarizes sound levels that relate to human health and speech, as documented in the scientific literature.

The first, 35 dBA, is designed to address the health effects of sleep interruption. Recent studies suggest that sound events as low as 35 dBA can have adverse effects on blood pressure while sleeping (Haralabidis 2008). The second value addresses the World Health Organization's recommendations that noise levels inside bedrooms remain below 45 dBA (Berglund et al. 1999). The third value, 52 dBA, is based on the United States Environmental Protection Agency's (USEPA) speech interference threshold for speaking in a raised voice to an audience at 10 m (32.8 ft) (USEPA 1974). This threshold addresses the effects of sound on interpretive presentations in parks. The final value, 60 dBA, provides a basis for estimating impacts on normal voice communications at 1 m(3.3 ft).

Hikers and visitors viewing scenic vistas in the park would likely be conducting such conversations. The NSNSD determined the percent of time sound levels were above these four decibel reference levels for both day (7:00 am to 7:00 pm) and night (7:00 pm to 7:00 am) (NPS 2013) at Northeast Rim.

% Reduction in Listening Area

A one decibel change is not readily perceivable by the human ear, but any addition to this difference could begin to impact listening ability. To assess the condition of the acoustic environment, it is useful to consider the functional effects that increases in sound levels might produce. For instance, the listening area, the area in which a sound can be perceived by an organism, will be reduced when background sound levels increase. Seemingly small increases in sound level can have substantial effects, particularly when quantified in terms of loss of listening area as previously shown in Figure 4.3.1-2 (Barber et al. 2010). Each 3 dB increase in the background sound level will reduce a given listening area by half.

Failure to perceive a sound because other sounds are present is called masking. Masking interferes with wildlife communication, reproductive and territorial advertisement, and acoustic location of prey or predators (Barber et al. 2010). However, the effects of masking are not limited to wildlife. Masking also inhibits human communication and visitor detection of wildlife sounds. In urban settings, masking can prevent people from hearing important sounds like approaching people or vehicles, and interfere with the way visitors experience cultural sounds or interpretive programs.

To determine the effect noise from air tours and other aircraft has on the natural soundscape at Northeast Rim we calculated percent reduction in listening area from the natural ambient sound level to each of three sound level categories: existing ambient, existing ambient without air tour noise, and existing ambient without all aircraft noise. Air tour noise is distinguished from other aircraft noise because low-level fixed wing/propeller aircraft present unique sound signatures that are indicative of air tour activity. However, it is possible that some portion of these events were categorized erroneously as air tours. These metrics were reported as the level of sound that exceeded fifty percent of the time at a given location, or L_{50} (NPS 2013).

Natural ambient sound level refers to all naturally occurring sounds and excludes all anthropogenic noise. Existing ambient sound level includes all sounds in a given area, natural and anthropogenic. Existing ambient sound level without air tour noise includes all sounds, natural and anthropogenic, minus noise from air tours. Existing ambient sound level without all aircraft noise includes all sounds, natural and anthropogenic, minus noise from all aircraft, including

Table 4.3.2-2. Sound level values related to human health and speech.

Sound Levels (dBA)	Relevance
35	Blood pressure and heart rate increase in sleeping humans (Haralabidis et al. 2008)
45	World Health Organization's recommendation for maximum noise levels inside bedrooms (Berglund et al. 1999)
52	Speech interference for interpretive programs (USEPA 1974)
60	Speech interruption for normal conversation (USEPA 1974)

Source: NPS (2013).

air tours, commercial jets, military overflights, and any other aircraft. Existing ambient sounds levels were reported for both day (7:00 am to 7:00 pm) and night (7:00 pm to 7:00 am), while existing ambient sound levels without air tour noise and without all aircraft noise were reported for day only since this is when noise from aircraft is most likely to impact visitor enjoyment (NPS 2013).

To determine the effects of gunshot noise from the Northern Arizona Shooting Range, NPS staff conducted a 22-day monitoring effort at Southeast Rim. Over the 22 days, baseline information on existing ambient sound levels were collected. On August 26, 2010 the Northern Arizona Shooting Range conducted a firing test to assist the NPS in determining the effects of gunshot noise on the monument's acoustical environment. During the test day, different caliber rifles, revolvers, pistols, and shotguns were fired at three time periods: 7 a.m., 12 p.m., and 5 p.m. (Acoustical Consulting Services 2010). Using these data we calculated the percent reduction in listening area from reported existing ambient sound levels since natural ambient sound levels were not available. However, this is a reasonable comparison since the purpose was to determine the additional effects of gunshot noised on the acoustical environment.

<u>% Time Audible</u>
Percent time audible is the amount of time that various sound sources are audible to humans with normal hearing. It is a measure that correlates well with visitor complaints of excessive noise and annoyance. Most noise sources are audible to humans at lower levels than virtually all wildlife species. Therefore, percent time audible is a protective proxy for wildlife. The NSNSD determined the percent time audible of sounds in each of four categories (three anthropogenic and one natural), as follows: fixed-wing aircraft and helicopters, other aircraft sounds, other human sounds, and natural sounds. Data were gathered via in-situ site visits and by audio recordings collected at Northeast Rim and analyzed later.

<u>L_{50} Impact (Mennitt et al. 2013)</u>
The geospatial model estimated sound pressure levels for the continental United States by using actual acoustical measurements combined with a multitude of explanatory variables such as location, climate, landcover, hydrology, wind speed, and proximity to noise sources (e.g., roads, railroads, and airports). The 270-meter (886-feet) resolution model predicts daytime sound levels during midsummer. Each square of color maps generated from this effort represents 270 m^2 (2,960 ft^2), and each pixel on the map represents a median sound level (L_{50}). It should be noted that while the model excels at predicting acoustic conditions over large landscapes, it may not reflect recent localized changes such as new access roads or development.

Model parameters useful for assessing a park's acoustic environment include the understanding of a) natural conditions, b) existing acoustic conditions including both natural and human-caused sounds, and c) the impact of human-caused sound sources in relation to natural conditions. The L_{50} impact condition demonstrates the influence of human activities to the acoustic environment and is calculated by zeroing all anthropogenic factors in the model and recalculating ambient conditions. It is effectively the difference between existing and natural condition.

4.3.3. Reference Conditions
Table 4.3.3-1 summarizes the condition thresholds for measures in good condition, those warranting moderate concern, and those warranting significant concern.

<u>% Time Above Reference Sound Levels</u>
We used decibel levels presented in Table 4.3.2-2 as thresholds to separate the three reference conditions displayed in Table 4.3.3-2 (USEPA 1974, Berglund et al. 1999, and Haralabidis et al. 2008). If sound levels were below the World Health Organization's recommended maximum noise level in bedrooms (45 dBA), then we considered the condition to be good. If sound levels were above that which is expected to cause speech interference for interpretive programs, we considered the condition to warrant significant concern.

<u>% Reduction in Listening Area</u>
Walnut Canyon NM is considered a non-urban park, or park with at least 90% of their land located outside an urban area. Parks outside an urban area are usually quieter and more susceptible to noise intrusions (Turina et al. 2013). Visitors likely have a greater expectation for quiet at non-urban parks and wildlife are likely more adapted to a noise-free environment. Therefore, the thresholds separating reference conditions for non-urban parks are more stringent than for those located in urban areas. A reduction in listening area of 30% would indicate good condition,

Table 4.3.3-1. Reference conditions used to assess the sound levels at Walnut Canyon NM.

Indicator	Measure	Good	Moderate Concern	Significant Concern
Sound Level	% Time Above Reference Sound Levels	The majority of sound levels recorded were <45 dBA.	The majority of sound levels recorded were between 45 - 52 dBA.	The majority of sound levels recorded were >52 dBA.
	% Reduction in Listening Area*	Listening area was reduced by ≤ 30% over natural ambient sound levels.	Listening area was reduced by 30-50% over natural ambient sound levels.	Listening area was reduced by >50% over natural ambient sound levels.
Audibility of Anthropogenic Sounds	% Time Audible	Dominant sounds are consistent with the non-urban setting of the monument. Natural ambient sounds such as wind, birds singing, thunder claps, etc. dominate, but some sounds related to recreational activities, and/or traffic are also sometimes audible.	Dominant sounds are generally consistent with the park's non-urban setting, but noise occurs more frequently and noise from the adjacent highways, etc., begins to infiltrate the area.	A high percentage of the audible sounds heard are from noises such that the natural and/or cultural sense of place is compromised; therefore, the enjoyment of visitors is compromised.
Geospatial Model	L_{50} Impact*	≤ 1.5	1.5 - ≤ 3.0	>3

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

while a more than 50% reduction in listening area would warrant significant concern (Turina et al. 2013).

<u>% Time Audible</u>
We considered this measure to be in good condition if the dominant sounds at Northeast Rim were natural. While some anthropogenic noise is expected, it generally does not interfere with the natural soundscape. In contrast, if the dominant sounds are from anthropogenic sources, then we consider this measure to warrant significant concern.

<u>L_{50} Impact (Mennitt et al. 2013)</u>
Reference conditions for this measure were developed by Turina et al. 2013 and are presented in Table 4.3.3-2. We used thresholds for non-urban parks, which are those with at least 90% of their land located outside an urban area (Turina et al. 2013).

4.3.4. Condition and Trend

<u>% Time Above Reference Sound Levels</u>
Figure 4.3.4-1 shows the percent time sound levels were above the reference sound levels at the Northeast Rim monitoring site during day (7 a.m. - 7 p.m.) and night (7 p.m. - 7 a.m.) hours. The 35 dBA sound level was exceeded approximately 25% of time during the day and 30% of the time at night. This pattern is usually typical of places with high nocturnal insect activity, but at Walnut Canyon the greater proportion of time above 35 dBA during night than during the day was attributed to highway traffic and train activity despite the monitoring site's relatively remote location (NPS 2013). However, sound levels rarely exceeded 45 dBA day or night, which is the World Health Organization's recommendation for maximum noise level in bedrooms; therefore, we considered this measure to be in good condition at the Northeast Rim monitoring site. Confidence in this condition rating is high, but since data were collected at this site for one season only, trend could not be determined.

<u>% Reduction in Listening Area</u>
Existing Ambient L_{50} dBA
Table 4.3.4-1 summarizes ambient daytime sound level data for Northeast Rim. L_{50} represents the level of sound exceeded 50% of the time during the given measurement period. The daytime existing ambient L_{50} value was 29.7 dBA. At night existing ambient sound levels were higher at 31.7 dBA (data not shown in Table 4.3.4-1). Daytime values exceeded the baseline condition (median L_{NAT}) by 7.6 dBA, which corresponds to a reduction in listening area over natural ambient sound levels of 83%. Since the reduction in listening area was greater than 50% this measure warrants significant concern.

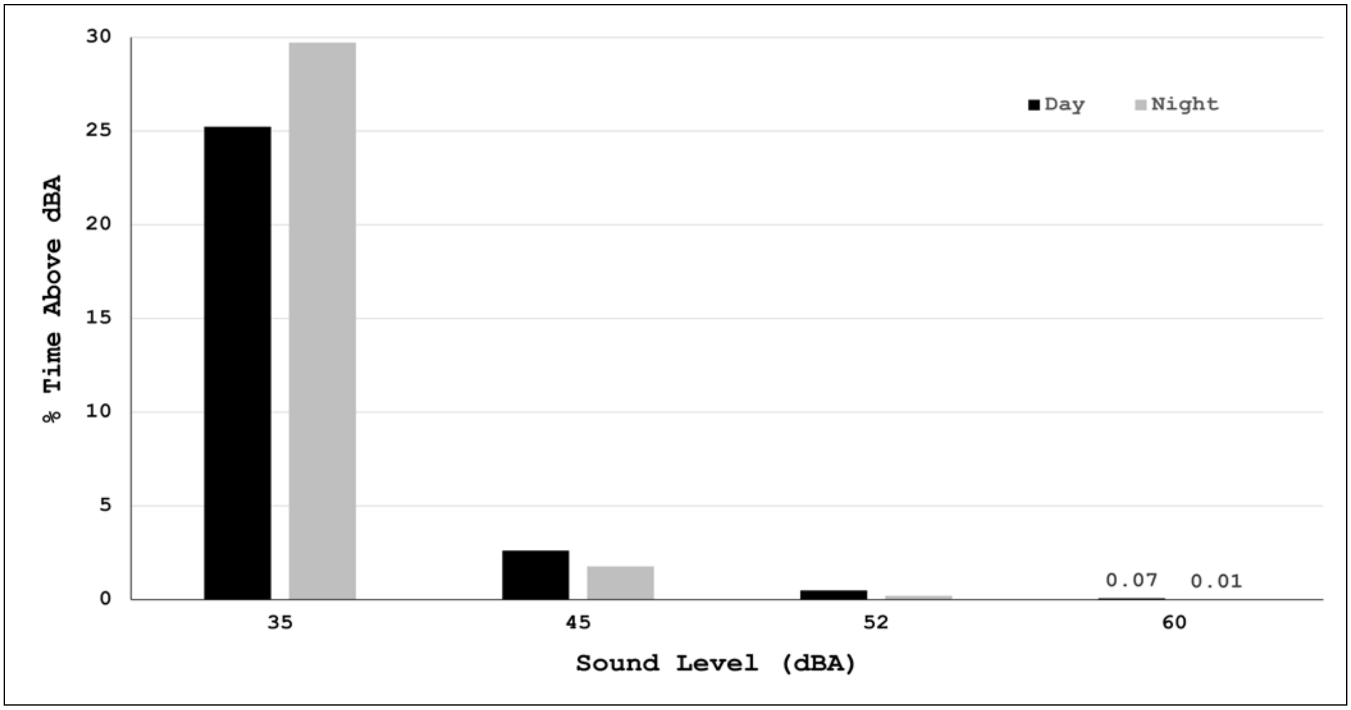


Figure 4.3.4-1. Percent time above reference sound levels at Northeast Rim in Walnut Canyon NM.

Existing Ambient L_{50} w/out Air Tour Noise

Existing ambient sound level without air tour noise was slightly lower than existing ambient values, but still greater than natural ambient values (Table 4.3.4-1). At Northeast Rim this measure exceeded natural ambient conditions by 6.7 dBA, which corresponds to a listening area reduction of 79%. By eliminating the air tour events, the listening area increased by only about 4 percentage points over existing ambient conditions. Although some sound signatures may have been erroneously categorized as air tours, these types of overflights are not common at Walnut Canyon NM. Since 2013, 0 air tours have been reported over the monument (FAA 2014, 2015, 2016). Since the listening area was reduced by 79% over natural ambient sound levels, this measure warrants significant concern.

Existing Ambient L_{50} w/out All Aircraft

Compared with the other measures, existing ambient sound levels without all aircraft sound exhibited the lowest values except for natural ambient sound levels. At Northeast Rim the natural ambient sound level was exceeded by 5.2 dBA. This resulted in a listening area reduction of 70%. Since the listening area was reduced by more than 50%, the condition for this measure warrants significant concern.

Existing Ambient L_{50} with Gunshot Noise

The median existing ambient sound level over the 22 days of monitoring at Southeast Rim was 25 dbA. This was slightly higher than natural ambient sound levels and lower than existing ambient sound levels at Northeast Rim. During test shooting, sound levels ranged from 30 dBA to 60 dBA with most shots centered around either 38 dBA or 55 dBA. These latter values correspond to a listening area reduction of 95% to 100%, which warrants significant concern for the Southeast Rim monitoring location.

Overall Summary

All three measures of reduction in listening area with respect to aircraft noise warrant significant concern,

Table 4.3.4-1. Ambient daytime (7:00 am to 7:00 pm) sound levels at Northeast Rim in Walnut Canyon NM.

Site Location	Natural Ambient L_{50} (dBA)	Existing Ambient L_{50} (dBA)	Existing Ambient w/out Air Tours L_{50} (dBA)	Existing Ambient w/out All Aircraft L_{50} (dBA)
Northeast Rim	22.1	29.7 (83%)	28.8 (79%)	27.3 (70%)

Note: Percentages indicate reduction in listening area over natural ambient conditions.

which suggests that aircraft noise is not the dominant source of existing ambient noise levels. If aircraft noise dominated the acoustical environment, the listening area would have substantially improved as the different levels of aircraft noise were removed from the data. Gunshot noise from the Northern Arizona Shooting Range indicate near complete masking of existing ambient sounds from the Southeast Rim. Gunshot noise could also be heard clearly from several other locations in the monument, including the visitor center, entrance station, and remote regions of the monument (NPS, C. Schelz, Ecologist, written comments to the joint Flagstaff City Council-Coconino County Board of Supervisors, 18 January 2011). Based on these data, the overall condition for reduction in listening area warrants significant concern at both monitoring locations. Confidence in this condition rating is high since these data were based on in situ field measurements and analysis in the lab by the NSNSD and the Volpe Center. Since data were collected during one season only, we could not determine trend.

% Time Audible

A detailed analysis of audibility at Northeast Rim (Figure 4.3.4-2) found that human sounds, mostly vehicles, contributed significant amounts of noise to the acoustical environment (49%). This is supported by data presented in the previous measure. Aircraft were audible 27% of daytime hours, while natural sounds were audible 24% of daytime hours. Noise from vehicles and aircraft has the potential to mask natural sounds that provide a sense of place and add to the natural character at Walnut Canyon NM. Based on reference conditions we consider the condition to warrant significant concern at Northeast Rim. Since these data are based on in situ field measurements and analysis in the lab by the Volpe Center, confidence is high. Trend could not be determined based on these data.

L_{50} Impact (Mennitt et al. 2013)

Figure 4.3.4-3 shows the modeled mean impact sound level map for the monument. The modeled mean impact was 1.30 dBA above natural conditions but ranged from 0 dBA in the least impacted areas to 8.80 dBA in the most impacted areas. The map depicts the area most influenced by human-caused sounds (i.e., lighter areas). The existing and natural acoustic environment condition maps for the monument are included in Appendix D.

Summary statistics of the L_{50} values for the natural, existing, and impact conditions are provided in Table 4.3.4-2. Average values represent the average L_{50} value occurring within the monument boundary, and since this value is a mean, visitors may experience sound levels higher and lower than the average L_{50}. A one decibel change is not readily perceivable by the human ear, but any addition to this difference could begin to impact a visitor's listening ability to hear natural sounds or interpretive programs.

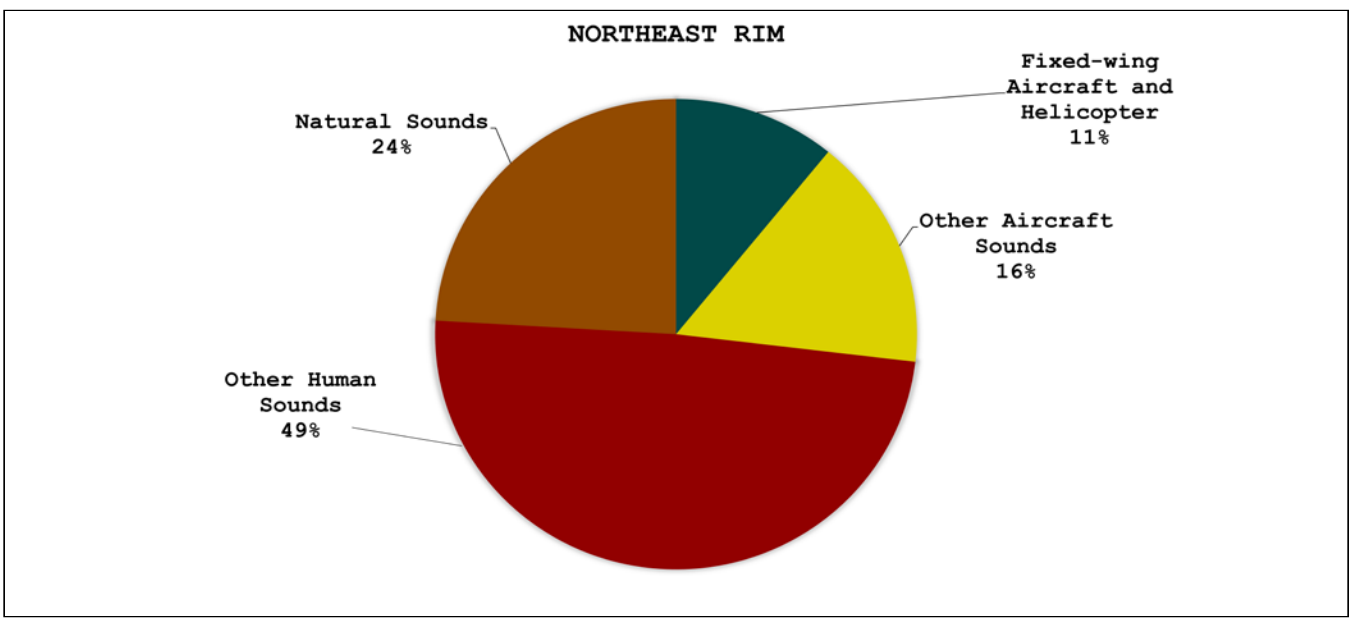


Figure 4.3.4-2. Percent time various sounds were audible at Northeast Rim in Walnut Canyon NM.

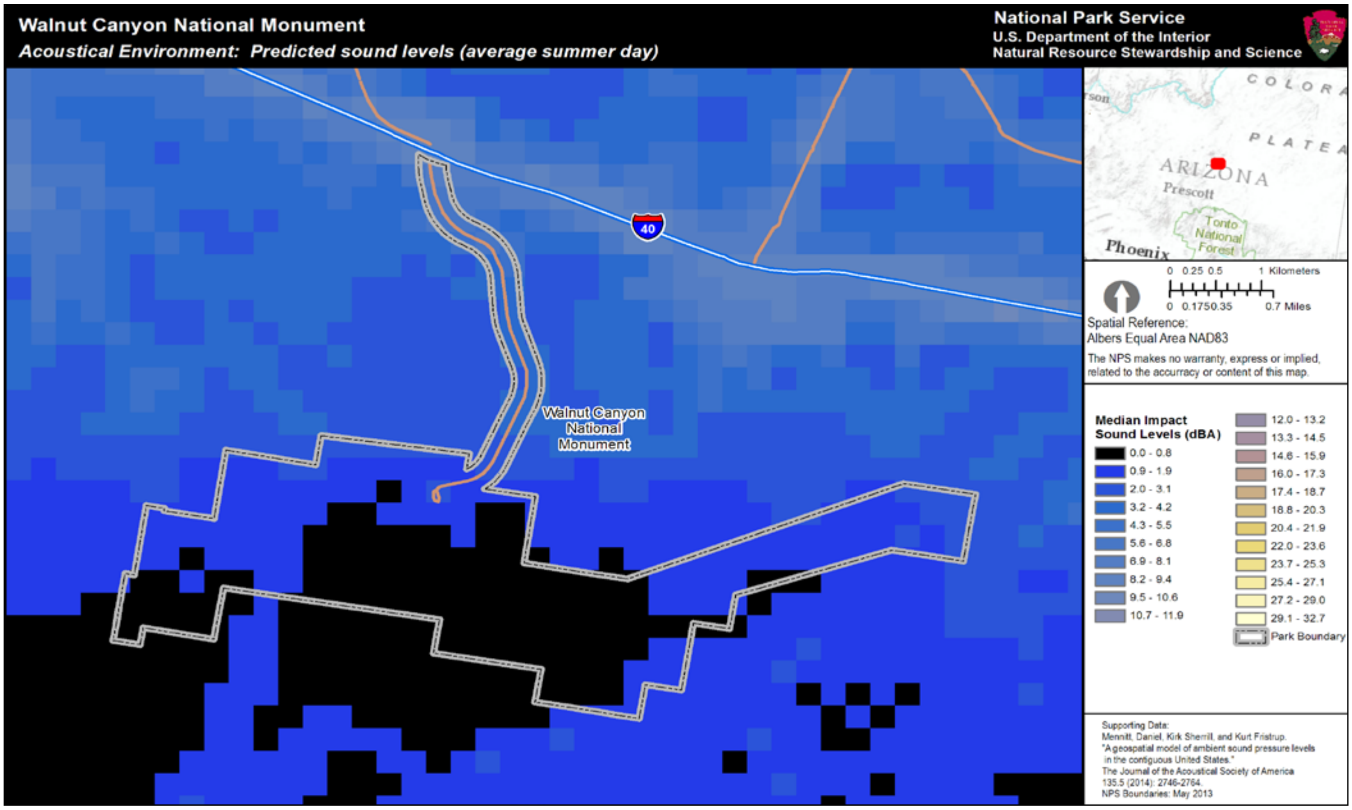


Figure 4.3.4-3. The modeled L_{50} impact sound level at Walnut Canyon NM. Lighter colors represent higher impact areas. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction. Figure Credit: Emma Brown, NPS NSNDS.

Mennitt et al. (2013) suggest that in a natural environment, the average summertime L_{50}, which is the sound level exceeded half of the time (and is a fair representation of expected conditions) is not expected to exceed 41 dBA. However, acoustical conditions vary by area and depend on vegetation, landcover, elevation, climate, and other factors (Mennitt et al. 2013). Any one place may be above or below this average depending on these and other variables. Mennitt et al. (2013) also state that "an impact of 3 dBA suggests that anthropogenic noise is noticeable at least 50% of the hour or more." The modeled median impact result for the monument was below 1.5 dBA, thus the L_{50} Impact was considered to be in good condition according to the reference thresholds developed by Turina et al. (2013). Since these data are modeled, confidence is medium. Trend could not be determined based on these data.

Overall Condition, Trend, Confidence Level, and Key Uncertainties

Overall, we consider the soundscape at Walnut Canyon NM to warrant moderate concern. This condition rating was based on three indicators with a total of four measures, which are summarized in Table 4.3.4-3. In sum, noise levels were greater at night than during the day, and most noise was attributed to vehicles and trains, although noise from aircraft was also audible in the monument. Although anthropogenic noise dominated the monument's soundscape, the proportion of time decibels were above reference conditions was relatively low, especially for sounds greater than 45 dBA. Lastly, the geospatial model indicates good condition across the monument.

Table 4.3.4-2. Summary of the modeled minimum, maximum, and average L_{50} measurements in Walnut Canyon NM.

Acoustic Environment	Min. (dBA)	Max. (dBA)	Avg. (dBA)
Natural	28.96	31.61	30.07
Existing	29.80	37.92	31.41
Impact	0.00	8.80	1.30

Source: Emma Brown, NPS NSNSD.

Table 4.3.4-3. Summary of soundscape indicators, measures, and condition rationale.

Indicators of Condition	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Sound Level	% Time Above Reference Sound Levels		Sound levels rarely exceeded 45 dBA day or night, which is the World Health Organization's recommendation for maximum noise level in bedrooms; therefore, we considered this measure to be in good condition. Confidence in this condition rating is high, but since data were collected at this site for one month, trend could not be determined.
	% Reduction in Listening Area		All three measure of reduction in listening area with respect to aircraft noise warrant significant concern, which suggests that aircraft noise is not the dominant source of existing ambient noise levels. Gunshot noise from the Northern Arizona Shooting Range indicate near complete loss of existing ambient sounds from the Southeast Rim. Gunshot noise could also be heard clearly from several other locations in the monument. The confidence in this condition rating is high since these data are based on in situ field measurements and analysis in the lab by the Volpe Center and NSNSD. Since data were collected during one season only, we could not determine trend.
Audibility of Anthropo-genic Sounds	% Time Audible		Human sounds, mostly vehicles, contributed significant amounts of noise to the acoustical environment (49%). Aircraft were audible 27% of daytime hours, while natural sounds were audible 24% of daytime hours. Based on reference conditions we consider the condition to warrant significant concern at Northeast Rim. Since these data are based on in situ field measurements and analysis in the lab by the Volpe Center, confidence is high. Trend could not be determined based on these data.
Geospatial Model	L_{50} Impact		The modeled mean impact sound level map for the monument was 1.30 dBA above natural conditions but ranged from 0 dBA in the least impacted areas to 8.80 dBA in the most impacted areas. Since the modeled median impact results for the monument was below 1.5, the L_{50} Impact was considered to be in good condition. Since these data were modeled, confidence is medium. Trend could not be determined based on these data.
Overall Condition			Overall, we consider the soundscape at the national monument to warrant moderate concern. Noise levels were greater at night than during the day, and most noise was attributed to vehicles and trains, although noise from aircraft was also audible in the monument. Although anthropogenic noise dominated the monument's soundscape, the proportion of time decibels were above reference conditions was relatively low, especially for sounds greater than 45 dBA. Lastly, the geospatial model indicates good condition across the monument. Trend in sound levels is unknown and confidence in the data is high.

Those measures for which confidence in the condition rating was high were weighted more heavily in the overall condition rating than measures with medium confidence. None of the condition ratings were assigned low confidence. Factors that influence confidence in the condition rating include age of the data (<5 yrs unless the data are part of a long-term monitoring effort), repeatability, field data vs. modeled data, and whether data can be extrapolated to other areas of the monument. Only one of the four measures, L_{50} impact, was given a medium confidence rating since it was based on modeled data. Although we assigned this measure medium confidence, the model provides a useful map of how sound may vary across the monument. The remaining measures were assigned high confidence since they were based on field data despite being six years old, although we acknowledge that these data may not reflect current condition. Since data were collected during one season (2010), we could not determine trend.

Approximately 93% of the monument lies within the Resource Preservation Zone, an area of limited access (NPS 2007a). The monument's developed area footprint, which includes the visitor center, employee housing, and administrative buildings, is relatively small and limits human-caused noise produced from within the monument. Both locations monitored in this study were within the Resource Preservation Zone. Despite this protection, anthropogenic noise contributed significantly to the monument's acoustical environment and this may be a reflection of the monument's highly linear landscape and proximity to the city of Flagstaff, AZ, which is located 11 km (7 mi) west of the monument. Most of the anthropogenic noise was associated with sounds produced outside the monument such as vehicles, trains, aircraft, and gunshots from the Northern Arizona Shooting Range. Even without aircraft, anthropogenic noise remained high and listening area increased only somewhat. Data presented in this assessment show that these sources of noise tend to be loudest at night (except for gunshots from the Northern Arizona Shooting Range).

The Arizona Game and Fish Department owns the shooting range and constructed large earthen berms for sound abatement, but gunfire is still audible from nearly all locations within the monument (NPS 2015). However, sound level testing in 2010 found noise levels during the test firing to be in compliance with state and local ordinances (NPS 2015). Although noise produced from the shooting range was within state and local ordinances, these sounds have the ability to mask other natural sounds that can interfere with the visitor experience of and influence wildlife behavior in the monument.

A key uncertainty is that these results may not fully represent typical sources of anthropogenic noise heard within the monument since data were collected during one season, and some sound signatures may be misidentified throughout the analysis process. Also, sound levels vary by time of day, with the weather, topography, and other factors (NPS 2013). The monument's complex topography results in high variability in sound levels depending on location (NPS, C. Schelz, Ecologist, written comments to the joint Flagstaff City Council-Coconino County Board of Supervisors, 18 January 2011). And finally, the information is already six years old (2010) and may no longer reflect current condition. Continued monitoring will provide more information about how and if Walnut Canyon NM's soundscape is changing.

<u>Threats, Issues, and Data Gaps</u>

In addition to the noise from gunshots, the increased traffic along the access road to the shooting range may influence sound levels within the monument, but this has not been evaluated. In places, the road comes within 0.8 km (0.5 mi) of the monument's boundary (NPS 2011c). The increased traffic may create dust and promote the spread of non-native plants. Although no air tours were reported during 2013-2015, other aircraft noise, including military overflights and high altitude commercial aircraft, is a regular disruption to the monument's solitude (NPS 1996).

Noise from Interstate 40 is nearly constant and can be heard from anywhere in the monument (NPS 1996). Currently, an estimated 1,866 to 5,215 vehicles travel along the Interstate 40 corridor every hour (NPS 2013), and traffic volume is likely to increase as the population of Flagstaff, AZ rises. Approximately 70,320 people live in Flagstaff as of July 1, 2015 (U.S. Census Bureau 2016a). This is a 6.4% increase since April 2010 and the population is expected to increase (U.S. Census Bureau 2016a). Arizona is the fourth fastest growing state in the U.S. based on projected percent change in population size from 1995 to 2025 (U.S. Census Bureau 2016b).

In addition to influencing our experience of the landscape, human-caused noise can influence the behavior and ability of wildlife to function naturally on the landscape as can frequency. With respect to the effects of noise, there is compelling evidence that wildlife can suffer adverse behavioral and physiological changes from noise and other human disturbances, but the ability to translate that evidence into quantitative estimates of impacts is presently limited (Shannon et al. 2015). In a review of literature addressing the effects of noise on wildlife published between 1990 and 2013, wildlife responses to noise were observed beginning at about 40 dBA, and further, 20% of papers showed impacts to terrestrial wildlife at or below noise levels of 50 dBA (Shannon et al. 2015). Wildlife response to noise was found to be highly variable between taxonomic groups. Furthermore, response to noise varied with behavior type (e.g., singing vs. foraging) (Shannon et al. 2015). One of the most common and readily observed biological responses to human noise is change in vocal communication. Birds use vocal communication primarily to attract mates and defend territories, but anthropogenic noise can influence the timing, frequency, and duration of their calls and songs (Shannon et al. 2015). Similar results have been found for some species of mammal, amphibians, and insects, which also rely on vocal communication for breeding and territorial defense. Other changes include changes in time spent foraging, ability to orient, and territory selection (Shannon et al. 2015).

Several sensitive bird species breed in Walnut Canyon NM, including golden eagles (*Aquila chrysaetos*), Mexican spotted owls (*Strix occidentalis lucida*), peregrine falcons (*Falco peregrinus*), and northern goshawks (*Accipiter gentilis*) (NPS 2011c).

Several recommendations have been made for human exposure to noise, but no guidelines exist for wildlife and the habitats we share. The majority of research on wildlife has focused on acute noise events, so further research needs to be dedicated to chronic noise exposure (Barber et al. 2010). In addition to wildlife, standards have not yet been developed to assess the quality of physical sound resources (the acoustic environment), separate from human or wildlife perception. Scientists are also working to differentiate between impacts to wildlife that result from the noise itself or the presence of the noise source (Barber et al. 2010). Walnut Canyon NM staff has continued to collect sound data to further evaluate changes in the monument's soundscape and possible effects anthropogenic noise may have on wildlife.

4.3.5. Sources of Expertise

The NPS Natural Sounds and Night Skies Division (NSNSD) scientists help parks manage sounds in a way that balances the various expectations of park visitors with the protection of park resources. They provide technical assistance to parks in the form of acoustical monitoring, data collection and analysis, and in developing acoustical baselines for planning and reporting purposes. For more information, see http://nps.gov/nsnsd.

Emma Brown, Acoustical Resource Specialist with the NSNSD, provided an NRCA soundscape template used to develop this assessment and the sound model statistics and maps.

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4.4. Air Quality

4.4.1. 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] 2012a) (Figure 4.4.1-1).

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 acres) or wilderness areas over 2,023 ha (5,000 acres) that were in existence when the CAA was amended in 1977 (NPS-ARD 2010). Walnut Canyon National Monument (NM) is designated as a Class II airshed. 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 Standards

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 2016a). The two types of NAAQS are primary and secondary, with the primary standards establishing limits to protect human health, and the secondary

Figure 4.4.1-1. A view of the canyon in Walnut Canyon NM on a sunny day. Photo Credit: NPS.

standards establishing limits to protect public welfare from air pollution effects, including decreased visibility, and damage to animals, crops, vegetation, and buildings (USEPA 2016a).

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.

Visibility can be subjective and value-based (e.g., a visitor's reaction viewing a scenic vista while observing a variety of forms, textures, colors, and brightness) (Figure 4.4.1-2), or it can be measured objectively by determining the size and composition of particles in the atmosphere that interfere with a person's ability to see landscape features (Malm 1999). The Viewshed assessment of this report addresses the subjective aspects of visibility, whereas this section addresses measurements of particles and gases in the atmosphere affecting 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 2017a). Ozone is also phytotoxic, causing foliar damage to plants (NPS-ARD 2003). 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 (Kohut 2004).

Ozone penetrates leaves through stomata (openings) and oxidizes plant tissue, which alters the physiological and biochemical processes (NPS-ARD 2012b). Once the ozone is inside the plant's cellular system, the chemical reactions can cause cell injury or even death (NPS-ARD 2012b), but more often reduce the plant's resistance to insects and diseases, reduce growth, and reduce reproductive capability (NPS-ARD 2012c).

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 2017a). 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 (Brooks 2003, 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).

Figure 4.4.1-2. A scenic view at Walnut Canyon NM. Photo Credit: NPS.

According to the USEPA (2016b), 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 2016b), including at Walnut Canyon 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 2017a).

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).

4.4.2. Data and Methods

The approach we used to assess the condition of air quality within Walnut Canyon NM's airshed was developed by the NPS-ARD for use in Natural Resource Condition Assessments (NPS-ARD 2015a,b). 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 are derived from all available monitors, data monitoring nearby stations "outweigh" more distant monitoring stations. Trends are computed from data collected over a 10-year period at on-site or nearby representative monitors. Trends are calculated for sites that have at least six years of annual data and an annual value for the end year of the reporting period.

<u>Haze Index</u>

Visibility is monitored by the Interagency Monitoring of Protected Visual Environments (IMPROVE) Program (NPS-ARD 2010). Visibility data were collected at the IMPROVE monitoring station SYCA1, AZ, which is located 42 km (26 mi) west of the monument. NPS-ARD considers stations located within 150 km (93 mi) of NPS units representative of Class II airsheds (NPS-ARD 2015a).

NPS-ARD assesses visibility condition status based on the deviation of the estimated current Group 50 visibility conditions from estimated Group 50 natural visibility conditions (i.e., those estimated for a given area in the absence of human-caused visibility impairment; USEPA-454/B003-005). Group 50 is defined as the mean of the visibility observations falling within the range of the 40th through the 60th percentiles, as expressed in terms of a Haze Index in deciviews (dv; NPS-ARD 2015a). A factor of the haze index is light extinction, which is used as an indicator to assess the quality of scenic vista and is proportional to the amount of light lost due to scattering or absorption by particles in the air as light travels a distance of one million meters. The haze index for visibility condition is calculated as follows:

Visibility Condition/Haze Index (dv) =
estimated current Group 50 visibility – estimated Group 50 visibility
(under natural conditions)

The deciview scale scores pristine conditions as a zero and increases as visibility decreases (NPS-ARD 2015a).

For visibility condition assessments, annual average measurements for Group 50 visibility are averaged over a 5-year period at each visibility monitoring site with at least 3-years of complete annual data. Five-year averages are then interpolated across all monitoring locations to estimate 5-year average values for the contiguous U.S. The maximum value within national monument 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.

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 data were collected at the Flagstaff, Arizona Middle School monitoring station (040051008), which is located 13.7 km (8.5 mi) west of the monument's visitor center. NPS-ARD considers stations located farther than 10 km (7 mi) of NPS units beyond the range that is representative for calculating trends in Class II airsheds (NPS-ARD 2015a). However, we reported the 5-year trends from 2008-2012 since the available monitoring station is close to the NPS-ARD distance threshold (5-year trends for 2011-2015 were not available).

Human Health: Annual 4th-highest 8-hr Concentration

The primary NAAQS for ground-level ozone is set by the USEPA, and is 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 October 1, 2015, the USEPA strengthened the national ozone standard by setting the new level at 70 ppb (USEPA 2016a). 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 are averaged over a 5-year period at all monitoring sites. Five-year averages are interpolated for all ozone monitoring locations to estimate 5-year average values for the contiguous U.S. The ozone condition for human health risk at the park is the maximum estimated value within park boundaries derived from this national analysis.

Vegetation Health: 3-month Maximum 12-hr 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. One annual index is the W126, which 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 during the ozone season 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 park is the maximum value within park boundaries derived from this national analysis.

Trends in Level of Ozone

Annual fourth-highest daily maximum 8-hour average ozone concentrations (ppb) were used to calculate human health based ozone trends. Vegetation-based ozone trends were developed by using annual 3-month maximum 12-hour W126 statistics. We obtained trends for the years 2008-2012 from the Federal Land Manager Environmental Database webpage (FLMED, no date).

Indicator, atmospheric wet deposition, is monitored across the United States as part of the National Atmospheric Deposition Program/National Trends Network (NADP/NTN) for nitrogen and sulfur wet deposition, and at the Mercury Deposition Network (MDN) for mercury wet deposition.

Nitrogen and Sulphur

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 park, the maximum value is assigned a condition status. Wet deposition trends are evaluated using pollutant concentrations in precipitation (micro equivalents/liter) so that yearly variations in precipitation amounts do not influence trend analyses. Nitrogen and sulfur data were interpolated from multiple monitoring stations located farther than 16 km (10 mi). NPS-ARD considers stations located farther than this distance outside the range that is representative for calculating trends in Class II airsheds (NPS-ARD 2015a).

Mercury

The condition of mercury was assessed using estimated 3-year average mercury wet deposition (ug/m^2/yr) and the predicted surface water methylmercury concentrations at NPS Inventory & Monitoring parks. 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 2015b). 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 (NPS-ARD 2015a).

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. For individual parks, minimum and maximum values within park boundaries are reported from this national analysis.

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. Mercury data were interpolated from multiple monitoring stations located farther than 16 km (7 mi). NPS-ARD considers stations located farther than this distance outside the range that is representative for calculating trends in Class II airsheds (NPS-ARD 2015a).

4.4.3. Reference Conditions

The reference conditions against which current air quality parameters are assessed are identified by NPS-ARD (2015a,b) for NRCAs and listed in Table 4.4.3-1.

Table 4.4.3-1. Reference conditions for air quality parameters.

Indicator and Measure	Very Good	Good	Moderate Concern	Significant Concern
Visibility Haze Index	n/a	< 2	2-8	>8
Ozone Human Health (ppb)	n/a	≤ 54	55-70	≥ 71
Ozone Vegetation Health (ppm-hrs)	n/a	<7	7-13	>13
Nitrogen and Sulfur Wet Deposition (kg/ha/yr)	n/a	< 1	1-3	>3
Mercury Wet Deposition ((µg/m^2/yr)	< 3	≥ 3 and < 6	≥ 6 and < 9	≥ 9 and < 12
Predicted Methylmercury Concentration (ng/L)	< 0.038	≥ 0.038 and .< 0.053	≥ 0.053 and < 0.075	≥ 0.075 and < 0.12

Sources: NPS-ARD (2015a,b), USEPA (2016a).

Note: Human health ozone thresholds have been revised since NPS-ARD (2015a).

Visibility (Haze Index)
A visibility condition estimate of 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.

Level of Ozone
Human Health
The human health ozone condition thresholds are based on the 2015 ozone standard set by the USEPA (USEPA 2016a) 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.

Vegetation Health
The 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" (NPS-ARD 2015a).

Wet Deposition
Nitrogen and Sulfur
The NPS-ARD selected a wet deposition threshold of 1.0 kg/ha/yr as the level below which natural ecosystems are likely protected from harm. This 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."

Mercury
Ratings for mercury wet deposition and predicted methylmercury concentrations can be evaluated using the mercury condition assessment matrix shown in Table 4.4.3-1 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 (NPS-ARD 2015a).

Table 4.4.3-1. 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: NPS-ARD (2015a)

4.4.4. Condition and Trend

The values used to determine conditions for all air quality indicators and measures are listed in Table 4.4.4-1.

<u>Haze Index</u>

The estimated 5-year (2011-2015) value (5.2 dv) for the park's visibility condition fell within the moderate concern condition rating, which indicates visibility is degraded from the good reference condition of <2 dv above the natural condition (NPS-ARD 2015a,b). For 2005-2014, the trend in visibility at Walnut Canyon NM was stable on the 20% clearest days and on the 20% haziest days (Figure 4.4.4-1) (IMPROVE Monitor ID: SYCA1, AZ). We did not use trend data for 2006-2015 since annual data for 2015 were not available. The CAA visibility goal requires visibility improvement on the 20% haziest days, with no degradation on the 20% clearest days (NPS-ARD 2015a). The visibility goal was not met for the 20% haziest days but was met for the 20% clearest days. Confidence in this measure is high because there is an on-site or 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, NO_x and SO_2. The

Table 4.4.4-1. Condition and trend results for air quality indicators at Walnut Canyon NM.

Data Span	Visibility (dv)	Ozone: Human Health (ppb)	Ozone: Vegetation Health (ppm-hrs)	N (kg/ha/yr)	S (kg/ha/yr)	Mercury (µg/m²/yr)	Mercury (ng/L)
Condition	Moderate Concern (5.2) 2011-2015	Moderate Concern (70.6) (2011-2015)	Significant Concern (17.1) (2011-2015)	Moderate Concern (1.8) 2011-2015	Good (0.7) 2011-2015	Moderate Concern (8.7-8.8) 2013-2015	Unknown 2013-2015
Trend: 2005-2014	The trend in visibility remained stable on the 20% clearest days and on the 20% haziest days (IMPROVE Monitor ID: IKBA1, AZ) (text excerpted from NPS 2016b).						

Sources: NPS-ARD (2016b,c,d)

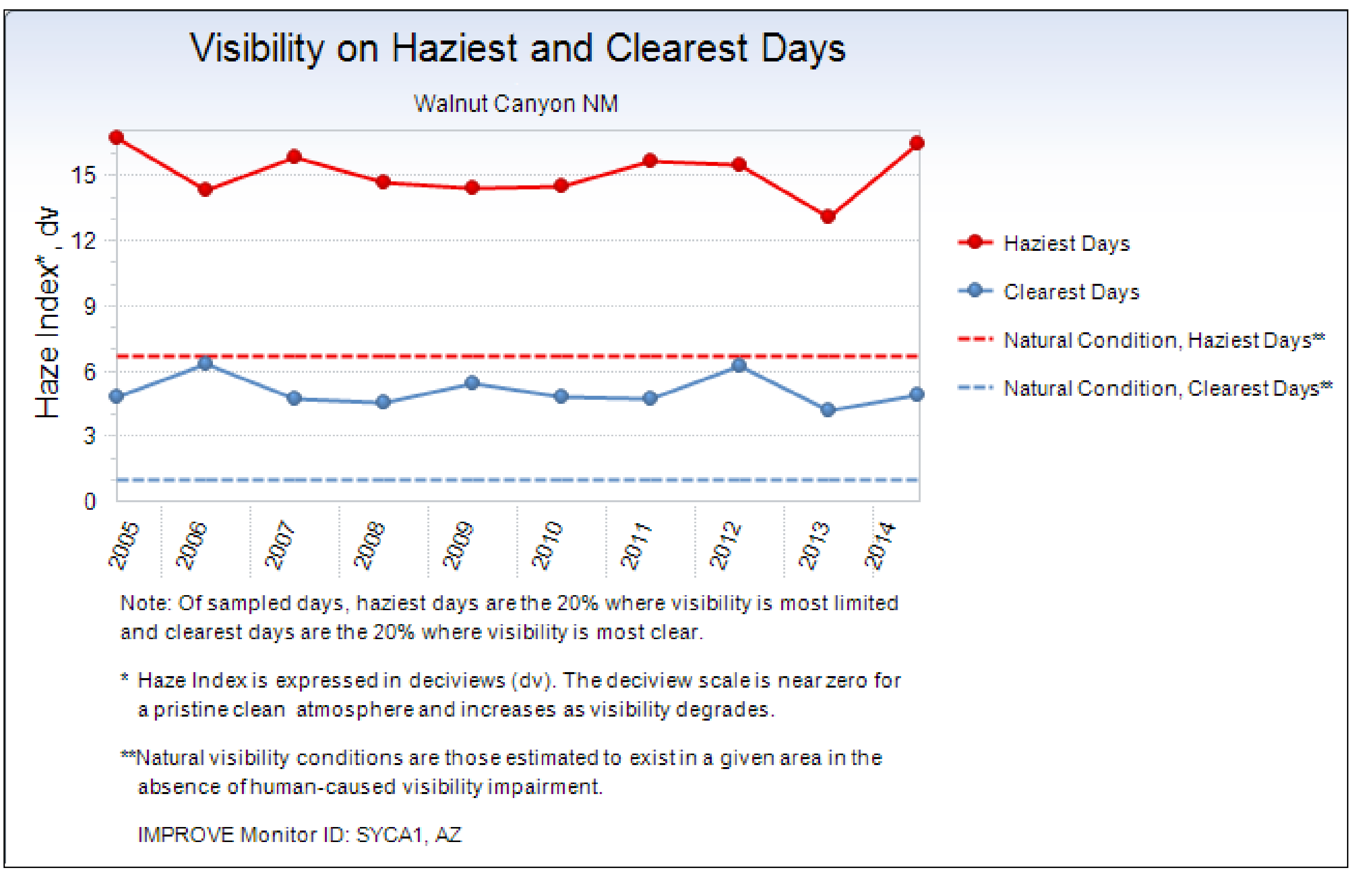


Figure 4.4.4-1. Trend in visibility on the haziest and clearest days (2005-2014). Figure Credit: NPS-ARD 2017b.

contributions made by different classes of particles to haze on the clearest days and on the haziest days are shown in Figures 4.4.4-2 and 4.4.4-3, respectively, using data collected at the IMPROVE monitoring location, SYCA1, AZ.

The primary visibility-impairing pollutants on the clearest days from 2005-2014 were ammonium sulfate and organic carbon. On the haziest days, organic carbon and coarse mass were the primary visibility-impairing pollutants (NPS-ARD 2016b). 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 2014, the clearest days occurred during January (Figure 4.4.4-4), while the haziest days occurred during the months of May, June, and July (Figure 4.4.4-5). These data were not available for 2015. (K. Taylor, Air Resources Division, pers. comm.).

Human Health: Annual 4th-highest 8-hr Concentration

Ozone data used for this measure were derived from estimated five-year (2011-2015) values of 70.6 parts per billion for the 4th highest 8-hour concentration, which resulted in a condition rating warranting moderate concern for human health. The level of confidence is medium because estimates are based on interpolated data from more distant ozone monitors. Trend data indicate unchanging conditions during 2008-2012 (trend data for 2011-2015 were not available); however, these data were based on a monitor located at the Flagstaff, Arizona middle school, which is beyond the threshold used by NPS-ARD to determine trend with high confidence (Figure 4.4.4-6).

Vegetation Health: 3-month Maximum 12-hr W126)

Ozone data used for this measure of the condition assessment were derived from estimated five-year (2011-2015) values of 17.1 parts per million-hours (ppm-hrs) for the W126 Index. Using these numbers, vegetation health risk from ground-level ozone warrants significant concern at Walnut Canyon NM. Our level of confidence in this measure is medium

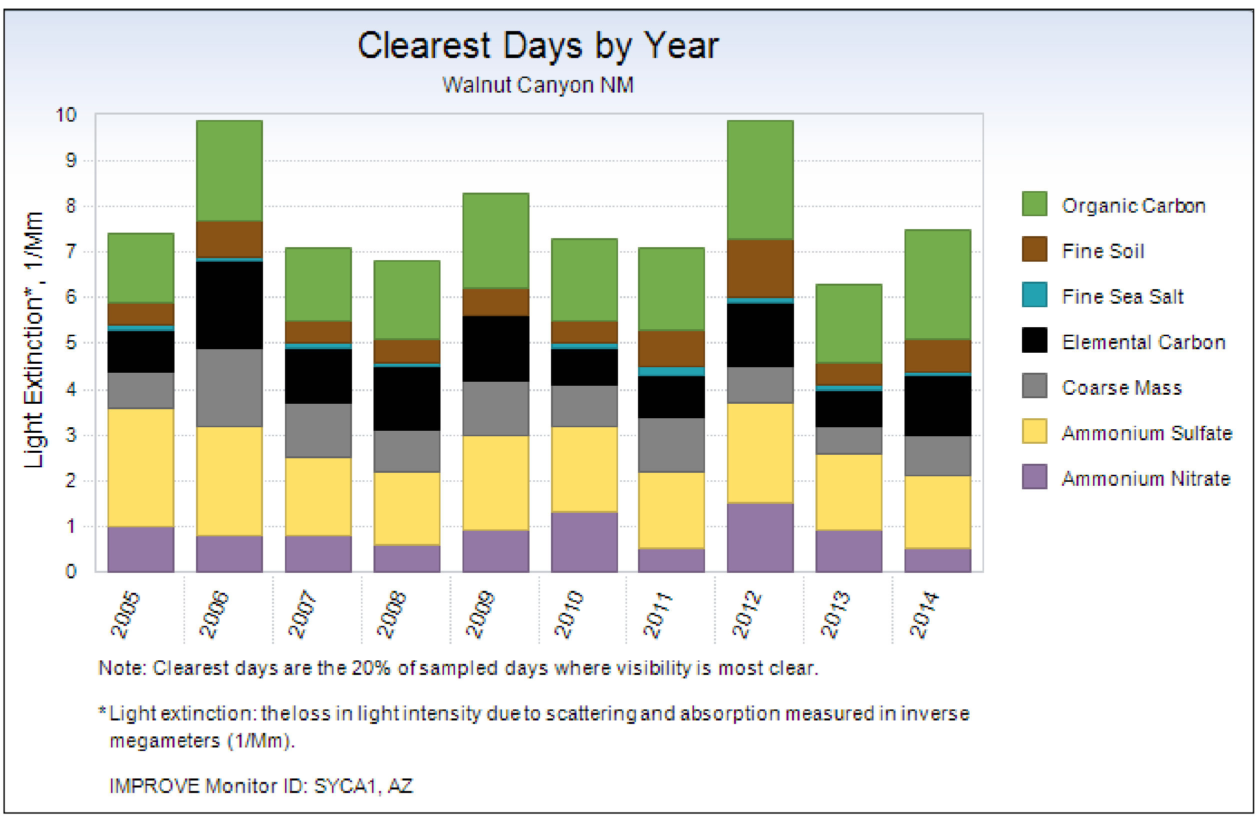


Figure 4.4.4-2. Visibility data collected at SYCA1, AZ IMPROVE station showing the composition of particle sources contributing to haze during the clearest days by year (2005-2014). Figure Credit: NPS-ARD 2017b.

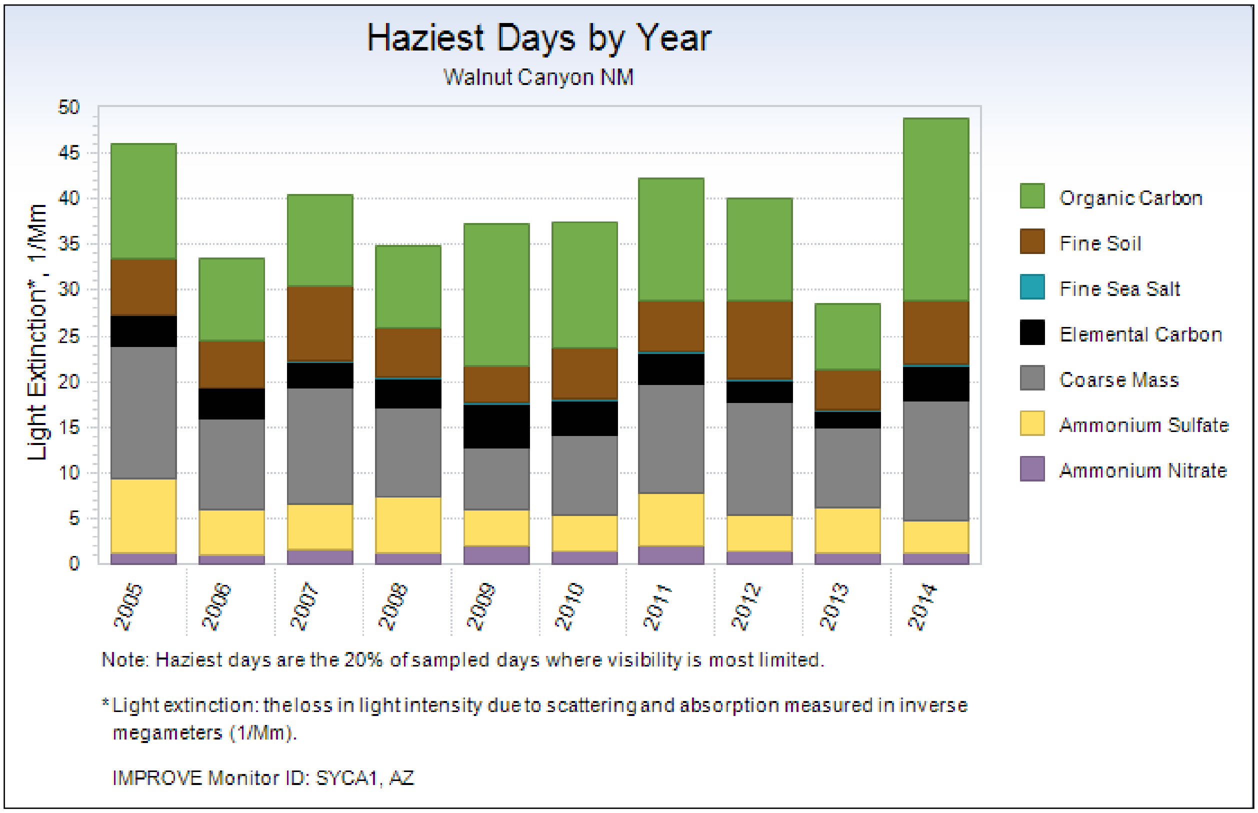


Figure 4.4.4-3. Visibility data collected at SYCA1, AZ IMPROVE station showing the composition of particle sources contributing to haze during the haziest days by year (2005-2014). Figure Credit: NPS-ARD 2017b.

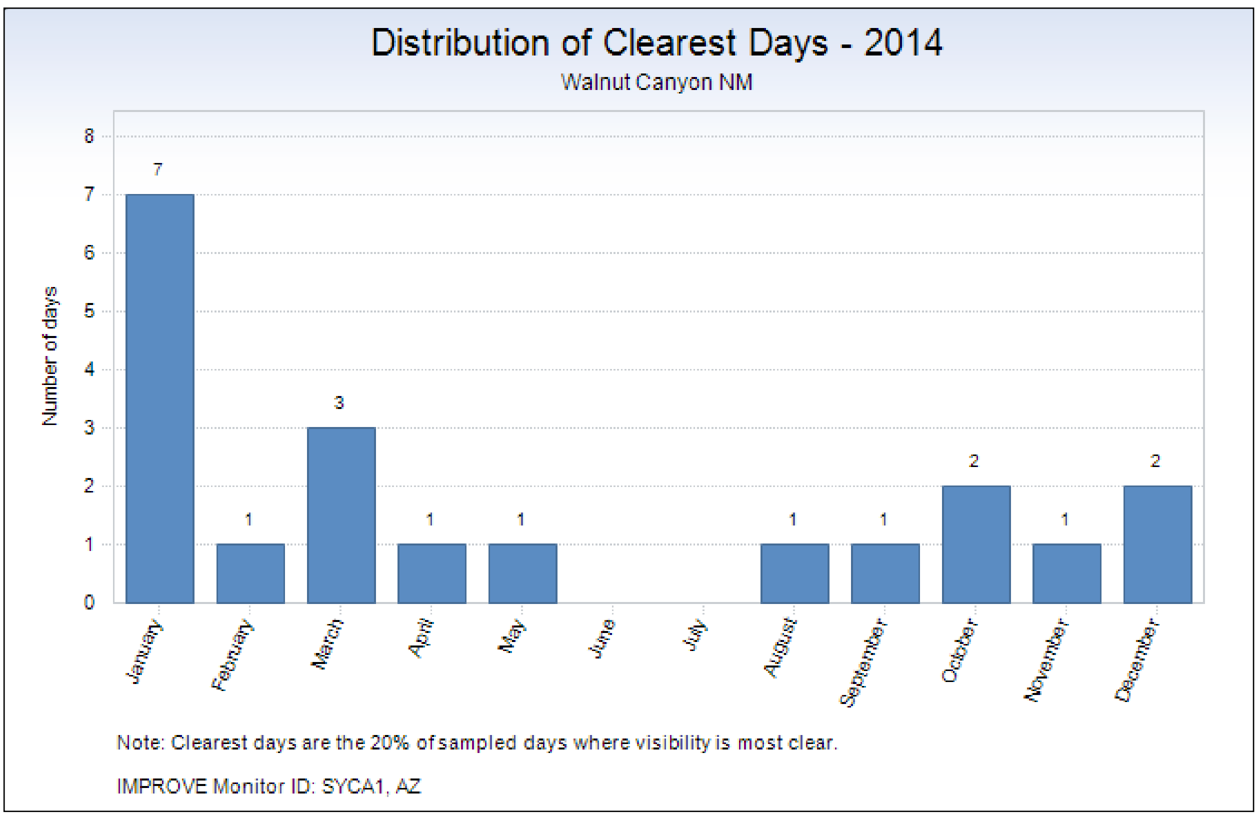


Figure 4.4.4-4. Visibility data collected at SYCA1, AZ IMPROVE station showing the distribution of clearest days by month for 2014. Figure Credit: NPS-ARD 2017b.

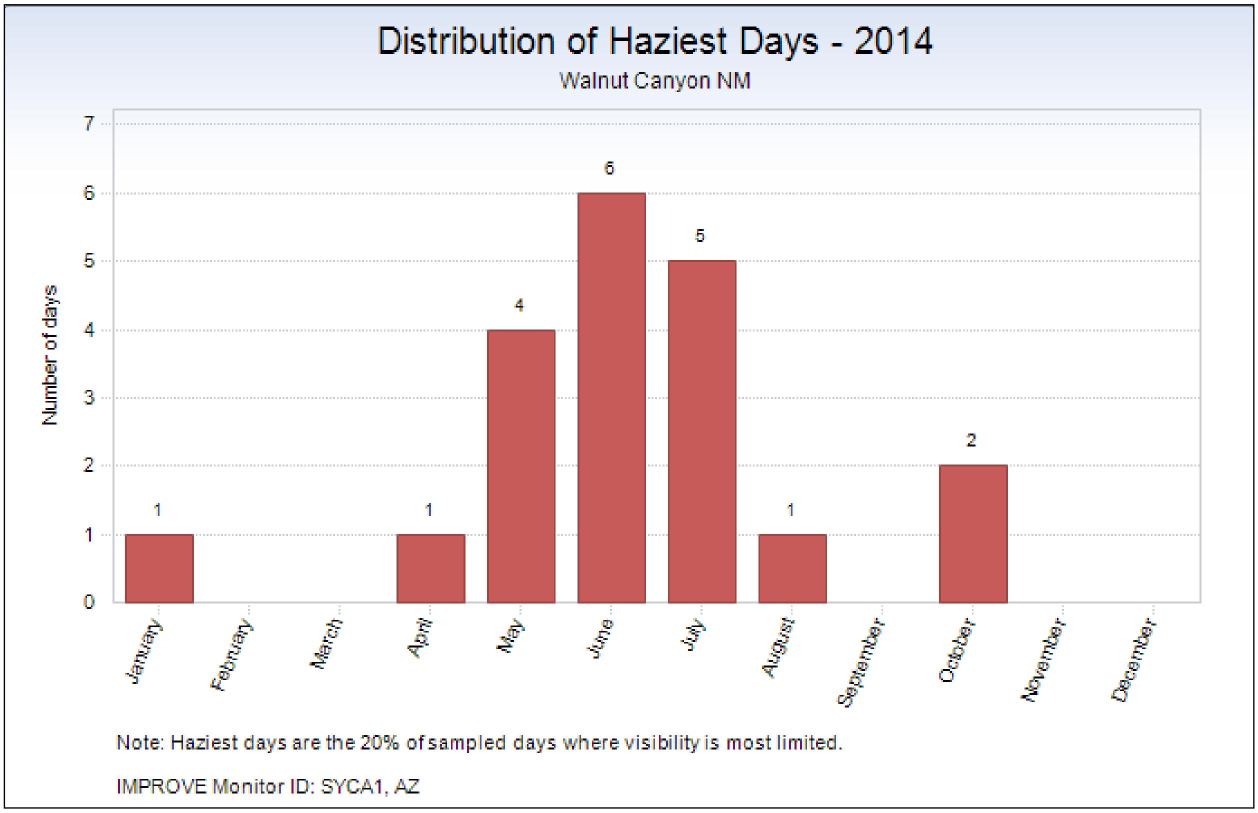


Figure 4.4.4-5. Visibility data collected at SYCA1, AZ IMPROVE station showing the distribution of haziest days by month for 2014. Figure Credit: NPS-ARD 2017b.

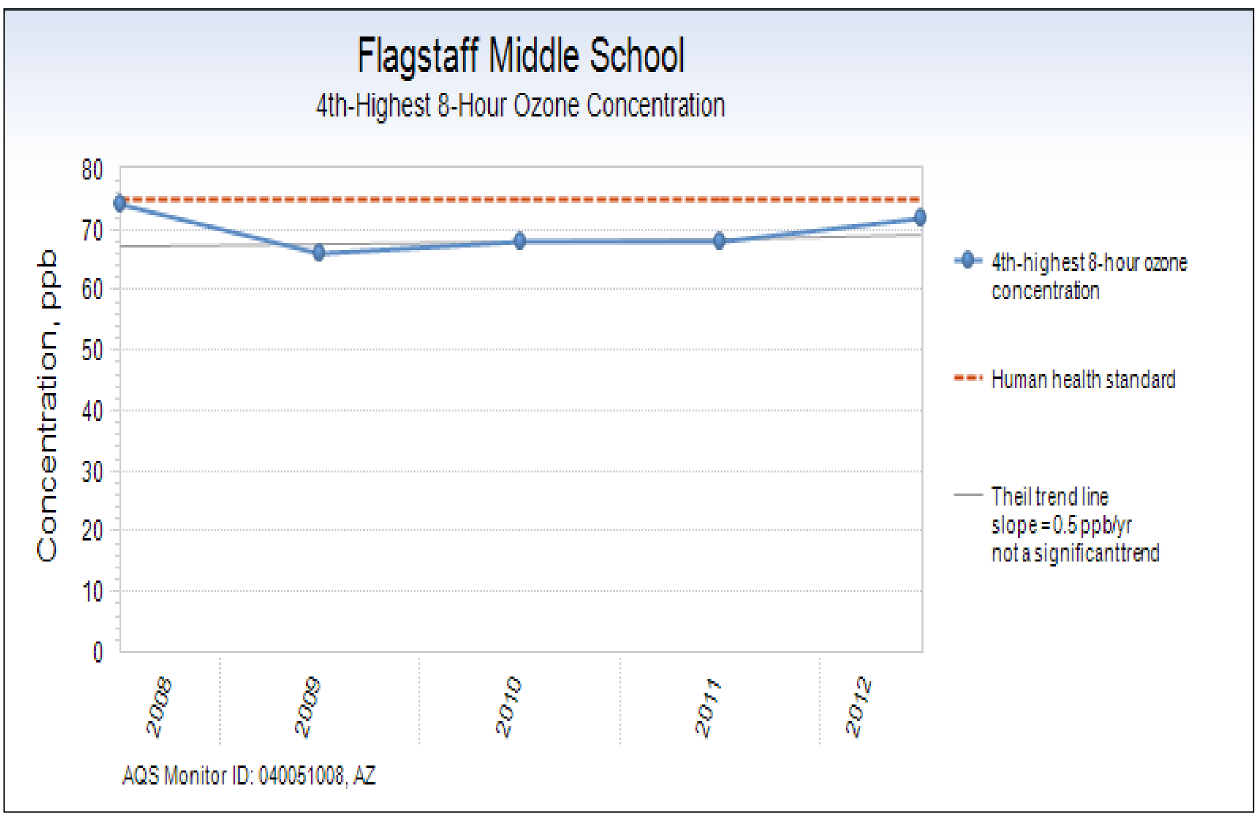


Figure 4.4.4-6. Trend in 4th-highest 8-hour ozone concentration at 040051008, AZ station during 2008-2012. Figure Credit: Federal Land Manager Environmental Database.

because estimates are based on interpolated data from a distant ozone monitor. Trend data for 2008-2012 indicate unchanging conditions (trend data for 2011-2015 were not available); however, these data were based on a monitor located at the Flagstaff, Arizona middle school, which is beyond the threshold used by NPS-ARD to determine trend with high confidence (Figure 4.4.4-7).

An ozone risk assessment conducted by Kohut (2004, 2007) for Southern Colorado Plateau Network parks concluded that plants in the national monument were at moderate risk of foliar ozone injury. The three plant species identified as ozone sensitive at the monument during the Kohut (2004) effort are listed in Table 4.4.4-2. An additional 10 species were listed as ozone sensitive by Bell (in review). Seven species listed in Table 4.4.4-2 could be used as a bioindicator, which can reveal ozone stress in ecosystems by producing distinct visible and identifiable injuries to plant leaves. Bioindicator status is noted the table.

Nitrogen

Wet N deposition data used for the condition assessment were derived from estimated five-year average values (2011-2015) of 1.8 kg/ha/yr. This resulted in a condition rating of moderate concern. No trends could be determined given the lack of nearby monitoring stations. Confidence in the assessment is medium because estimates are 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.

Sulfur

Wet S deposition data used for the condition assessment were derived from estimated five-year average values (2011-2015) of 0.7 kg/ha/yr, which resulted in a good condition rating for Walnut Canyon NM. No trends could be determined given the lack of nearby monitoring stations. Confidence in the assessment is medium because estimates are based on interpolated data from more distant deposition monitors. For further discussion of sulfur, see below.

Additional Information on Nitrogen and Sulfur

Sullivan et al. (2011a) studied the risk from acidification from acid pollutant exposure and ecosystem sensitivity for Southern Colorado Plateau Network (SCPN)

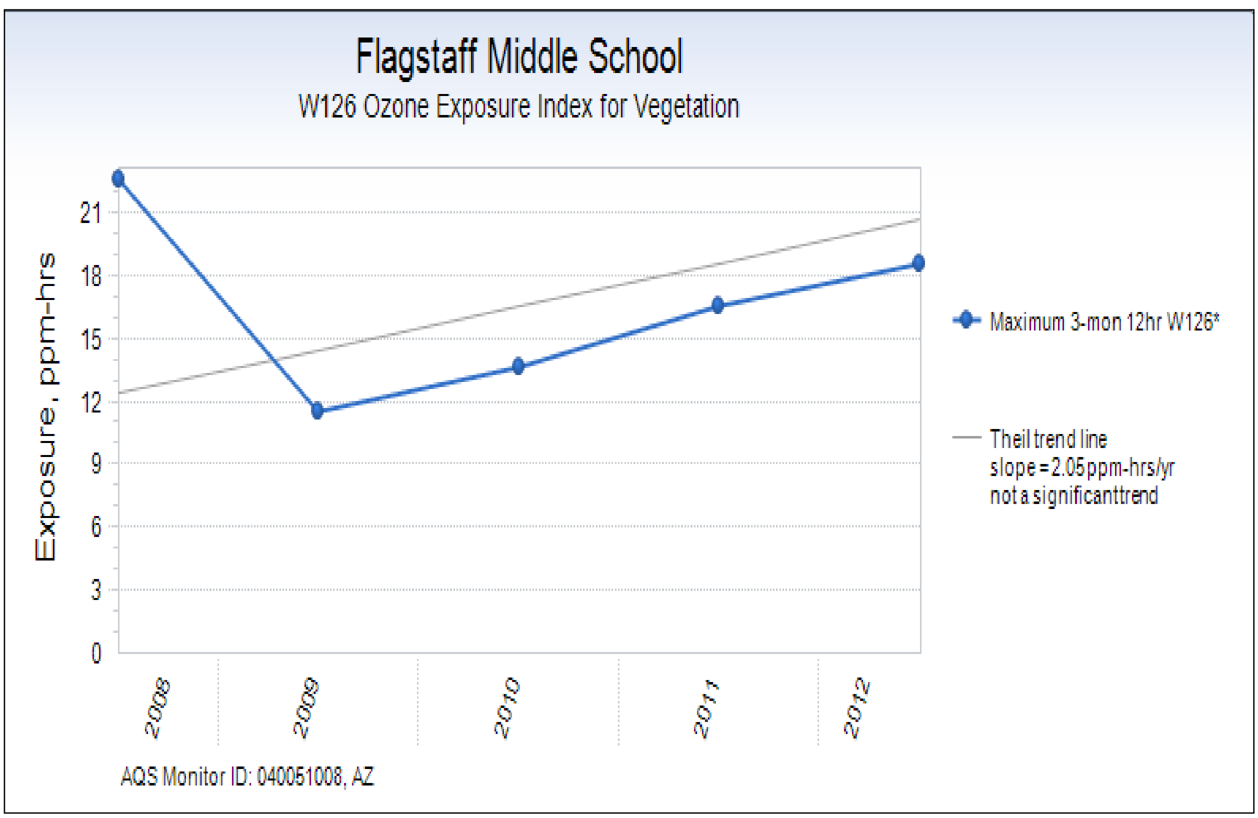


Figure 4.4.4-7. Trend in W126 ozone exposure index for vegetation at 040051008, AZ station during 2008-2012. Figure Credit: © Federal Land Manager Environmental Database.

Table 4.4.4-2. Ozone sensitive plants found at Walnut Canyon NM.

Scientific Name	Common Name	Bell (in review)	Kohut (2004)	Bioindicator?
Acer negundo	Boxelder	X	–	Yes
Achillea millefolium	Bloodwort	X	–	No
Amelanchier utahensis	Utah serviceberry	X	–	No
Apocynum cannabium	Common dogbane	X	–	No
Artemisia ludoviciana	Prairie sagebrush	X	–	Yes
Mentzelia albicaulis	White blazingstar	X	–	Yes
Oenothera elata ssp. *hookeri*	Hooker's evening primrose	X	–	Yes
*Parthenocissus quinquefolia**	American ivy	X	X	No
Parthenocissus vitacea	Virginia creeper	X	–	No
Populus fremontii	Fremont's cottonwood	X	–	Yes
Populus tremuloides	Quaking aspen	X	X	Yes
Pinus ponderosa	Blackjack pine	X	X	Yes
Prunus virginiana	Virginia chokecherry	X	–	No

* Indicates non-native species.

parks, which included Walnut Canyon 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 acid pollutant exposure at the park, moderate for ecosystem sensitivity, and moderate for park protection from acidification, for an overall summary risk of moderate (Sullivan et al. 2011a). The effects of acidification can include changes in water and soil chemistry that impact ecosystem health.

Sullivan et al. (2011b) also developed risk rankings for nutrient N pollutant exposure and ecosystem sensitivity to nutrient N enrichment. These risk rankings were considered low for pollutant exposure at the park, high for ecosystem sensitivity, and moderate for park protection, with an overall summary risk of low for the park. 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. These nitrogen sensitive communities cover a relatively large portion of Walnut Canyon NM, mostly as arid and semi-arid plant communities (Figure 4.4.4-8), but again, the overall summary risk was low for the park (Sullivan et al. 2011b).

In general, nitrate, sulfate, and ammonium deposition levels have changed over the past 20 years throughout the United States (Figure 4.4.4-9). 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, although a rise in ammonium ion deposition has occurred in large part due to the agricultural and livestock industries (NPS-ARD 2012d). A study conducted by Lehmann and Gay (2011) indicated a statistically significant decrease in sulfate concentrations from 1985-2009 in the area surrounding the monument, but a statistically significant increase in nitrate concentrations. According to the Lehmann and Gay (2011) study, for the areas that saw a change in nitrate concentrations across the county, most saw a decrease; increases were seen primarily in Arizona, New Mexico, and a portion of western Texas. It seems reasonable to expect a continued improvement in sulfate deposition levels because of CAA requirements. At this time, however, ammonium levels are not regulated by the USEPA, and may therefore continue to rise (NPS-ARD 2010).

Mercury and Predicted Methylmercury

The 2013–2015 wet mercury deposition ranged from 8.7 to 8.8 micrograms per square meter per year

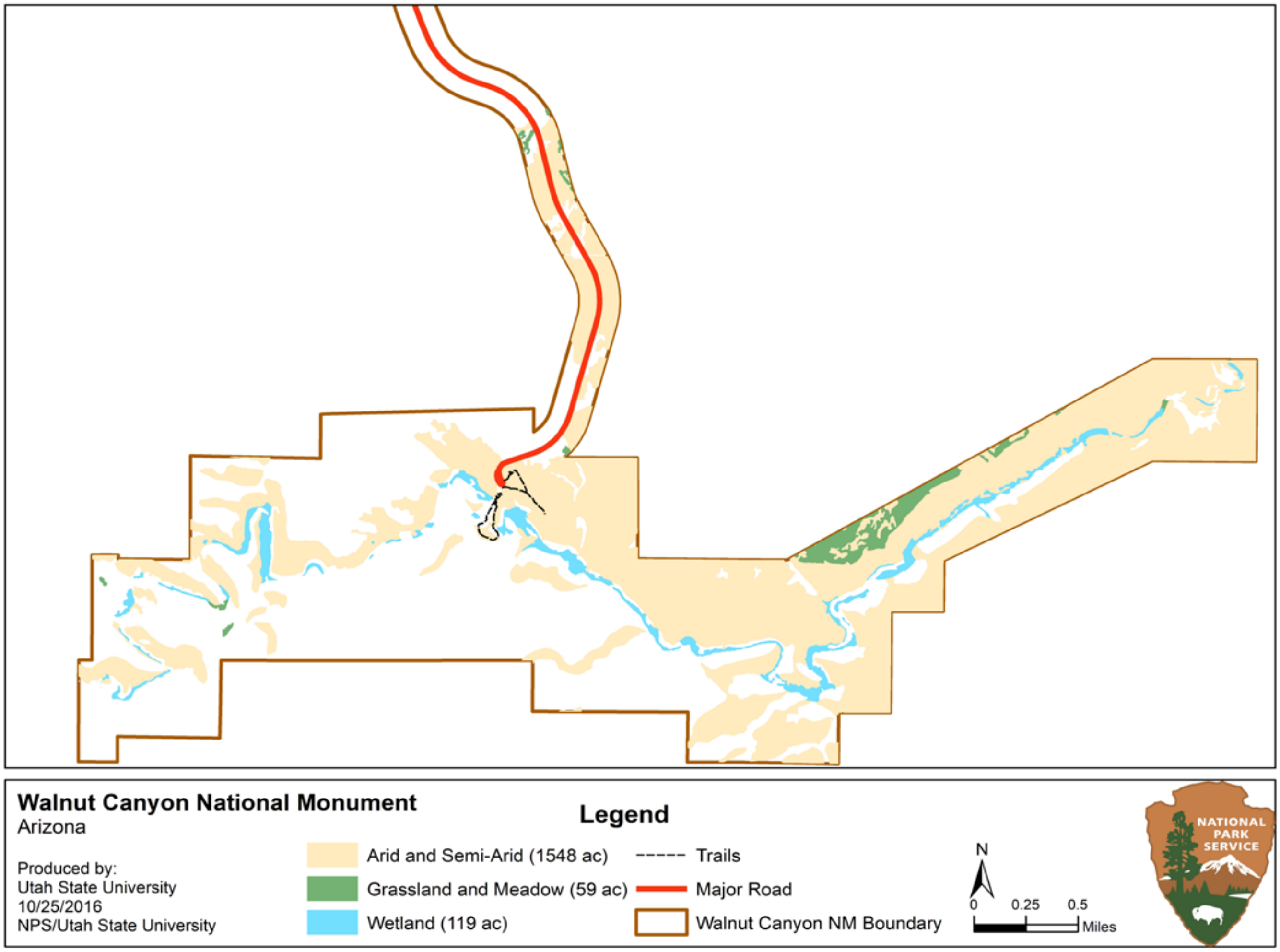


Figure 4.4.4-8. Locations of nitrogen sensitive communities at Walnut Canyon NM using the NPS/USGS veg mapping dataset. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction. Secondary Data Source: E&S Environmental Chemistry, Inc. (2009).

(NPS-ARD 2016). These values warrant moderate concern at the monument. The level of confidence in this measure is low because wet deposition estimates are based on interpolated data rather than in-park studies. The predicted methylmercury concentration in park surface waters was not available (USGS 2015). Because landscape factors influence the uptake of mercury in the ecosystem (i.e., dissolved organic carbon, wetlands, pH), the status of overall mercury condition could not be determined. When both measures are available, the mercury status assessment matrix shown in Table 4.4.3-2 can be used to determine overall mercury/toxics status (NPS-ARD 2015a). Furthermore, there are no park-specific studies examining contaminant levels in taxa from park ecosystems, which are useful in determining overall condition for mercury/toxics condition.

Overall Condition and Trend, Confidence Level, and Key Uncertainties

For assessing the condition of air quality, we used three air quality indicators. Our indicators/measures for this resource were intended to capture different aspects of air quality, and a summary of how they contributed to the overall condition is summarized in Table 4.4.4-3.

Based on these indicators and measures, we consider the overall condition of air quality at Walnut Canyon NM to be of moderate concern. Among the individual measures, one was considered good, four were considered to be of moderate concern, and one was considered to be of significant concern. The only measure that was in good condition was wet deposition of sulfur and the only measure considered to be of significant concern was vegetation health risk from ozone. We consider the confidence level as high for

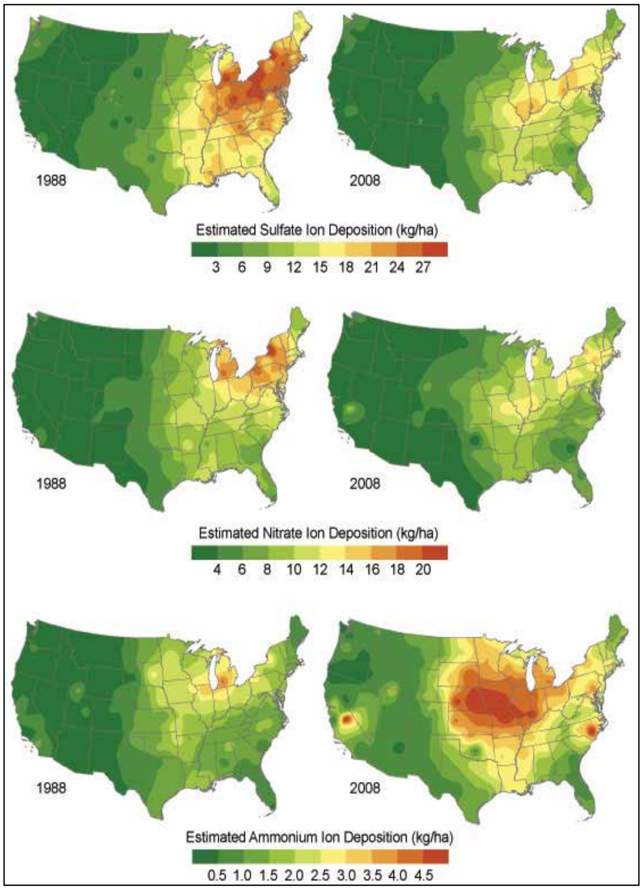


Figure 4.4.4-9. Change in wet deposition levels from 1988-2008 throughout the United States. Figure Source: http://www.nature.nps.gov/air/Monitoring/wetmon.cfm.

visibility based on the IMPROVE monitoring station, SYCA1, AZ. The confidence levels for ozone and wet deposition of N and S are medium because estimates are based on interpolated data from more distant monitors. Finally, the confidence level for mercury/toxics deposition is low because wet deposition values were based on interpolated data and predicted methylmercury concentration data were not available. Based on these confidence levels, we assigned an overall medium confidence to the air quality condition rating.

Those measures for which confidence in the condition rating was high were weighted more heavily in the overall condition rating than measures with medium or low confidence. Factors that influence confidence level include age of the data (<5 yrs unless the data are part of a long-term monitoring effort), repeatability, field data vs. modeled data, and whether data can be extrapolated to other areas in the monument.

The trend in visibility at Walnut Canyon NM did not change on the 20% clearest days nor on the 20% haziest days (IMPROVE Monitor ID: SYCA1, AZ). Trends for the remaining indicators cannot be derived because on-site monitoring does not occur and no monitoring sites are located near enough to be representative of conditions at the park. Since we could derive trend for only one measure, we did not assign an overall trend for air quality.

A key uncertainty of the air quality assessment is knowing the effect(s) of air pollution, especially of nitrogen deposition, on ecosystems at the park.

<u>Threats, Issues, and Data Gaps</u>

Clean air is fundamental to protecting human health, the health of wildlife and plants within parks, and for protecting the aesthetic value of lands managed by the NPS (NPS 2006). The majority of threats to air quality within Walnut Canyon NM originate from outside the monument and include the effects of climate change, forest fires (natural or prescribed), dust created from mineral and rock quarries, and carbon emissions.

The western U.S., and especially the Southwest, 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). One effect of climate change is an increase in wildfire activity (Abatzoglou and Williams 2016). Fires contribute a significant amount of trace gases and particles into the atmosphere that affect local and regional visibility and air quality (Kinney 2008). In addition to prescribed burns by the U.S. Forest Service (USFS 2016a), 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 also increase the rate at which ozone and secondary particles form (Kinney 2008). Declines in precipitation may also lead to an increase in wind-blown dust (Kinney 2008). Weather patterns influence the dispersal of these atmospheric particulates. Because of their small particle size, airborne particulates from fires, motor vehicles, power plants, and wind-blown dust may remain in the atmosphere for days, traveling potentially hundreds of miles before settling out of the atmosphere (Kinney 2008). The Navajo Generating Station ~200 km (124 mi) north, the Cholla Power Plant 100 km (62 mi) east,

Table 4.4.4-3. Summary of air quality indicators, measures, and condition rationale.

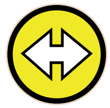
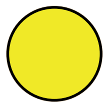
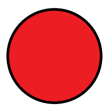
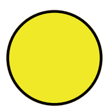
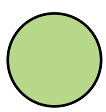
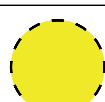
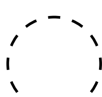
Indicators of Condition	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Visibility	Haze Index		Visibility warrants moderate concern at Walnut Canyon NM. This is based on NPS ARD benchmarks and the 2011-2015 estimated visibility on mid-range days of 5.2 deciviews (dv) above estimated natural conditions. For 2005-2014, the trend in visibility at the park remained stable on the 20% clearest days and on the 20% haziest days (IMPROVE Monitor ID: SYCA1, AZ). The Clean Air Act visibility goal requires visibility improvement on the 20% haziest days (not met), with no degradation on the 20% clearest days (met). The level of confidence is high because there is an on-site or nearby visibility monitor.
Level of Ozone	Human Health: Annual 4th-Highest 8-hour Concentration		Human health risk from ground-level ozone warrants moderate concern at Walnut Canyon NM. This status is based on NPS ARD benchmarks and the 2011-2015 estimated ozone of 70.6 parts per billion (ppb). Trend data indicate unchanging conditions during 2008-2012 for areas outside the monument, but the trend for the monument is unknown. The level of confidence is medium because estimates are based on interpolated data from more distant ozone monitors.
	Vegetation Health: 3-month maximum 12hr W126		Vegetation health risk from ground-level ozone warrants significant concern. This status is based on NPS ARD benchmarks and the 2011-2015 estimated W126 metric of 17.1 parts per million-hours (ppm-hrs). The W126 metric relates plant response to ozone exposure. A risk assessment concluded that plants in the park were at moderate risk for ozone damage (Kohut 2007, Kohut 2004). Trend data indicate unchanging conditions during 2008-2012 for areas outside the monument, but the trend for the monument is unknown. The confidence level is medium because estimates are based on interpolated data from more distant ozone monitors.
Wet Deposition	N in kg/ha/yr		Wet nitrogen deposition warrants moderate concern. This status is based on NPS ARD benchmarks and the 2011-2015 estimated wet nitrogen deposition of 1.8 kilograms per hectare per year (kg/ha/yr). Ecosystems in the park were rated as having high sensitivity to nutrient-enrichment effects relative to all Inventory & Monitoring parks, but the overall risk was low (Sullivan et al. 2011a; Sullivan et al. 2011b). Nitrogen deposition may disrupt soil nutrient cycling and affect biodiversity of some plant communities, including arid and semi-arid communities, grasslands, and wetlands. No trend information is available because there are not sufficient on-site or nearby deposition monitoring data. The confidence level is medium because estimates are based on interpolated data from more distant deposition monitors.
	S in kg/ha/yr		Wet sulfur deposition is in good condition. This status is based on NPS ARD benchmarks and the 2011-2015 estimated wet sulfur deposition of 0.7 kilograms per hectare per year (kg/ha/yr). Ecosystems in the park were rated as having moderate sensitivity to acidification effects relative to all Inventory & Monitoring parks (Sullivan et al. 2011a; Sullivan et al. 2011b). Acidification effects can include changes in water and soil chemistry that impact ecosystem health. No trend information is available because there are not sufficient on-site or nearby deposition monitoring data. The level of confidence is medium because estimates are based on interpolated data from more distant deposition monitors.
	Mercury		The 2013–2015 estimated wet mercury deposition ranged from 8.7 to 8.8 micrograms per square meter per year. These values correspond to a moderate concern condition. The level of confidence in the measure is low, because wet deposition estimates are based on interpolated data rather than in-park studies.
	Predicted Methylmercury Concentration		The predicted methylmercury concentration in park surface waters was not available (USGS 2015). Therefore, we could not determine condition for this measure. The measure is used in conjunction with mercury to determine the overall condition of mercury/toxics, but since no data were available to assess predicted methylmercury, we did not use these measures to determine the overall condition rating.

Table 4.4.4-3 continued. Summary of air quality indicators, measures, and condition rationale .

Indicators of Condition	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Overall Condition			Overall, we consider air quality at the national monument to be of moderate concern. Certain aspects, however, warrant significant concern (i.e., vegetation health risk from ground-level ozone), and others appear to be in good condition (e.g., wet deposition of sulfur). Overall, confidence in the assessment is medium, with confidence in two measures high and medium for the remaining four measures for which we could assess condition. However, the two measures of mercury should be considered concurrently in order to determine the overall condition for mercury/ toxics but predicted methylmercury concentration data were not available. Therefore, we did not consider the two measures of mercury in the overall condition rating. The overall trend is unknown, although the haze index indicates unchanging conditions for this measure.

Condition summary text was primarily excerpted from NPS-ARD (2016b, 2016c).

and the Coronado Generating Station ~200 km (124 mi) east are potential sources for air quality impacts.

4.4.5. 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.

4.5. Cherry Pools in Cherry Canyon

4.5.1. Background and Importance

Cherry Creek is a major drainage to Walnut Creek in Walnut Canyon National Monument (NM) (Graham 2008). Water flows in Cherry Creek in response to spring snowmelt and summer rainstorms (Soles and Monroe 2012). In spring, flows may occur continuously over several days while summer flows are usually shorter in duration (i.e., hours) depending on the amount of rainfall (Monroe and Soles 2015).

Cherry Canyon originates south of the monument on the basalt-capped Anderson Mesa. The Cherry Creek watershed is 21.7 km^2 (8.4 mi^2), a small portion of which occurs within Walnut Canyon NM, where approximately 0.7 km (0.4 mi) flow through Cherry Canyon (Graham 2008, Holton 2007). Cherry Canyon's walls are composed of Coconino Sandstone capped by the gray limestone of the Kaibab Formation (Graham 2008). In wet years, water may flow from fractures or bedding planes in the canyon walls as a result of groundwater recharge from local precipitation. These wet areas often support hanging gardens, an important spring type distinctive to the Colorado Plateau (Hansen et al. 2004, Springer et al.). The main water resource in Cherry Canyon is a reach approximately 125 m (410 ft) long where pools occur in natural depressions or small basins formed by erosion of the porous Coconino Sandstone (Holton 2007).

These naturally occurring pools are a rare but critically important resource for wildlife and plants in the monument (Figure 4.5.1-1a,b). During a 2001-2003 survey of the monument's herpetofauna, a small, isolated population of canyon treefrogs (*Hyla arenicolor*) was discovered in Cherry Canyon pools (Persons and Nowak 2006). The nearest known population of canyon treefrogs is located approximately 13 km (10 mi) northeast of the monument and is separated by uninhabitable dry forests and woodlands (Persons and Nowak 2006). Other sensitive species, including mountain lions (*Puma concolor*), American black bears (*Ursus americanus*), and Mexican spotted owls (*Strix occidentalis lucida*) have also been observed utilizing the canyon's unique pool environment (Walnut Canyon NM, unpublished data). The steep canyon walls and dense forest vegetation offer shade and refuge for these and other wildlife species. Cherry Canyon pools may have also served as a supplementary water supply for ancestral Puebloans who inhabited the region from approximately AD 1100 to 1300 (Downum et al. 1995).

Cherry Canyon pools are especially important today considering two dams located upstream of Walnut Creek have interrupted water flow through Walnut

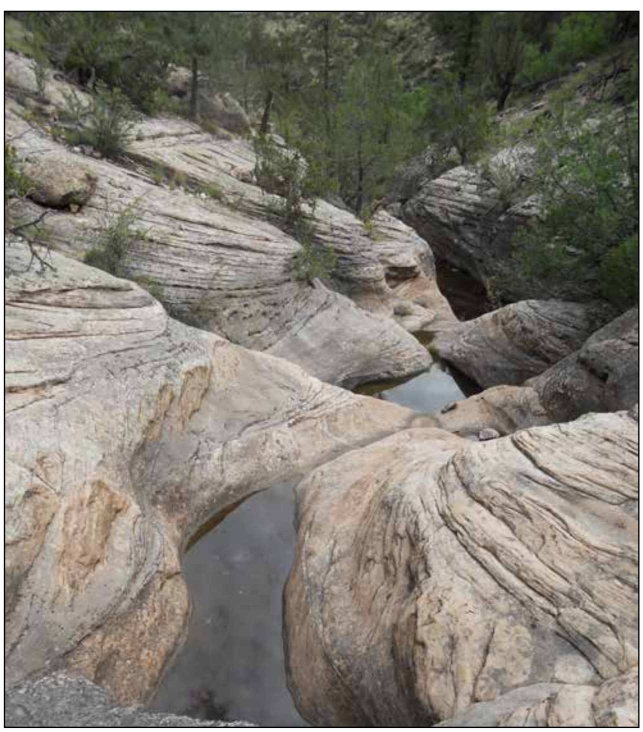


Figure 4.5.1-1a. Cherry Canyon pools. Photo Credit: NPS.

Figure 4.5.1-1b. Canyon treefrogs. Photo Credit: NPS.

Canyon (Soles and Monroe 2012). Rowlands et al. (1995) estimated that 11 flow events occurred in Walnut Canyon between 1941, when the second dam was completed, and 1993. Four flow events have been recorded in the canyon since 1993.'

Therefore, water availability in Walnut Canyon NM's major drainage is unreliable. Although pools occasionally develop in Walnut Canyon in response to summer monsoonal rains, none of these pools are considered perennial and many have been filled in by sediments in the absence of scouring floods (Holton 2007, Soles and Monroe 2012). Thus, the only perennial natural water sources available in the monument are the pools in Cherry Canyon.

4.5.2. Data and Methods

To assess the condition of Cherry Canyon pools in the monument (Figure 4.5.2-1), we used three indicators, water quantity and availability, water quality, and biodiversity, with a total of 14 measures. These measures were based on data from several sources, some of which were more than five years old but represent the most current or only data available.

Stream Flow (timing, duration, and magnitude)

The Southern Colorado Plateau Network (SCPN) Inventory and Monitoring (I&M) Program has identified stream flow as one of seven hydrologic vital signs to monitor across the 19 network parks (Thomas et al. 2006). Vital signs are a subset of key indicators selected to represent the overall health or condition of NPS resources (Thomas et al. 2006). To this end, the SCPN has established a recording stage gage in Cherry Creek (see the Walnut Creek Riparian assessment for Walnut Creek stream gage data). The station was originally established by the United States Geological Survey (USGS) in 1995 and was maintained until 2002 (McCormack et al. 2003). Crest-stage gages (CSG) record the height of flood events, providing

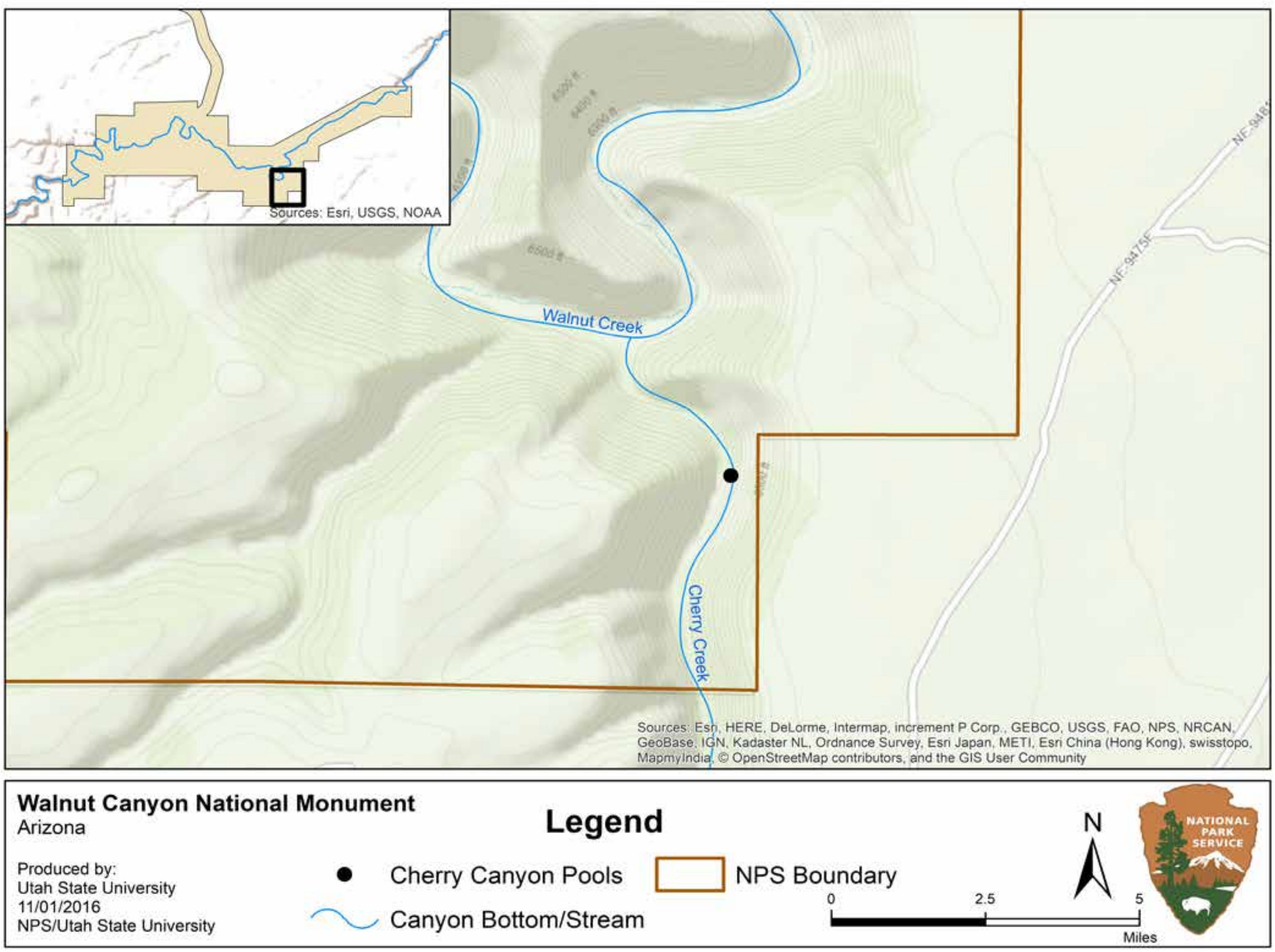


Figure 4.5.2-1. Location of the main Cherry Canyon pools in Walnut Canyon NM. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction.

information on whether a flood occurred since the previous site visit and the height of the flood, but CSGs do not record when the flood occurred, flood duration, or whether more than one flood event occurred since the gage was last read. Nevertheless, these data provide a useful historical context for the more recent flow data described below and were therefore, included in this assessment (data provided by S. Monroe, hydrologist, SCPN partner).

In 2010 the SCPN converted the crest-stage gage to a recording stage gage, which provides information on the timing, duration, and height above thalweg for all high flow events. The thalweg is the lowest point in a creek bed and is the location at which water flows fastest. Thus, height above the thalweg serves as a measure of flow magnitude. The gage records in 15-minute intervals. Because the gage is located approximately 0.17 m (0.55 ft) from the bottom of the channel to allow water to flow in and out of the gage for recording purposes, flows lower than the gage height were not recorded. To address this data gap, a camera was installed in 2014 to supplement recording stage data. In conjunction, these data will provide a near complete record of flows in Cherry Creek with the exception of low flows occurring at night that are not captured by the camera. Time lapse photography data were not available as of the writing of this assessment.

In addition to the historical (1995-2002) USGS crest-stage data, we reported the dates and duration of flows for the Cherry Creek recording stage gage from 13 October 2010 to 30 September 2016, which roughly corresponds to six water years. A water year begins 1 October and ends 30 September and is the period that best delineates seasonal precipitation patterns (Monroe and Soles 2015). We also included the height above thalweg for water years 2010-2014. Height above thalweg for water years 2015-2016 were not available for inclusion in this assessment (SCPN partner, S. Monroe, hydrologist, e-mail message, 14 November 2016).

Persistence of Pooled Water (%)

We used biweekly estimates of water volume for the main pool located in upper Cherry Canyon (Holton 2007). The total capacity of the pool was determined by multiplying its length, width, and depth. The pool was estimated as measuring approximately 4.5 m x 2.1 m x 0.6 m (15 ft x 7 ft x 2 ft) (NPS, B. Holton, wildlife biologist, e-mail message, 15 November

Figure 4.5.2-2. Photo of the recording stage gage at Cherry Creek. Photo Credit: © Steve Monroe, SCPN Partner.

2016) for a total capacity of 5.9 m^3 (210 ft^3). On each of 25-biweekly visits from 1 October 2004 through 15 October 2005, observers classified water availability in one of five pool volume classes: 0% full, 1-25% full, 26-50% full, 51-75% full, or 76-100% full (Holton 2007). We plotted these data over time by taking the midpoint of the pool volume classes.

Water Quality Measures

We reported data for a suite of water quality measures for two locations in Cherry Canyon that were reported in Springer et al. (2006) and Thomas et al. (2003). In Thomas et al. (2003), water quality data were collected at Cherry Canyon seep upstream from the confluence with Walnut Creek (Thomas et al. 2003). On 18 September 2001 four core water quality measures (specific conductance, pH, alkalinity, and temperature) as well as indicator bacteria and inorganic chemicals and uranium were collected at this location. On 2 May 2002 Cherry Canyon seep was resampled for the four core water quality measures as well as for measures of nitrogen (Thomas 2003). Although a temperature data logger is located in Cherry Creek as part of the recording stage gage described for the stream flow measure, the device only records water temperature during periods of flow and air temperature during low or no-flow periods (Monroe and Soles 2015). Since the temperature data logger is not located within the pool itself, we did not include these data.

On 10 May 2005, Springer et al. (2006) sampled Cherry Canyon pools for all five core water quality measures (specific conductance, pH, alkalinity, temperature, and dissolved oxygen). These data were collected as part of a 2005 effort to assess baseline condition for 75 springs across the Northern and Southern Colorado Plateau I&M Network parks (Springer et al. 2006). The significance of each water quality measure is described below.

Core Water Quality Parameters

Specific Conductance (µs/cm)

Specific conductance 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 2016bb).

pH (SU)

The pH of water determines the solubility and availability of compounds and minerals to organisms. The amount of dissolved materials, including heavy metals, rises with increasing acidity. Therefore, pH is a good indicator of change in water chemistry and pollution (USGS 2016bb). Groundwater with higher temperatures typically exhibits lower pH, which in turn means that more minerals from the surrounding rock will be dissolved than in cooler water.

Alkalinity (mg/L as $CaCO_3$)

Alkalinity is the ability of water to neutralize acid and is determined by the supporting soil and bedrock of a water feature (USGS 2016bb). It is related to pH and is an important indicator of a water body's ability to neutralize acidic pollution from rainfall (USGS 2016bb).

Dissolved Oxygen (mg/L)

Oxygen enters a water body from both the atmosphere and groundwater discharge. Temperature is an important factor in controlling the amount of dissolved oxygen in a water body. The colder the water, the more oxygen it can retain. Therefore, dissolved oxygen exhibits both daily and seasonal cycles (USGS 2016bb). Photosynthesis affects the dissolved oxygen-temperature relationship, which in turn, affects the rate of photosynthesis. Dissolved oxygen affects the ability of microorganisms and plants to live and grow in water bodies.

Temperature (° C)

Temperature influences all core water quality measures and is thus, important to include in any water sampling study (USGS 2016bb). Water temperature from most springs is fairly constant both daily and seasonally. Water temperature tends to fluctuate more in springs that discharge from shallow aquifers or springs with high rates of surface water recharge (SCPN, S. Monroe, hydrologist, comments on draft assessment, 14 November 2016).

Indicator Bacteria (cols./100 ml)

We report total coliform, fecal coliform, and *Escherichia coli* in colonies (cols.) per 100 ml. Total coliforms are widely spread in nature and are not necessarily associated with the gastrointestinal tract of mammals (USGS 2016bb). The measure of total coliform is often used as an indicator for potable water. Fecal coliform are a subgroup of coliform bacteria and indicate fecal contamination by mammals. *E. coli* is a common bacteria found in the gastrointestinal tracts of mammals and can cause illness in humans (USGS 2016bb). Coliform bacteria could enter water bodies through past grazing within the monument or through current grazing practices within the watershed (Thomas 2003).

Inorganic Chemicals and Uranium (µg/L)

We describe the chemical constituents of water resources at Cherry Canyon seep as reported in Thomas (2003). We only report measurements for variables that are considered a human health hazard by the U.S. Environmental Protection Agency (USEPA) (USEPA 2016c). These are antimony, arsenic, barium, beryllium, cadmium, chromium, copper, lead, uranium, and nitrogen (nitrates and nitrites). Sources of these compounds may be attributed to agricultural practices, mining activities, and waste disposal (USGS 2016b).

Biodiversity of Plants, Invertebrates, Birds, Mammals and Herpetofauna

We draw from three reports (Persons and Nowak 2006, Springer et al. 2006, Holton 2007), a wildlife camera database provided by Walnut Canyon NM natural resources staff (Walnut Canyon NM, unpublished data), and a database provided by the SCPN (Erika Nowak, herpetologist, Northern Arizona University Colorado Plateau Research Station [NAU CPRS]) to develop species lists for major taxonomic groups (plants, invertebrates, birds, mammals, and herpetofauna). The methods used to develop species lists for each group are described below.

Plants
We developed a list of plant species presented in Springer et al. (2006). Plant species were inventoried and mapped at Cherry Canyon pools as part of a 2005 effort to assess baseline condition for 75 springs across the Northern and Southern Colorado Plateau I&M Network parks. For each plant species, we determined its wetland status using the U.S. Department of Agriculture's (USDA) PLANTS Database (USDA 2016). Plants were divided into five categories based on wetland status. The categories are: obligate wetland (OBL = almost always occurs in wetlands), facultative wetland (FACW = usually occurs in wetlands but may occur in non-wetlands), facultative (FAC = occurs in wetlands and non-wetlands), facultative upland (FACU = usually occurs in non-wetlands), and obligate upland (UPL = almost never occurs in wetlands).

Invertebrates
Terrestrial and aquatic invertebrates were recorded at Cherry Canyon pools in 2005 as part of the Northern and Southern Colorado Plateau I&M Network parks inventory as described above (Springer et al. 2006). Invertebrates were sampled using a variety of methods, including sweep-netting, dip-netting, inspecting rocks, and spot sampling in and around the pools (Springer et al. 2006). As of the writing of this assessment, many invertebrates had not been identified to the species level (Figure 4.5.2-3). We reported the species when possible and the order when species level data were not available along with the total number of specimens collected for each order. We also included camera trap data provided by Walnut Canyon NM natural resources staff. An infrared trailcam (M880) was set up at Cherry Canyon pools in order to opportunistically survey wildlife. Photographs were collected from 5 May 2014 through 7 December 2015 in a series of phototrap sessions. The camera takes a photograph when the infrared beam is broken day or night. Although the trailcam was not specifically designed to survey invertebrates, we included records of invertebrates captured by the trailcam. Photographs of all invertebrates were identified to order.

Birds
Birds were recorded via camera traps set at Cherry Canyon pools through two different monitoring efforts. In October 2004 through June 2006 cameras were installed at Cherry Canyon pools to determine wildlife use of water resources in the monument (Holton 2007). Cameras were programmed to record activity 24-hours a day and were checked twice per month (see Holton 2007 for more details). We also included camera trap data provided by Walnut Canyon NM natural resources staff as described for invertebrates.

Mammals
We used data collected via camera traps to describe mammal species recorded Cherry Canyon pools provided in Holton (2007). We also included camera trap data provided by Walnut Canyon NM natural resources staff as described above (Walnut Canyon NM, unpublished data).

Herpetofauna
We used data provided by the SCPN (Erika Nowak, herpetologist, NAU CPRS). During 2001 and 2003, twelve National Park Service (NPS) units were surveyed for reptiles and amphibians (Persons and Nowak 2006). Walnut Canyon NM was surveyed during 2001-2003 using a variety of methods, including pitfall traps, area searches, road-based nocturnal driving surveys, habitat specific surveys, and random encounters (Persons and Nowak 2006). Using the database provided by herpetologist Erika Nowak, we extracted species that were recorded as occurring within washes, riparian areas, floodplains, seeps, wetlands, and rocky pools. These data do not necessarily reflect species found at Cherry Canyon pools since species were listed by habitat type rather than location. Nevertheless, the species found in these

Figure 4.5.2-3. Damselfly nymph in Cherry Pools. Photo Credit: NPS.

habitat types are likely to occur in Cherry Canyon pools. We also included camera trap data provided by Walnut Canyon NM natural resources staff as described above (Walnut Canyon NM, unpublished data) as well as a summary of canyon treefrog data collected opportunistically by NPS staff.

4.5.3. Reference Conditions

Reference conditions for this assessment are shown in Table 4.5.3-1. Reference conditions are described for resources in good, moderate concern, and significant concern conditions for each of the three indicators and 14 measures.

Stream flow (timing, duration, and magnitude)

We considered stream flow to be in good condition if timing, duration of flow, and magnitude (height above thalweg) data indicate Cherry Creek functions as a naturally occurring ephemeral stream, especially after spring snowmelt. If flows are somewhat impaired but occur regularly during spring and summer, we considered this to warrant moderate concern. If there is significant impairment of natural stream flow, this would indicate significant concern.

Persistence of Pooled Water (%)

We considered the persistence of water to be in good condition if the main pool contained water on at least 50% of all site visits, moderate concern if the pool contained water between 25 and 49% of all site visits, and significant concern if the pool contained water on less than 25% of all site visits.

Water Quality

We compared core water quality data (pH and dissolved oxygen) to reference conditions for Aquatic and Wildlife cold using water quality standards developed by the Arizona Department of Environmental Quality (AZDEQ 2016). Standards were developed separately for surface water occurring above and below 1,524 m (5,000 ft). According to the monument's digital elevation model, all water resources described in this assessment were located above 1,524 m (5,000 ft); therefore, we used water quality standards as described for cold water resources. Water quality standards were not available for specific conductance, alkalinity, or temperature (AZDEQ 2016). For indicator bacteria, inorganic chemicals, and uranium we used maximum allowable thresholds developed by the USEPA (USEPA 2016c). For coliform bacteria, the USEPA's goal is 0 cols/100 ml. If samples test positive, the USEPA requires that the water body be retested. If repeat samples also test positive, then the maximum allowable contaminant level has been violated (USEPA 2016c).

Biodiversity

We did not develop reference conditions for biodiversity in Walnut Canyon NM based on the recommendation of NPS staff. Instead, NPS staff recommended reporting species lists that can be used for future comparisons.

4.5.4. Condition and Trend

Stream Flow (timing, duration, and magnitude)

The USGS crest-stage data recorded at least five flood events between 1995 and 2002 (Table 4.5.4-1). Flood height ranged from 0.67 m (2.20 ft) to 0.08 m (0.27 ft) (Table 4.5.4-2). These data show that in most years there were high flood events, but the gage did not capture the timing or duration of these floods. It is likely that floods below the crest-stage gage occurred during at least some years and that more than one peak flood event occurred during recorded flood years. Data were not available from 1 March 2002 to 12 October 2010.

From 13 October 2010 to 31 October 2016, there were 16 recorded flow events in Cherry Creek, seven of which occurred during the 2013 water year (Table 4.5.4-2). Flows were not recorded by the gage during the 2010 or 2012 water years. Flows were as short as one day to as long as 12 days. As expected, spring flows were generally longer in duration than flows occurring at other times of the year (Figure 4.5.4-1). However, flood magnitude (height of water above thalweg) was generally greater during summer than during spring. Height above thalweg varied from 0.3 m (1.0 ft) on 12 March 2013 to as much as 1.1 m (3.6 ft) on 15 August 2014.

These data show that floods occurred during most years, that floods were variable in magnitude and duration, and that floods occurred largely during spring and summer months. These characteristics are typical of a naturally functioning ephemeral and intermittent stream on the Colorado Plateau (Scott et al. 2005). Therefore, we consider the condition of this measure to be good. Confidence is high but trend could not be determined. Although there were data for approximately 14 of the last 22 water years, the two different measurement methods (1995-2002 USGS

Table 4.5.3-1. Reference conditions used to assess Cherry Canyon pools in Walnut Canyon NM.

Indicator	Measure	Good	Moderate Concern	Significant Concern
Water Quantity and Availability	Stream Flow (timing, duration, and magnitude)	Timing, duration, and height above thalweg are indicative of a naturally functioning, reliable ephemeral stream, especially following spring snowmelt.	Some impairment of stream flow, but flows do occur fairly regularly during spring and summer.	Significant impairment of natural stream flow, especially during spring and summer.
	Persistence of Pooled Water (%)	Water is considered reliable (i.e., available on at least 50% of all site visits).	Water is considered moderately reliable (i.e., contains water between 25% and 49%).	Water is considered unreliable (i.e., contains water < 25% of all site visits).
Water Quality	Specific Conductance (µ/cm)	AZDEQ standards not established.	AZDEQ standards not established.	AZDEQ standards not established.
	pH (SU)	The pH is between 6.5 and 9 SU.	The pH does not meet AZDEQ water quality standards.	The pH does not meet AZDEQ water quality standards.
	Alkalinity (mg/L as $CaCO_3$)	AZDEQ standards not established.	AZDEQ standards not established.	AZDEQ standards not established.
	Dissolved Oxygen (mg/L)	Dissolved oxygen is ≥ 7.0 mg/L.	Dissolved oxygen is ≤ 7.0 mg/L.	
	Temperature (°C)	AZDEQ standards not established.	AZDEQ standards not established.	AZDEQ standards not established.
	Indicator Bacteria (cols./100 ml)	sample is negative	sample is positive	sample is positive
	Antimony (µg/L)	< 6 µg/L	> 6 µg/L	> 6 µg/L
	Arsenic (µg/L)	< 10 µg/L	> 10 µg/L	> 10 µg/L
	Barium (µg/L)	< 2,000 µg/L	> 2,000 µg/L	> 2,000 µg/L
	Beryllium (µg/L)	< 4 µg/L	> 4 µg/L	> 4 µg/L
	Cadmium (µg/L)	< 5 µg/L	> 5 µg/L	> 5 µg/L
	Chromium (µg/L)	< 100 µg/L	> 100 µg/L	> 100 µg/L
	Copper (µg/L)	< 1,300 (µg/L)	> 1,300 µg/L	> 1,300 µg/L
	Lead (µg/L)	< 15 µg/L	> 15 µg/L	> 15 µg/L
	Uranium (µg/L)	< 30 µg/L	> 30 µg/L	> 30 µg/L
	Nitrogen, nitrite (µg/L)	< 100 µg/L	> 100 µg/L	> 100 µg/L
	Nitrogen, nitrite + nitrate (µg/L)	< 11,000 µg/L	> 11,000 µg/L	> 11,000 µg/L
Biodiversity	Plants	No Condition Thresholds Established.	No Condition Thresholds Established.	No Condition Thresholds Established.
	Invertebrates	No Condition Thresholds Established.	No Condition Thresholds Established.	No Condition Thresholds Established.
	Birds	No Condition Thresholds Established.	No Condition Thresholds Established.	No Condition Thresholds Established.
	Mammals	No Condition Thresholds Established.	No Condition Thresholds Established.	No Condition Thresholds Established.
	Herpetofauna	No Condition Thresholds Established.	No Condition Thresholds Established.	No Condition Thresholds Established.

Table 4.5.4-1. Floods recorded in Cherry Creek.

Date Gage Checked	Peak Flood Height in m (ft)
10/26/1995	No flood recorded
10/13/1996	–
6/11/1997	0.48 (1.57)
10/29/1997	0.67 (2.20)
10/1/1998	0.47 (1.54)
10/20/1999	No flood recorded
6/13/2000	0.08 (0.27)
3/1/2002	0.25 (0.83)

Table 4.5.4-2. Floods recorded in Cherry Creek.

Flood Date	Height of Flood Above Thalweg in m (ft)	Length of Flow in Days
3/05/2011	0.4 (1.3)	5
1/27/2013	0.4 (1.3)	2
3/12/2013	0.3 (1.0)	2
8/26/2013	0.7 (2.3)	1
8/30/2013	0.7 (2.3)	2
8/31/2013	0.9 (3.0)	2
9/9/2013	0.9 (3.0)	2
9/10/2013	0.4 (1.3)	2
3/1/2014	0.4 (1.3)	3
8/15/2014	1.1 (3.6)	2
1/13/2015	Not Available	1
1/30/2015	Not Available	1
3/2/2015	Not Available	12
8/11/2015	Not Available	1
2/15/2016	Not Available	8
7/31/2016	Not Available	5

data vs. 2011-2016 SCPN data) were not comparable. Furthermore, long term data is necessary to capture the natural seasonal variability in stream flow and finally, not all data (i.e., time lapse photography) have been analyzed.

Persistence of Pooled Water (%)
Water was observed in the main pool on 100% of the 25-biweekly site visits (Figure 4.5.4-2). The estimated average estimated pool volume was 82% during 1 October 2004 through 15 October 2005. Pool volume was never estimated below 50% during any of the 25-biweekly surveys, and during 19 of the 25 surveys, the pool was estimated to be at least 75% full. Therefore, the condition for this measure is considered good; however, confidence is low since these data are more than 10 years old. Furthermore, Holton (2007)

Figure 4.5.4-1. Flow event recorded on 18 March 2015 in Cherry Creek. Photo Credit: © S. Monroe, SCPN Partner.

monitored three additional pools for wildlife use, but only monitored water volume in the largest pool since it was most likely to consistently contain water for wildlife (NPS, B. Holton, e-mail message, 31 October 2016). Thus, this pool may not be representative of all pools in Cherry Canyon. We could not determine trend since only one year of data were available.

Specific Conductance (μS/cm)
Specific conductance ranged from 244 μS/cm at Cherry Canyon pools on 10 May 2005 to 446 μS/ cm at Cherry Canyon seep on 2 May 2002, but we could not evaluate this measure since no condition thresholds have been established by AZDEQ (Table 4.5.4-3). Furthermore, these data are more than 10 years old. Therefore, the current condition for this measure is unknown and the confidence is low. We could not determine trend based on the three samples in two different locations.

pH (SU)
The pH ranged from 7.3 at Cherry Canyon seep on 18 September 2001 to 9.5 at Cherry Canyon pools on 10 May 2005 (Table 4.5.4-3). This latter measurement exceeded the range identified as good by AZDEQ; however, since the most recent data available are more than 10 years old and there are only three samples from two different locations, the current condition for this measure is unknown and confidence is low. Trend could not be determined.

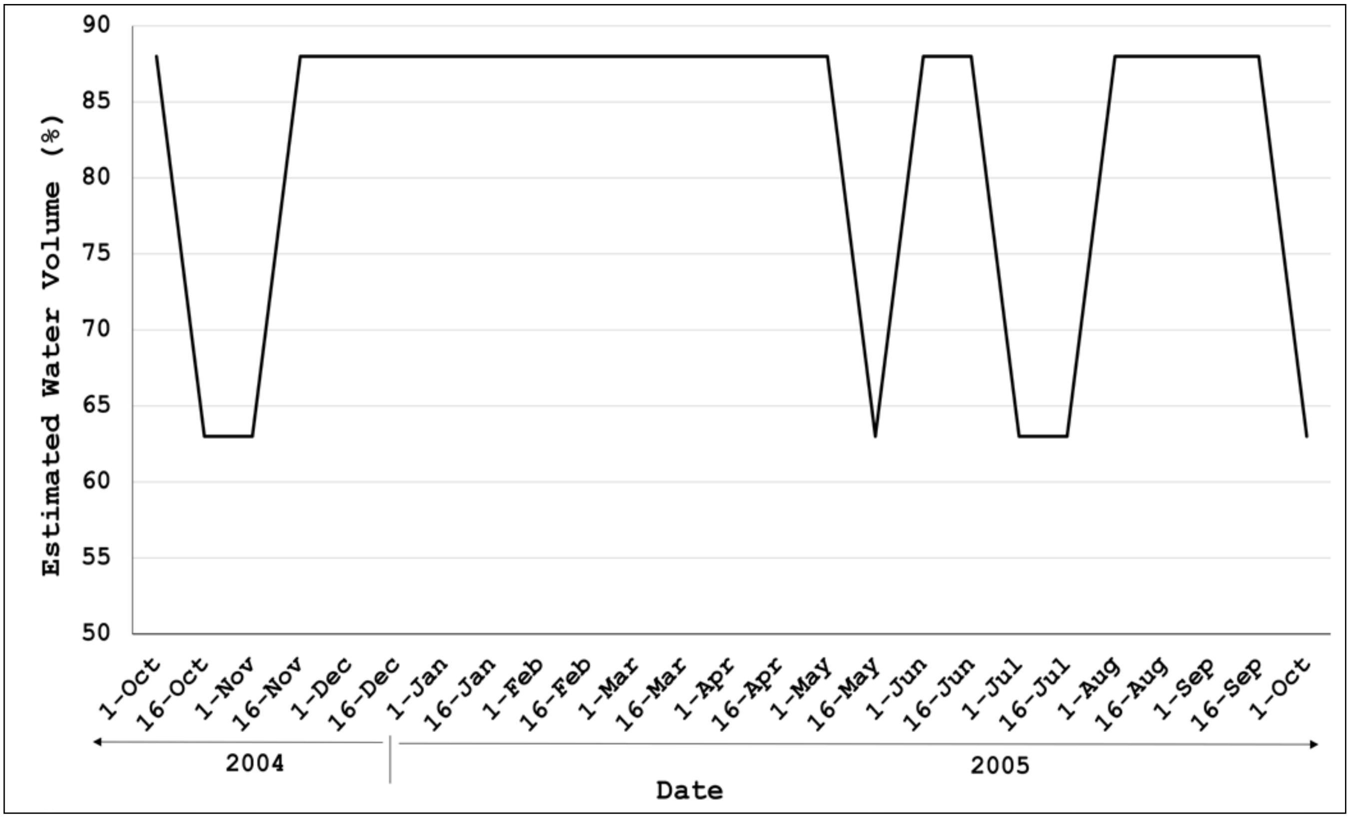


Figure 4.5.4-2. **Persistence of water in one pool located in Cherry Canyon at Walnut Canyon NM.**

Table 4.5.4-3. Water quality data for water resources in Cherry Canyon in Walnut Canyon NM.

Water Resource	Date	Specific Conductance (µS/cm)	pH (SU)	Alkalinity (mg/L as $CaCo_3$)	Dissolved Oxygen (mg/L)	Temperature (°C)	Data Source
Cherry Canyon Seep	9/18/2001	446	7.3	220	–	16.0	Thomas (2003)
	5/2/2002	405	7.4	197	–	8.8	Thomas (2003)
Cherry Canyon Pools	5/10/2005	245	9.5	142	8.08	9.5	Springer et al. (2006)

Alkalinity (mg/L as $CaCO_3$)

Alkalinity ranged between 197-220 mg/L at Cherry Canyon seep between 2001 and 2002 (Table 4.5.4-3). Only one sample was collected at Cherry Canyon pools (142 mg/L). Since these data are more than 10 years old, there were only three samples from two different locations, and no condition thresholds for this measure have been established, the current condition for this measure is unknown and confidence is low. Trend could not be determined.

Dissolved Oxygen (mg/L)

Dissolved oxygen was only reported for Cherry Canyon pools on May 10, 2005 (Table 4.5.4-3). This measurement was 8.08 mg/L, which meets the criteria for cold water resources established by AZDEQ. However, since the data are more than 10 years old and there is only one sample, the current condition for this measure is unknown and confidence is low. Trend could not be determined for this single measurement.

Temperature (°C)

In general, temperatures were lower in spring (2002 and 2005) than during early autumn (2001), but this is based on only three measurements (Table 4.5.4-3). Since these data are more than 10 years old, and no condition thresholds have been established for this measure, the current condition for this measure is unknown and confidence is low. We could not determine trend based on these three samples in the two locations.

Indicator Bacteria (cols/100 ml)

Only one sample from Cherry Canyon was collected and it tested positive for total coliform, fecal coliform, and *E. coli* on 18 September 2001 (Table 4.5.4-4). However, since the data are more than 10 years old, and only one sample was collected, the current condition for this measure is unknown and confidence is low. Trend could not be determined for this single measurement.

Inorganic Chemicals and Uranium (µg/L)

All of the inorganic chemicals and uranium were well below the maximum allowable concentration identified by the EPA (2016) (Table 4.5.4-5). However, since these data are more than 10 years old, the current condition for this measure is unknown and confidence is low. Trend could not be determined based on these data.

Plants

A total of 16 species and six additional plants that could only be identified to genus or family were recorded at Cherry Canyon pools in 2005 (Table 4.5.4-6). Only two non-native species were reported in Springer et al. (2006). These were lesser clubmoss (*Selaginella* sp.) and dandelion (*Taraxacum officinale*). Only four of the 15 native species present are normally associated with wetlands as determined by their wetland indicator status (USDA 2016). Two were considered facultative wetland species (usually occurs in wetlands but may occur in non-wetlands) and two were considered facultative (may occur in wetlands and non-wetlands). The remaining 11 species were considered upland plant species (usually occurs in non-wetlands) or facultative upland species (almost never occurs in wetlands). No species was considered an obligate wetland species. Although most plants found at Cherry Canyon pools were considered upland species, this is not surprising since stream flow is naturally variable and the creek bottom is characterized by bedrock with little soil development. Typical riparian plants and trees such as Arizona walnut (*Juglans major*) and narrowleaf cottonwood (*Populus angustifolia*) would not be expected to occur there. None of the plant species detected were of management concern (Springer et al. 2006). Since no reference conditions were developed, we did not assign a current condition for this measure. Confidence in this measure is low since the data are more than 10 years old. Trend could not be determined based on one year of data.

Table 4.5.4-4. Indicator bacteria for Cherry Canyon seep.

Water Resource	Date	Total Coliform (cols./100 ml)	Fecal Coliform (cols./100 ml)	*E. coli* (cols./100 ml)
Cherry Canyon Seep	9/18/2001	> 8,000	400	500

Note: Data extracted from Thomas (2003).

Table 4.5.4-5. Concentration inorganic chemicals and uranium in Cherry Canyon seep.

Concentration (µg/L)	9/18/2001	5/2/2002
Antimony	0.12	–
Arsenic	1.60	–
Barium	60	–
Beryllium	< 0.06	–
Cadmium	< 0.04	–
Chromium	13.5	–
Copper	1.9	–
Lead	0.14	–
Uranium, natural	0.2	–
Nitrogen, nitrite	0.03	< 0.006
Nitrogen, nitrite + nitrate	0.11	1.4

Note: Data extracted from Thomas (2003).

Invertebrates

A total of five invertebrate species, seven individuals identified to genus, and specimens from six orders were documented at Cherry Canyon pools (Table 4.5.4-7). Most of individuals were identified during the 2005 SCPN monitoring effort; however, a few were also recorded by NPS wildlife cameras in 2014 and 2015. Of those identified to species or genus, only two were aquatic. These were the water strider (*Gerris* sp.) and predaceous diving beetle (*Rhantus* sp.) (Springer et al. 2006). The remaining species identified to species or genus were terrestrial. Since no reference conditions were developed, we did not assign a current condition for this measure. Confidence in this measure is low since the majority of data is 10 years old (Springer et al. 2006) and the more recent camera trap data was not specifically designed to collect information on invertebrates (Walnut Canyon NM, unpublished data). Trend could not be determined.

Table 4.5.4-6. Plants documented at Cherry Canyon pools.

Scientific Name	Common Name	Wetland Status
Asteraceae	Sunflowers	–
Artemisia ludoviciana	White sagebrush	FACU
Brickellia sp.	Brickelbush	–
Carex geophila	White mountain sedge	UPL
Cercocarpus montanus	Alderleaf cercocarpus	UPL
Chamaebatiaria millefolium	Fernbush	UPL
Cornus sericea	Red-osier dogwood	UPL
Heuchera parviflora	Littleflower alumroot	UPL
Iris missouriensis	Rocky Mountain iris	FACW
Juniperus osteosperma	Utah juniper	UPL
Penstemon sp.	Beard tongue	–
Pinus edulis	Colorado pinyon	UPL
Poa sp.	Bluegrass	–
Poaceae	Grasses	–
Pseudotsuga menziesii	Douglas fir	UPL
Rosa woodsii	Wood's rose	FACU
Selaginella sp.*	Lesser clubmoss	FACW
*Taraxacum officinale**	Dandelion	FACU
Thalictrum fendleri	Fendler meadowrue	FAC
Toxicodendron rydbergii	Poison ivy	FACU
Vicia americana	American deervetch	FAC
Yucca baccata	Banana yucca	UPL

Note: Data collected in May 2005 (Springer et al. (2006).

* Indicates non-native species.

Table 4.5.4-7. Invertebrates documented at Cherry Canyon pools.

Common Name	Scientific Name
Blue glass landsnail[1]	*Nesovitrea binneyana*
Brown hive snail[1]	*Euconulus fulvus*
Buckeye butterfly[1]	*Junonia* sp.
Duskywing[1]	*Erynnis* sp.
Earthworm[1]	*Lumbricus* sp.
Glossy pillar snail[1]	*Cochlicopa lubrica*
Land snail[1]	*Pupilla* sp.
Painted lady[1]	*Vanessa cardui*
Predaceous diving beetle[1]	*Rhantus* sp.
Sara orangetip butterfly[1]	*Anthocharis sara*
Spider wasp[1]	*Pepsis* sp.
Water strider[1]	*Gerris* sp.
Unidentified butterfly[2]	Order Lepidoptera (2)
Unidentified centipede[1]	Order Chilopoda (1)
Unidentified cricket or grasshopper	Order Orthoptera (1)
Unidentified dragonfly[2]	Order Odonata
Unidentified fly[1]	Order Diptera (8)
Unidentified spider[2]	Order Araneae

[1] Data collected in May 2005 and presented in Springer et al. (2006).

[2] Camera trap data collected during 2014-2015 and provided by Walnut Canyon NM staff.

Birds

A total of 33 bird species, including one species that could only be identified to order, were captured on camera in Cherry Canyon during either the 2004-2006 monitoring effort (Holton 2007) or during the 2014-2015 monitoring effort (Walnut Canyon NM, unpublished data) (Table 4.5.4-8). Among the species detected was the U.S. Fish and Wildlife Service (USFWS) threatened Mexican spotted owl (USFWS 2016a). Golden eagles (*Aquila chrysaetos*), a species of conservation concern in the USFWS Southwest Region, which includes Arizona, New Mexico, Oklahoma, and Texas (USFWS 2008), were observed during both monitoring efforts. None of the 33 species detected were non-native.

From 2004 to 2006, 15 species of bird were observed (Holton 2007), while the NPS cameras captured 26 of the 33 species (Walnut Canyon NM, unpublished data). Six species identified via camera traps were also reported in Springer et al. (2006). The surrounding riparian and forested habitat of Cherry Canyon likely contributed to the high bird species diversity observed there. Since no reference conditions were developed, we did not assign a current condition for this measure. While camera trap data are a reliable method for assessing which bird species directly utilize pools for foraging (e.g., aquatic insects) or drinking, confidence in this measure is low since the reference condition is unknown. Trend could not be determined based on these data.

Mammals

A total of 18 mammal species were detected via the two camera trap studies, two of which could only be identified to genus or order (Table 4.5.4-9). Ten of the 18 species were identified by the NPS trailcam during 2014 to 2015 (Walnut Canyon NM, unpublished data) and 13 species were identified by Holton (2007) in between 2004 and 2006. All four species of skunk known to occur in Arizona were observed in Cherry Canyon and several rare and secretive species were also observed, including mountain lion, American black

Table 4.5.4-8. Birds documented in Cherry Canyon pools.

Common Name	Scientific Name
American robin[1]	*Turdus migratorius*
Ash-throated flycatcher[2,3]	*Myiarchus cinerascens*
Black-throated gray warbler[1]	*Setophaga nigrescens*
Blue-gray gnatcatcher[1]	*Polioptila caerulea*
Broad-tailed hummingbird[2,3]	*Selasphorus platycercus*
Canyon wren[2,3]	*Catherpes mexicanus*
Chipping sparrow[1]	*Spizella passerina*
Common raven[1,3]	*Corvus corax*
Cooper's hawk[1]	*Accipiter cooperii*
Dark-eyed junco[1,3]	*Junco hyemalis*
Golden eagle[1,3]	*Aquila chrysaetos*
Northern goshawk[1]	*Accipiter gentilis*
Great horned owl[1,3]	*Bubo virginianus*
Hairy woodpecker[2,3]	*Picoides villosus*
House finch[1]	*Haemorhous mexicanus*
Lazuli bunting[1]	*Passerina amoena*
Lesser goldfinch[1]	*Spinus psaltria*
Mexican spotted owl[1]	*Strix occidentalis lucida*
Mourning dove[1,3]	*Zenaida macroura*
Northern flicker[1,3]	*Colaptes auratus*
Northern goshawk[1]	*Accipiter gentilis*
Northern mockingbird[1]	*Mimus polyglottos*
Pinyon jay[1]	*Gymnorhinus cyanocephalus*
Plumbeous vireo[2,3]	*Vireo plumbeus*
Red-tailed hawk[1]	*Buteo jamaicensis*
Rock wren[2,3]	*Salpinctes obsoletus*
Ruby-crowned kinglet[1]	*Regulus calendula*
Sharp-shinned hawk[3]	*Accipiter striatus*
Spotted towhee[1]	*Pipilo maculatus*
Steller's jay[1,3]	*Cyanocitta stelleri*
Turkey vulture[1,3]	*Cathartes aura*
Warbler sp.[1]	Order Passeriformes
Western tanager[1]	*Piranga ludoviciana*

[1] Camera trap data collected during 2014-2015 and provided by Walnut Canyon NM staff.

[2] Data collected in May 2005 and presented in Springer et al. (2006).

[3] Data collected between October 2004 and June 2006 and presented in Holton (2007).

bear, and bobcat (*Lynx rufus*). Only one non-native mammal, a domestic dog (*Canis familiaris*), was caught on camera in June 2015 (Walnut Canyon NM, unpublished data). Since no reference conditions were developed, we did not assign a current condition for this measure and confidence is low for the reasons

Table 4.5.4-9. Mammals documented in Cherry Canyon pools.

Common Name	Scientific Name
Abert's squirrel[1,2]	*Sciurus aberti*
American black bear[1,2]	*Ursus americanus*
Bobcat[2]	*Lynx rufus*
Chipmunk (cliff or least)[2]	*Tamias* sp.
Coyote[2]	*Canis latrans*
Domestic dog[1]*	*Canis familiaris*
Western spotted skunk[1]	*Spilogale gracilis*
Elk[2]	*Cervus elaphus*
Gray fox[1,2]	*Urocyon cinereoargenteus*
Hooded skunk[2]	*Mephitis macroura*
Long-tailed weasel[2]	*Mustela frenata*
Mountain lion[1,2]	*Puma concolor*
Ring-tailed cat[2]	*Bassariscus astutus*
Rock squirrel[1,2]	*Otospermophilus variegatus*
Striped skunk[2]	*Mephitis mephitis*
Western hog-nosed skunk[1]	*Conepatus mesoleucus*
White-nosed coati[1]	*Nasua narica*
Unidentified bat[1]	Order Chiroptera

* Indicates non-native species.

[1] Camera trap data collected during 2014-2015 and provided by Walnut Canyon NM staff.

[2] Data collected between October 2004 and June 2006 and presented in Holton (2007).

described for birds. Trend could not be determined based on these data.

<u>Herpetofauna</u>

Seven species of reptile and amphibian were identified between the NPS camera trap wildlife study (2014-2015) and the SCPN herpetofauna study (2001-2003) (Table 4.5.4-10). An additional four individuals were identified to genus, order, or suborder. During the SCPN study, the first population of canyon treefrogs in the monument was discovered in Cherry Canyon pools (Persons and Nowak 2006). As described in the introduction, this population is isolated from other populations by largely unhabitable terrain and is the only population known to occur in the monument (Persons and Nowak 2006). However, a single individual was also found at the sewage lagoons located north of the visitor center within the monument during the 2001 to 2003 SCPN study (Persons and Nowak 2006).

The canyon treefrog was identified as a monitoring target by the SCPN (Persons and Nowak 2006). To

Table 4.5.4-10. Herpetofauna documented in Cherry Canyon pools.

Common Name	Scientific Name
Canyon treefrog[1,2,3]	*Hyla arenicolor*
Eastern fence lizard (also known as Plateau lizard)[3]	*Sceloporus tristichus*
Little Striped whiptail[3]	*Aspidoscelis inornata*
Ornate tree lizard[3]	*Urosaurus ornatus*
Plateau striped whiptail[3]	*Aspidoscelis velox*
Terrestrial gartersnake[2]	*Thamnophis elegans*
Western rattlesnake[3]	*Crotalus oreganus*
Unidentified Aspidoscelis[3]	*Aspidoscelis* sp.
Unidentified lizard[2]	Suborder Lacterilia
Unidentified snake[2]	Suborder Serpentes
Unidentified tadpoles[2]	Order Anura

[1] Camera trap data collected during 2014-2015 and provided by Walnut Canyon NM staff and general NPS staff observations.

[2] Data collected between October 2004 and June 2006 and presented in Holton (2007).

[3] Data collected during 2001-2003 and provided by the Southern Colorado Plateau Network (Persons and Nowak 2006).

Table 4.5.4-11. Canyon treefrog observations at Cherry Canyon pools.

Date	Observation	Source
6/8/2009	Single adult	Natural History Field Observation Form
7/22/2011	Single adult	Wildlife Sighting Record
5/15/2012	Few calling individuals	Presence/Absence Audio Detection Survey
7/23/2013	Few calling individuals	Presence/Absence Audio Detection Survey
8/5/2013	None heard calling	Presence/Absence Audio Detection Survey
5/5/2014	Adult (s)	NPS Staff Observation
8/4/2014	Tadpoles	NPS Wildlife Camera Data
8/8/2014	Adult (s)	NPS Wildlife Camera Data
3/25/2015	Adult (s)	NPS Wildlife Camera Data
4/22/2015	Several adults observed and heard	NPS Staff Observation
7/23/2015	Tadpoles	NPS Wildlife Camera Data
8/4/2015	Tadpoles	NPS Wildlife Camera Data
8/5/2015	Tadpoles	NPS Wildlife Camera Data
5/10/2016	Adults	NPS Staff Observation

Note: Data provided by Walnut Canyon NM natural resources staff.

this end, NPS staff have collected observations of canyon treefrogs since at least 2009 (Table 4.5.4-11). These data indicate a small but persistent population in Cherry Canyon pools. Beginning in 2012, an audio recording device has been used to confirm the continued presence of canyon treefrogs in Cherry Canyon (Walnut Canyon NM, unpublished data). On 5 August 2013 an audio recording device was also used to check the mouth of Owl Canyon, but no treefrogs were heard calling at this location (Walnut Canyon NM, unpublished data). Since reference conditions were not developed for this measure, we did not assign a condition and confidence is low. Trend could not be determined based on one sample period.

Overall Condition, Trend, Confidence Level, and Key Uncertainties

Table 4.5.4-12 summarizes the condition rating and rationale used for each indicator and measure. The most important measures for assessing the condition of Cherry Canyon pools in Walnut Canyon NM is stream flow and persistence of pooled water, and these two measures indicate good condition. However, since the persistence of pooled water data were more than 10 years old, we assigned this measure low confidence. Flows for Cherry Creek indicate high variability in timing, duration, and height above thalweg. Variability in stream flow characterizes many aquatic systems of the Colorado Plateau (Scott et al. 2005). Natural variability in stream flow helps to maintain aquatic integrity by transporting sediment downstream, contributes to the dispersal of aquatic macroinvertebrates, and maintains core water quality parameters in pools that remain after flood events (Scott et al. 2005). However, core water quality data are lacking for Cherry Canyon pools. While the recording stage gage also collects temperature data, it only records temperature during periods of stream flow (Monroe and Soles 2015), while temperature data for water in pools regardless of stream flow would be more instructive. Aside from the two measures of water quantity and availability, the conditions of all remaining measures were considered unknown because of the age of the data, the fact that there were relatively few data (e.g., water quality), and/or because reference conditions had not been developed (e.g., biodiversity). Given the lack of historical reference conditions and availability of current data it was difficult to assign an overall condition for Cherry Canyon pools. However, based on the good condition rating for stream flow and persistence of pooled water and the unknown condition for water quality and biodiversity, we assigned an overall condition of unknown to good with low confidence and unknown trend.

Table 4.5.4-12. Summary of Cherry Canyon pools indicators, measures, and condition rationale.

Indicators of Condition	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Water Quantity and Availability	Stream flow (timing, duration, and magnitude)		Stream flow data show that floods occurred during most years, that floods were variable in magnitude and duration, and that floods occurred largely during spring and summer months. These characteristics are typical of a naturally functioning ephemeral and intermittent stream on the Colorado Plateau. Therefore, we consider the condition of this measure to be good. Confidence is high but trend could not be determined. Although there are data for approximately 14 of the last 22 water years, the two different measurement methods (1995-2002 USGS data vs. 2011-2016 SCPN data) are not comparable. Furthermore, long term data is necessary to capture the natural seasonal variability in stream flow and finally, not all data (i.e., time lapse photography) have been analyzed. Confidence in this condition rating is high.
	Persistence of Pooled Water (%)		Water was observed in the monitored pool on 100% of the 25-biweekly site visits. The estimated average estimated pool volume was 82% from 1 October 2004 through 15 October 2005. Pool volume was never estimated below 50% during any of the 25-biweekly surveys, and during 19 of the 25 surveys, the pool was estimated to be at least 75% full. Therefore, the condition for this measure is considered good; however, confidence is low since these data are more than 10 years old and because only one pool was monitored, which may not be representative of all pools in Cherry Canyon.
Water Quality	Core Water Parameters, Inorganic Chemicals, and Uranium		Although most water quality measures for which condition thresholds have been established were considered good, the data for all measures was more than 10 years old. Since no recent data (i.e., < 5 yrs) exists for water resources in Walnut Canyon NM, the condition for this indicator and all measures is unknown. Furthermore, most measures included only one or two samples. Since the condition is unknown, the confidence is low. Trends could not be determined.
Biodiversity	Plants, Invertebrates, Birds, Mammals, and Herpetofauna		We did not develop reference conditions for biodiversity in Walnut Canyon NM based on the recommendation of NPS staff. NPS staff recommended reporting species lists that can be used for future comparisons instead.
Overall Condition			The condition for the majority of measures used in this assessment is unknown (all seven water quality measures and all four biodiversity measures). This is because most data is more than 10 years old and are sparse, or reference conditions have not been established. Based on the lack of historical reference conditions and availability of current data it was difficult to assign an overall condition for Cherry Canyon pools. The most important measures for assessing the condition of Cherry Canyon pools is stream flow and persistence of pooled water, and these two measures indicate good condition. However, since the persistence of pooled water data were more than 10 years old, we assigned this measure low confidence. Thus, we assigned an overall condition of unknown to good condition with low confidence and unknown trend.

Factors that influence confidence in the condition rating include age of the data (< 5 yrs unless the data are part of a long-term monitoring effort), repeatability, field data vs. modeled data, and whether data can be extrapolated to other areas in the monument. The condition for the majority of measures used in this assessment is unknown because of these factors. The greatest uncertainty regarding Cherry Canyon pools is that their historical and current condition is largely unknown.

Threats, Issues, and Data Gaps

The primary threat to Cherry Canyon pools is that of climate change. Monahan and Fischelli (2014) evaluated which of 240 NPS units have experienced extreme climate changes during the last 10 to 30 years. The results of this study for Walnut Canyon NM were summarized in NPS (2014). Extreme climate changes were defined as temperature and precipitation conditions exceeding 95% of the historical range of variability. The results of this study indicate a trend toward extreme warm and extreme dry conditions within the monument (Monahan and Fischelli 2014) and are indicative of trends occurring throughout the southwestern U.S. (Prein et al. 2016). Reduced precipitation within the watershed will lower the amount of water available to recharge pools, and warmer temperatures will alter the timing of snowmelt. Cherry Canyon pools are primarily filled by spring runoff and summer monsoonal rains, but pools may also be recharged through groundwater; however, this remains largely untested (SCPN partner, S. Monroe, phone call, 15 November 2016). Evidence suggests that groundwater recharge is minimal. On 10 May 2005 there was no measurable discharge at Cherry Canyon pools (Springer et al. 2005) and on 18 September 2001 and 2 May 2002 discharge at Cherry Canyon seep was too small to be measured (Thomas 2002).

The positive effects of pools for wildlife and plants are driven by the persistence of water and thus far, the main Cherry Canyon pool is largely perennial, while the smaller pools hold water at least some of the time during most years. However, the threat of climate change may alter this pattern. Macroinvertebrates living in and around pools can be useful indicators of aquatic ecosystem health because they are sensitive to water quality and drive ecosystem dynamics at higher trophic levels (Scott et al. 2005). However, many invertebrates sampled at Cherry Canyon pools were considered terrestrial but to date not all specimens have been identified to species (Springer et al. 2006). The canyon treefrog relies on macrointertebrates for food and on pooled water for breeding and recruitment. In dry years canyon treefrogs may not be able to breed (Arizona Game and Fish Department 2003). Dry periods not only affect breeding and recruitment, but also have the potential to affect survival. The population could be extirpated within the monument following a prolonged drought. Additionally, the pools are an important source of drinking water for several mammal species, and Cherry Canyon appears to be a travel corridor for many of them (see the assessment on habitat connectivity).

In addition to the effects of decreased precipitation on water availability, climate change also has the potential to alter fire regimes, which in turn, can affect pool health through increased sedimentation, changes in water chemistry due to ash inputs, and loss of overhead vegetation (Earl and Blinn 2003, Moody and Martin 2009, Scott et al. 2005). In the southwest, fire frequency and severity has increased after decades of fire suppression (Abatzoglou and Williams 2016). An increase in severe-fire events in the southwest may result in increased runoff of sediment (Moody and Martin 2009), which has the potential to fill in pools and eliminate the macroinvertebrate community and canyon treefrog population, and the deposition of ash has at least a temporary affect on water quality (Scott et al. 2005). A fire within Cherry Canyon itself may lead to the loss of the forest canopy, which in turn would change water temperature in pools and thus, alter all other core water quality parameters (Earl and Blinn 2003). Perennial and ephemeral pools are one of the most important natural resources in Walnut Canyon NM, especially considering stream flow through Walnut Canyon has been severely altered. Thus, the pools in Cherry Canyon are the only remaining perennial water resources in the monument.

4.5.5. Sources of Expertise

Stephen Monroe (hydrologist, partner of SCPN) provided the data used to stream flow, in addition to interpretation of these data and a review of the assessment. Erika Nowak (herpetologist, NAU Colorado Plateau Research Station) provided data on herpetofauna.

Assessment author is Lisa Baril, biologist and science writer, Utah State University.

4.6. Walnut Creek Riparian Area

4.6.1. Background and Importance

In Walnut Canyon National Monument (NM) the major riparian corridor of Walnut Creek meanders from west to east through 13 km (8 mi) of Kaibab Limestone and Coconino Sandstone (Graham 2008) (Figure 4.6.1-1). From the north rim to the south rim the canyon spans an average distance of about 0.5 km (0.3 mi) and is roughly 120 m (400 ft) deep from the rim to the canyon bottom (Soles and Monroe 2012). The densely vegetated corridor provides important habitat for Mexican spotted owls (*Strix occidentalis lucida*), peregrine falcons (*Falco peregrinus*), black bears (*Ursus americanus*), and mountain lions (*Puma concolor*), as well as a variety of songbirds, invertebrates, and small mammals (NPS 2015a).

Walnut Canyon NM is influenced by three watersheds. They are the Cherry Canyon-Walnut Creek Watershed, the Walnut Creek-Upper Lake Mary Watershed, and the Walnut Creek-Lower Lake Mary Watershed (USDA Forest Service 2017) (Figure 4.6.1-2). Historically, water flowed in Walnut Creek in response to spring snowmelt and summer monsoonal rainstorms (Soles and Monroe 2012). Regular scouring of the creek bottom maintained an open riparian area that was dominated by riparian-obligate species, including willow (*Salix spp.*), redosier dogwood (*Cornus sericea*), and narrow-leaf cottonwood (*Populus angustifolia*). However, the Walnut Creek riparian corridor has been impaired by three dams that were built between 1885 and 1941 (Soles and Monroe 2012).

Near the downstream end of the canyon within the monument, the relatively small Santa Fe Dam was built in 1885/1886 to supply water to the Santa Fe Railway, but the dam failed to hold water (Brian 1992). In 1904, another dam was constructed upstream of the monument, which created Lower Lake Mary. Although the dam interrupts water flow in Walnut Creek, much of the water is lost due to seepage since the dam was built along a fault zone (Soles and Monroe 2012). In 1941, a second dam constructed upstream of Lower Lake Mary created Upper Lake Mary. Upper Lake Mary serves as an important water supply for the city of Flagstaff, Arizona (Soles and Monroe 2012).

Following construction of the two upper dams, flows through Walnut Canyon NM have been rare (Monroe and Soles 2015). The absence of seasonal stream flows during the last 113 years has altered the structure and function of Walnut Creek, including patterns of sedimentation, spring and seep recharge, the occurrence of ephemeral stream channel pools, and vegetation composition and structure (Brian 1992,

Figure 4.6.1-1. Walnut Creek corridor in Walnut Canyon NM. Photo Credit: NPS.

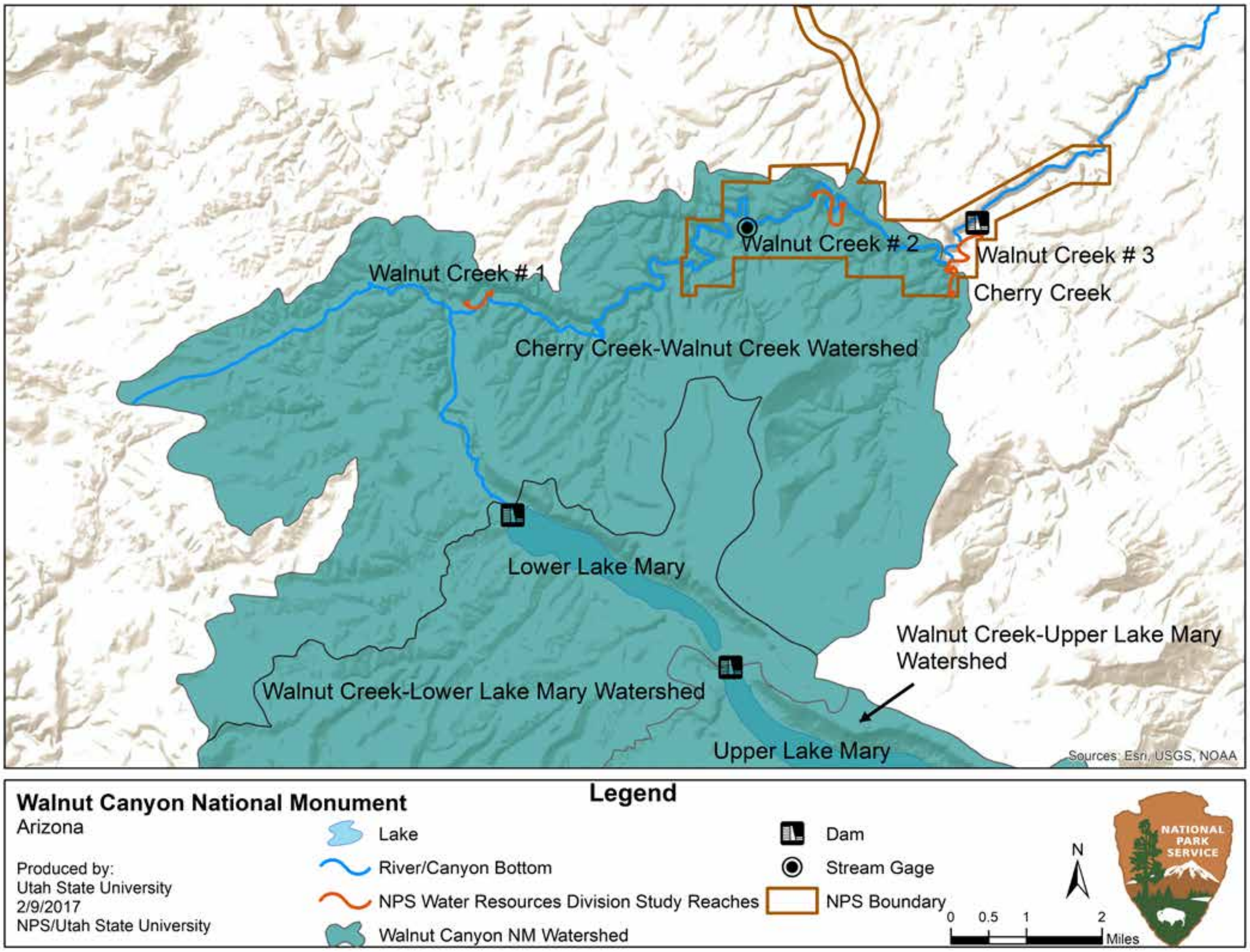


Figure 4.6.1-2. Walnut Canyon NM watershed and rapid assessment reaches along Walnut Creek. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction.

Rowlands et al. 1995, Soles and Monroe 2012, Wagner et al. 2017).

4.6.2. Data and Methods

To assess the condition of the Walnut Creek riparian corridor we relied on repeat sampling (1989-2006) of eight permanent vegetation plots located along Walnut Creek (Phillips 1990, Rowlands et al. 1995, Harms and Monroe 2006), data on the current status of the Arizona walnut (*Juglans major*) population along the riparian corridor (Allan 2012, Schelz et al. 2013), and a rapid qualitative assessment of Walnut Creek completed by the National Park Service's (NPS) Water Resources Division (WRD) during 27-29 September 2017 (Wagner et al. 2017).

WRD staff assessed three reaches along Walnut Creek and one reach along Cherry Creek (Figure 4.6.1-2). However, only two reaches were located along Walnut Creek within the monument. These two reaches (Walnut Creek #2 and Walnut Creek #3) were included in this assessment (see Wagner et al. 2017 for the remaining two assessments). Walnut Creek #2 is a 1.6 km (1.0 mi) stretch located upstream and downstream of Third Island Fort. Walnut Creek #3 is located 1.6 km (1.0 mi) downstream of the confluence with Cherry Creek to the Santa Fe Dam.

In total, we used six indicators with between one and six measures each for a total of 24 measures to evaluate the Walnut Creek riparian corridor in Walnut Canyon NM. Each measure is described below.

<u>Stream Flow (timing, duration, and magnitude)</u>
The Southern Colorado Plateau Network (SCPN) Inventory and Monitoring (I&M) Program has

identified stream flow as one of seven hydrologic vital signs to monitor across the 19 network parks (Thomas et al. 2006). Vital signs are a subset of key indicators selected to represent the overall health or condition of NPS resources (Thomas et al. 2006). To this end, the SCPN has established a recording stage gage in Walnut Creek (Figure 4.6.1-2). The station was originally established by the USGS in 1995 and was maintained until 2002 (McCormack et al. 2003). The original purpose of the station was to function as a crest-stage gage for water rights purposes (Soles and Monroe 2012). Crest-stage gages (CSG) record the height of flood events, providing information on whether a flood occurred since the previous site visit and the height of the flood, but CSGs do not record when the flood occurred, flood duration, or whether more than one flood event occurred since the gage was last read. Nevertheless, these data provide a useful historical context for the more recent flow data described below and were therefore included in this assessment (data provided by S. Monroe, hydrologist, SCPN partner).

In 2010 the SCPN converted the crest-stage gage to a recording stage gage, which provides information on the timing, duration, and height above thalweg for all high flow events. The thalweg is the lowest point in a creek bed and is the location at which water flows fastest. Thus, height above the thalweg serves as a measure of flow magnitude. The gage records in 15-minute intervals. We reported the historical USGS data collected from 1995 to 2002 and data collected by the SCPN from October 2010 to September 2016.

In 1989, eight permanent vegetation plots were established to survey plant community composition and cover (Phillips 1990). Plots were established along the canyon bottom. Each plot was 375 m^2 (0.1 ac^2), with minor adjustments based on local topography. Plots were resampled in 1993 (Rowlands et al. 1995) and then again in 2006 by SCPN staff (Harms and Monroe 2006). The SCPN has selected vegetation monitoring along Walnut Creek as a vital sign (Thomas et al. 2006).

Importance Value for Herbaceous/Shrub Layer

Within each plot described above, 50 subplots measuring 0.1 m^2 (1.0 ft^2) were established along transects. Observers recorded plant frequency, density, and cover in each subplot and then averaged these values per plot (Phillips 1990). Importance values were calculated as the relative frequency + relative density + relative cover. Importance values for each species with a facultative wetland plant status were compared by plot over the three time periods (1989, 1993, and 2006). Facultative wetland species are those that usually occur in wetlands but may also occur in non-wetlands, or those plants that occur in wetlands between 67% and 99% of the time (Harms and Monroe 2006).

Age-class Structure for Boxelder, Narrowleaf Cottonwood, and Arizona Walnut

Within each plot all living trees were censused and divided into three age-classes based on diameter at breast height (DBH), or at 1.5 m (4.9 ft) from the ground. The three age classes were: seedlings and saplings (0 - 13 cm [0 - 5 in]); poles or advanced regeneration (13 - 23 cm [5 - 9 in]); and mature (>23 cm [>9 in]) (Phillips 1990). The three riparian trees classified were boxelder (*Acer negundo*), narrowleaf cottonwood (*Populus angustifolia*), and Arizona walnut. The number of trees in each size class was compared between 1989 and 2006.

Population Size and Extent

In 2011 and 2012, the entire Walnut Canyon riparian corridor, including side canyons, was inventoried for Arizona walnut trees (Schelz et al. 2013). Although the majority of walnut trees occur in the main riparian corridor, trees occasionally grow along the canyon walls and, rarely, along the canyon rim (Schelz et al. 2013). Since the overall objective was to inventory the entire population of Arizona walnut trees in the monument, these areas were also included in the inventory. Observers walked 5-m wide (16.4-ft) transects throughout the target area. The total number of trees were counted and mapped to determine the population size and distribution, or extent. For every walnut tree located, observers mapped their location using a Trimble GeoXT global positioning unit (GPS), and each tree was flagged and photographed.

Age-class Distribution

The height and DBH were measured for each Arizona walnut tree encountered during the 2011-2012 survey described above (Schelz et al. 2013). Height was measured using a measuring tape or a digital or hand clinometer. DBH was measured using either a Mantex caliper or a standard DBH tape at 1.37 m (4.5 ft) from the tree base for all stems or trunks originating below this height. Each tree was classified separately by height and DBH in one of five age classes as shown in Table 4.6.2-1. Trees did not have to meet both DBH and

Table 4.6.2-1. Age classes for Arizona walnut based on height and DBH.

Age-Class	Tree Height	DBH
Seedling	2.54 - 12.7 cm (1-5 in)	< 7.62 cm (< 30 in)
Sapling	1.55 - 4.57 m (5.1 - 15 ft)	7.88 - 20.32 cm (3.1 - 8.0 in)
Young Mature	4.60 - 10.67 m (15.1 - 35 ft)	20.57 - 27.94 cm (8.1 - 11.0 in)
Mature	10.70 - 15.24 m (35.1 - 50 ft)	28.19 - 45.72 cm (11.1 - 18.0 in)
Old Growth	> 15.24 m (> 50 ft)	45.97 - 114.3 cm (18.1 - 45.0 in)

Source: Schelz et al. (2013).

height requirements for a particular age-class. Thus, trees may be categorized in two different age classes depending on height and DBH. This classification roughly corresponds with that of Phillips (1990), except that seedlings and saplings were separated by Schelz et al. (2013).

Percent Vigor

Each walnut tree encountered was assessed for vigor, and the results were averaged over all trees. Vigor refers to the health of the tree as determined by the proportion of live and dead stems as follows (Schelz et al. 2013):

- low vigor: approximately 10% live stems,
- medium vigor: approximately 25% live stems,
- high vigor: approximately 50% live stems with 50% dead stems,
- very high vigor: approximately 75% live stems with 25% dead stems, and
- vigorous: more than 90% live stems with ≤10% dead stems.

Genetic Diversity

Leaf samples were collected from 147 Arizona walnut trees by NPS staff during 2011 (Allan 2012). Samples were collected from trees growing above and below the Santa Fe Dam. The objectives were to determine the 1) overall genetic diversity of the monument's Arizona walnut population, 2) assess whether there were genetic differences between trees growing above and below the Santa Fe Dam, and 3) determine if the dam has led to increased inbreeding (Allan 2012).

To assess overall genetic diversity of the monument's walnut tree population, the author determined the total number of alleles (N_A), the effective number of alleles (N_E), Shannon's Information Index (I), observed and expected heterozygosity ($H_{O,}$ H_E), and the fixation index (f) for five microsatellite loci. The fixation index, a measure of inbreeding, varies on a scale from -1 to 1 with low values indicating little to no inbreeding. The Shannon Index is a measure of diversity with higher values indicating greater diversity. To determine whether the dam has had any effect on genetic structure or has caused inbreeding the six measures described above were compared for each population and an Analysis of Molecular Variation (AMOVA) and F-statistic (F_{ST}) tests were conducted to test for significant differences between the two populations.

WRD Riparian Condition Assessment

The following indicators and measures were used by the WRD to assess the proper functioning of riparian areas. The method is described in detail in "A User Guide to Assessing the Proper Functioning Condition and the Supporting Science for Lotic Areas" (Prichard et al. 1998). For the proper functioning condition (PFC) method, an interdisciplinary team of technical experts qualitatively evaluates 17 hydrology, vegetation, and erosion/deposition measures for the riparian area under consideration. However, we excluded two measures (beaver activity and availability of coarse and/or large woody debris) since no beaver dams were present along the reach and because the reach assessed does not depend on coarse woody material (Wagner et al. 2017). For each measure, a "yes" or "no" answer is given based on qualitative surveys of the reach. A full assessment was conducted for Walnut Creek #2 and a narrative assessment was conducted for Walnut Creek #3.

The following four measures of the PFC method were used to determine if the observed channel and floodplain morphology is stable and in balance with the landscape setting, given prevailing hydrologic and sediment inputs.

Floodplain

Is the floodplain above the "bankfull" channel elevation inundated by relatively frequent flows?

Sinuosity, Width/Depth Ratio, and Gradient

Are channel morphology parameters (sinuosity, gradient, and width-to-depth ratio) in balance with the landscape setting?

Riparian-Wetland Area
Is the riparian-wetland area widening or has it achieved its potential extent?

Upland Watershed Contribution
Upland watershed is not contributing to riparian-wetland degradation.

The following six measures of the PFC method were developed to evaluate a number of riparian-wetland vegetation parameters and characteristics such as species composition, age-class distribution, cover, vigor, soil moisture requirements, and ability to stabilize soils.

Age-class Distribution
Is there a diverse age-class distribution of riparian-wetland vegetation that is capable of providing recruitment for maintenance or recovery of the plant community?

Overall Community Composition
Is there a diverse composition of wetland-riparian vegetation for maintenance/recovery?

Wetland Plant Status
Do the plant species present indicate maintenance of riparian-wetland soil moisture characteristics?

Streambank Community Composition
Is streambank vegetation comprised of plants or plant communities that have root masses capable of withstanding high stream flow events?

Vigor
Do riparian-wetland plants exhibit high vigor?

Cover
Was there adequate riparian-wetland vegetative cover present to protect banks and dissipate energy during high flows?

The following five measures of the PFC method were developed to determine if there is an apparent balance between flow, sediment, and erosion/deposition processes in a stream and riparian system.

Floodplain and Channel Characteristics
Are channel and floodplain characteristics adequate to dissipate energy?

Point Bar Vegetation
Are point bars revegetating with riparian-wetland vegetation?

Lateral Stream Movement
Is lateral stream movement associated with natural sinuosity?

Vertical Stability of Stream Channel
Is the system vertically stable?

Sediment/Water Balance
Is the stream in balance with the water and sediment being supplied by the watershed?

4.6.3. Reference Conditions
Reference conditions for this assessment are shown in Table 4.6.3-1. Reference conditions are described for resources in good, moderate concern, and significant concern conditions for each of the six indicators and 24 measures. Measures of water quantity and availability, vegetation change, and current status of Arizona walnut were developed by NRCA and NPS staff. Reference conditions for the three indicators and measures associated with the Proper Functioning Condition assessment conducted by WRD (Hydrology, Vegetation, and Erosion/Deposition) were developed by Prichard et al. (1998). These measures either met the condition for a functioning riparian area (i.e., good condition) or did not meet the conditions for a functioning riparian area (i.e., significant concern condition). Checklist items that were rated as "not applicable" as a result of impaired stream function were considered to warrant significant concern. Based on this evaluation, the team assigns one of three ratings to the riparian corridor. The ratings are: "Proper Functioning Condition", "Functional At-Risk Condition", and "Non-Functional Condition". A "Proper Functioning Condition" rating for Walnut Creek would be considered good condition, while a "Non-Functional Condition" rating would warrant significant concern.

4.6.4. Condition and Trend
Stream Flow (timing, duration, and magnitude)
Between 1995 and 2002 no flow events were recorded by the stream gage located in Walnut Creek. During 2010 to 2016 only one flow event was recorded (SCPN partner, S. Monroe, hydrologist, e-mail message, 14 February 2017). The flow occurred over a six-day period beginning 9 September 2013 with a maximum

Table 4.6.3-1. Reference conditions used to assess Walnut Creek riparian corridor.

Indicator	Measure	Good	Moderate Concern	Significant Concern
Water Quantity and Availability	Stream Flow (timing, duration, and magnitude)	Timing, duration, and height above thalweg are indicative of a naturally functioning, reliable ephemeral stream, especially following spring snowmelt.	There is some impairment of stream flow, but flows do occur fairly regularly during spring and summer.	Significant impairment of natural stream flow, especially during spring and summer.
Vegetation Change (1989-2006)	Importance Value for Herbaceous/Shrub Layer	No change or an increase in importance value for herbaceous and shrub species with a facultative wetland status.	Some decline in importance value for herbaceous and shrub species with a facultative wetland status.	Significant decline in importance value for herbaceous and shrub species with a facultative wetland status.
	Boxelder Age-class Structure	No change in the number of individuals by size class or an increase in the number of seedlings and saplings, which would indicate reproduction. All size classes are represented in both time periods.	A slight decline in the number of individuals by size class, especially for seedlings and saplings. At least two size classes are represented in each time period.	A significant decline in the number of individuals by size class, especially for seedlings and saplings. Only one size class is represented in each time period.
	Narrowleaf Cottonwood Age-class Structure	Same as above	Same as above	Same as above
	Arizona Walnut Age-class Structure	Same as above	Same as above	Same as above
Current Status of Arizona Walnut	Population Size and Extent	A large number of trees occur throughout the riparian corridor with few gaps between clusters.	A modest number of trees throughout the riparian corridor with large gaps between clusters.	A small population of trees clustered into isolated populations in the riparian corridor.
	Age-class Distribution	A stable or growing population as indicated by more seedlings, saplings, and young mature trees than mature and old growth trees.	Fewer seedlings, saplings, and young mature trees than mature and old growth trees.	Significantly fewer seedlings, saplings, and young mature trees than mature and old growth trees.
	Vigor	The majority of trees exhibit very high vigor or are vigorous (i.e., 75% or more live stems with 25% or fewer dead stems).	The majority of trees exhibit medium or high vigor (i.e., 25-50% live stems with no more than 50% dead stems).	The majority of trees exhibit low vigor (10% live stems).
	Genetic Diversity	Relatively high genetic diversity with little to no inbreeding and no evidence of barriers to gene flow.	Modest genetic diversity with some evidence of inbreeding and restriction of gene flow.	Relatively low genetic diversity with evidence of inbreeding and restricted gene flow.
Hydrology	Floodplain	Floodplain above bankfull is inundated in "relatively frequent" events.	–	Frequent floods do not reach the floodplain.
	Sinuosity, Width/ Depth Ratio, and Gradient	Sinuosity, width/depth ratio, and gradient are in balance with the landscape setting (i.e., landform, geology, and bioclimatic region).	–	Sinuosity, width/depth ratio, and/or gradient are not in balance with the landscape setting (i.e., landform, geology, and bioclimatic region).
	Riparian-Wetland Area	Riparian-wetland area is widening or has achieved potential extent.	–	Riparian-wetland area is not widening or has not achieved potential extent.

Table 4.6.3-1 continued. ***Reference conditions used to assess Walnut Creek riparian corridor.***

Indicator	Measure	Good	Moderate Concern	Significant Concern
Hydrology *continued*	Upland Watershed Contribution	Upland watershed is not contributing to riparian-wetland degradation.	–	Upland watershed is contributing to riparian-wetland degradation.
Vegetation	Age-Class Distribution	There is diverse age-class distribution of riparian-wetland vegetation (for recruitment for maintenance/ recovery).	–	One or both age classes that indicate recruitment and replacement are absent. Other age classes may be present, but they do not contribute to population growth.
	Overall Community Composition	There is diverse composition of riparian-wetland vegetation (for maintenance/recovery). Two or more riparian-wetland species present.	–	There is not a diverse composition of riparian-wetland vegetation (for maintenance/recovery). One or no riparian-wetland species present.
	Wetland Plant Status	Species present indicate maintenance of riparian-wetland soil moisture characteristics (i.e., species designated as either obligate wetland, facultative wetland and/or facultative).	–	Species present do not indicate maintenance of riparian-wetland soil moisture characteristics (i.e., species designated as either obligate upland or facultative upland).
	Streambank Community Composition	Streambank vegetation is comprised of those plants or plant communities that have root masses capable of withstanding high stream flow events.	–	Streambank vegetation is dominated by species that lack extensive root masses, which leads to undercut banks that collapse during high flows.
	Vigor	Riparian-wetland plants exhibit high vigor.	–	Riparian-wetland plants do not exhibit high vigor.
	Cover	Adequate riparian-wetland vegetative cover is present to protect banks and dissipate energy during high flows.	–	Adequate riparian-wetland vegetative cover to protect banks and dissipate energy during high flows is lacking.
Erosion / Deposition	Floodplain and Channel Characteristics	Floodplain and channel characteristics (i.e., rocks, overflow channels, coarse and/ or large woody material) are adequate to dissipate energy.	–	Floodplain and channel characteristics (i.e., rocks, overflow channels, coarse and/or large woody material) are not adequate to dissipate energy.
	Point Bar Vegetation	Point bars are revegetating with riparian-wetland vegetation.	–	Point bars are not revegetating with riparian-wetland vegetation.
	Lateral Stream Movement	Lateral stream movement is associated with natural sinuosity.	–	Lateral stream movement is not associated with natural sinuosity.
	Vertical Stability of Stream Channel	System is vertically stable.	–	System is not vertically stable.
	Water/Sediment Balance	Stream is in balance with the water and sediment being supplied by the watershed (i.e., no excessive erosion or deposition).	–	Stream is not in balance with the water and sediment being supplied by the watershed (i.e., excessive erosion or deposition).

* Indicators, measures, and reference conditions extracted from Prichard et al. (1998).

height above thalweg of 1.2 m (3.9 ft) (Monroe and Soles 2015). The gage was not maintained during 2002 to 2010. NPS staff indicate three additional flow events as follows: January-February 1995 for approximately three weeks, 21-23 January 2010, and a two-week flow during February 2010 (Flagstaff National Monuments, P. Whitefield, natural resource specialist, comments to draft assessment, 7 March 2017). Occasionally, floods are recorded at the gage located below Lake Mary (Monroe and Soles 2015). There are too few data to assess trend, but this is because the two dams located upstream have inhibited flows since 1904. The lack of recorded flows during the 22-year period warrants significant concern. Confidence in these data is high.

Change in Importance Value for Herbaceous/Shrub Layer

Six species of perennial herbs and shrubs with a facultative wetland status were found among the eight permanent vegetation plots (Table 4.6.4-1). For redosier dogwood, the importance value declined in three of four plots. In plot four, dogwood increased from 1989 to 1993 but was absent in 2006. Dogwood was also absent in two additional plots in 2006. Importance values for smooth horsetail (*Equisetum laevigatum*) increased in two plots between 1989 and 1993 then declined in importance by 2006 in both plots. Rocky Mountain iris (*Iris missouriensis*) was found in only one plot and the remaining species exhibited variable importance values over time. The six species were not adequately distributed among the eight plots to assess change in importance value over time. Therefore, the condition for this measure is unknown. Confidence is low and trend is unknown. Although the condition for this measure is unknown, it is likely much of the vegetation change for the herbaceous and shrub layer had already occurred by 1989. The Upper Lake Mary Dam was constructed nearly 50 years prior to the first

Table 4.6.4-1. Importance values for facultative wetland perennial herbaceous and shrub species.

Plot #	Year	Redosier dogwood *(Cornus sericea)*	Smooth horsetail *(Equisetum laevigatum)*	Rocky Mountain iris *(Iris missouriensis)*	Marsh muhly *(Muhlenbergia racemosa)*	Woodbine *(Parthenocissus vitacea)*	Western poison ivy *(Toxicodendron rydbergii)*
Plot 1	1989	57.29	3.47	–	19.29	–	8.77
	1993	41.05	16.34	–	–	–	–
	2006	13.87	6.42	–	33.79	3.38	–
Plot 2	1989	16.56	–	–	15.17	49.74	–
	1993	5.23	–	–	–	10.96	–
	2006	–	–	–	13.59	18.17	–
Plot 3	1989	–	–	–	–	24.03	–
	1993	–	–	--	–	–	–
	2006	–	–	–	2.28	0.47	–
Plot 4	1989	3.97	–	6.82	–	–	11.99
	1993	9.48	–	7.88	–	–	3.14
	2006	–	–	–	–	7.82	20.67
Plot 5	1989	–	–	–	1.97	3.17	–
	1993	–	–	–	–	–	–
	2006	–	–	–	–	–	–
Plot 6	1989	64.42	–	–	–	–	–
	1993	36.3	–	–	–	–	–
	2006	–	–	–	–	–	–
Plot 7	1989	–	–	–	–	0.6	–
	1993	–	–	–	–	–	–
	2006	–	–	–	–	–	–
Plot 8	1989	–	9.7	–	–	–	–
	1993	–	13.32	–	–	13.1	–
	2006	–	10.71	–	–	–	–

Source: Harms and Monroe (2006).

vegetation survey. Harms and Monroe (2006) show that a majority of the herbaceous and shrub layer was composed of upland plant species rather than wetland species.

Change in Age-class Structure for Boxelder
Boxelder exhibited fewer individuals in each age-class in 2006 than in 1989, particularly for pole sized trees (Figure 4.6.4-1). These data indicate that recruitment of seedlings and saplings into reproductively mature individuals has declined somewhat, which warrants moderate concern. Confidence in the condition rating is medium due to the age of the data and small sample size.

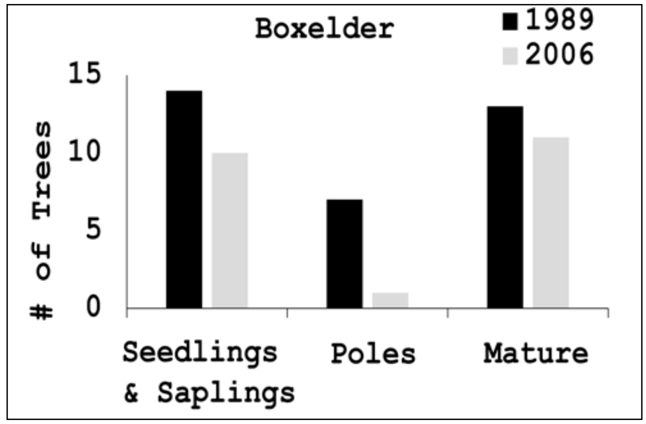


Figure 4.6.4-1. Change in age-class distribution of boxelder between 1989 and 2006.

Change in Age-class Structure for Narrowleaf Cottonwood
Narrowleaf cottonwood exhibited the largest changes in age structure of the three tree species (Figure 4.6.4-2). In 1989, approximately 130 seedlings and saplings were counted among the eight plots, but in 2006 fewer than 20 seedlings and saplings were counted. In both time periods the number of poles and mature trees was low and had declined by 2006. The low number of narrowleaf cottonwood seedlings in 2006 compared with 1989 and few pole and mature trees warrants significant concern for this species and indicates a deteriorating trend. Confidence in the condition rating is medium due to the age of the data and small sample size.

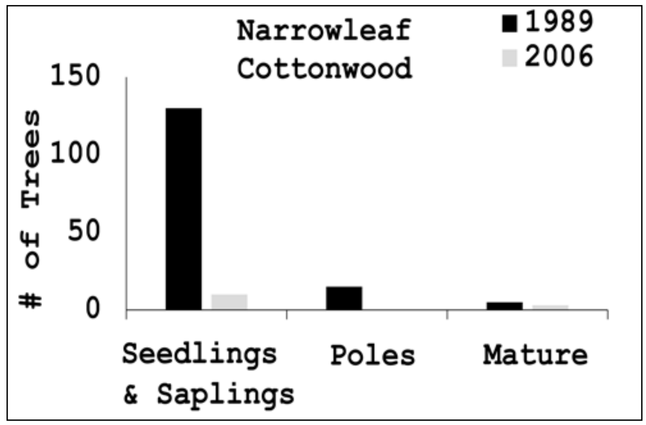


Figure 4.6.4-2. Change in age-class distribution of narrowleaf cottonwood between 1989 and 2006.

Change in Age-Class Structure for Arizona walnut
Among the eight plots Arizona walnut trees exhibited fewer seedlings and saplings in 2006 than in 1989, but the number of poles and mature trees remained the same (Figure 4.6.4-3). These data indicate that there has been recruitment of seedlings and saplings into reproductively mature individuals, which indicates good condition, but the slight decline in seedlings and saplings warrants moderate concern. Since the number of poles and mature trees was the same between the two time periods and the number of seedlings and saplings declined only slightly, the trend is unchanging. Confidence in the condition rating is medium due to the age of the data and small sample size.

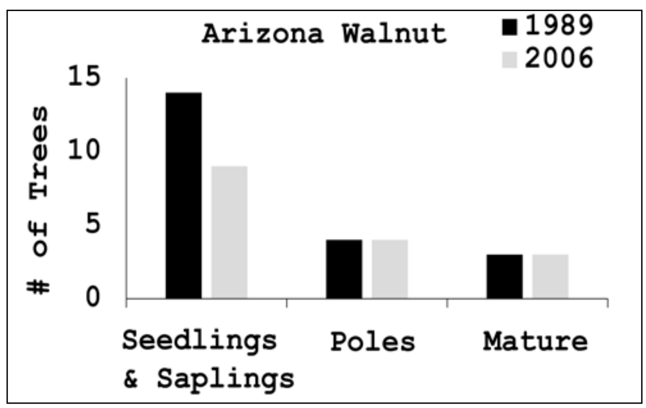


Figure 4.6.4-3. Change in age-class distribution of Arizona Walnut between 1989 and 2006.

Arizona Walnut Population Size and Extent
A total of 2,065 Arizona walnut trees were counted within the study area during 2011 and 2012 (Figure 4.6.4-4). Trees were distributed throughout the canyon with few gaps between clusters; however, there was a somewhat isolated cluster at the west end of the monument. Walnut trees were well distributed both above and below the Santa Fe Dam. Since the population is large and trees were well distributed throughout the monument, the condition for this measure is good. Confidence in this condition rating

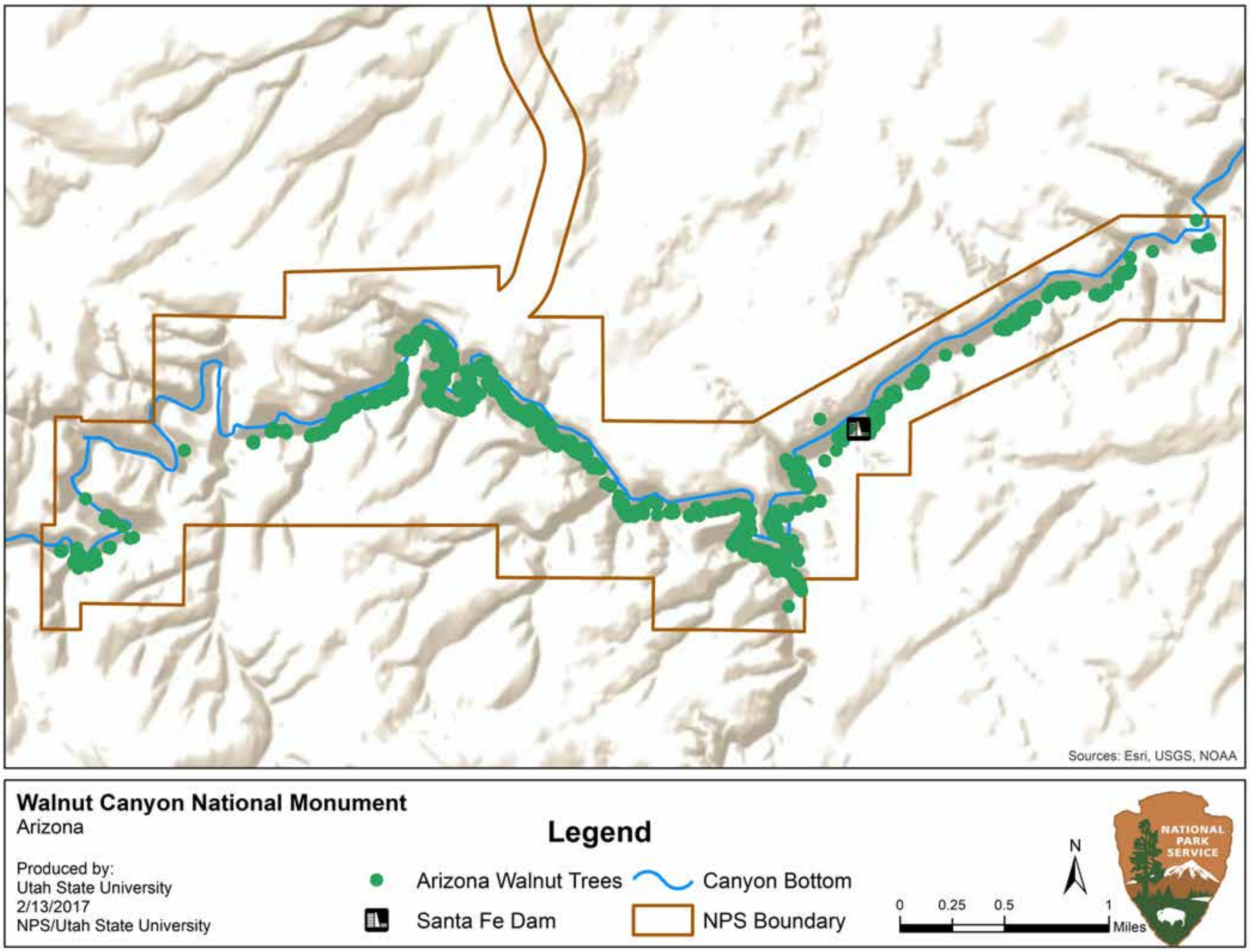


Figure 4.6.4-4. Distribution of Arizona walnut trees along Walnut Creek in 2011-2012. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction.

is high since these data were collected fairly recently (2011 and 2012). Trend does not apply to this measure.

Current Arizona Walnut Age Class Distribution

All age classes by tree height and DBH were represented in the monument's Arizona walnut population (Figure 4.6.4-5). In terms of tree height, seedlings represented just over half (53%) of all trees, while mature and old growth trees represented only 13% of all trees. The majority of all trees by DBH were classified as saplings or young mature trees (63%), while seedlings represented 23% of all trees. As with tree height, only 3% of all trees were classified as old growth by DBH. The large proportion of seedlings and saplings by height and DBH indicate a healthy population. Furthermore, trees in all age classes were well distributed throughout the monument (Schelz et al. 2013). Since trees from all age classes, including those signifying recruitment and reproduction were present, this measure is in good condition. Confidence in this condition rating is high since data were collected fairly recently (2011 and 2012) and is representative of the entire Arizona walnut population. Trend does not apply to this measure.

Arizona Walnut % Vigor

Just over half of all walnut trees exhibited very high vigor or were vigorous (Figure 4.6.4-6). Only 20% of trees exhibited medium or low vigor. Since the majority of trees exhibited at least very high vigor, this measure is in good condition. Confidence in this rating is high since these data were collected relatively recently (2011-20112) and because the study area included all walnut trees located within the monument. Trend does not apply to this measure.

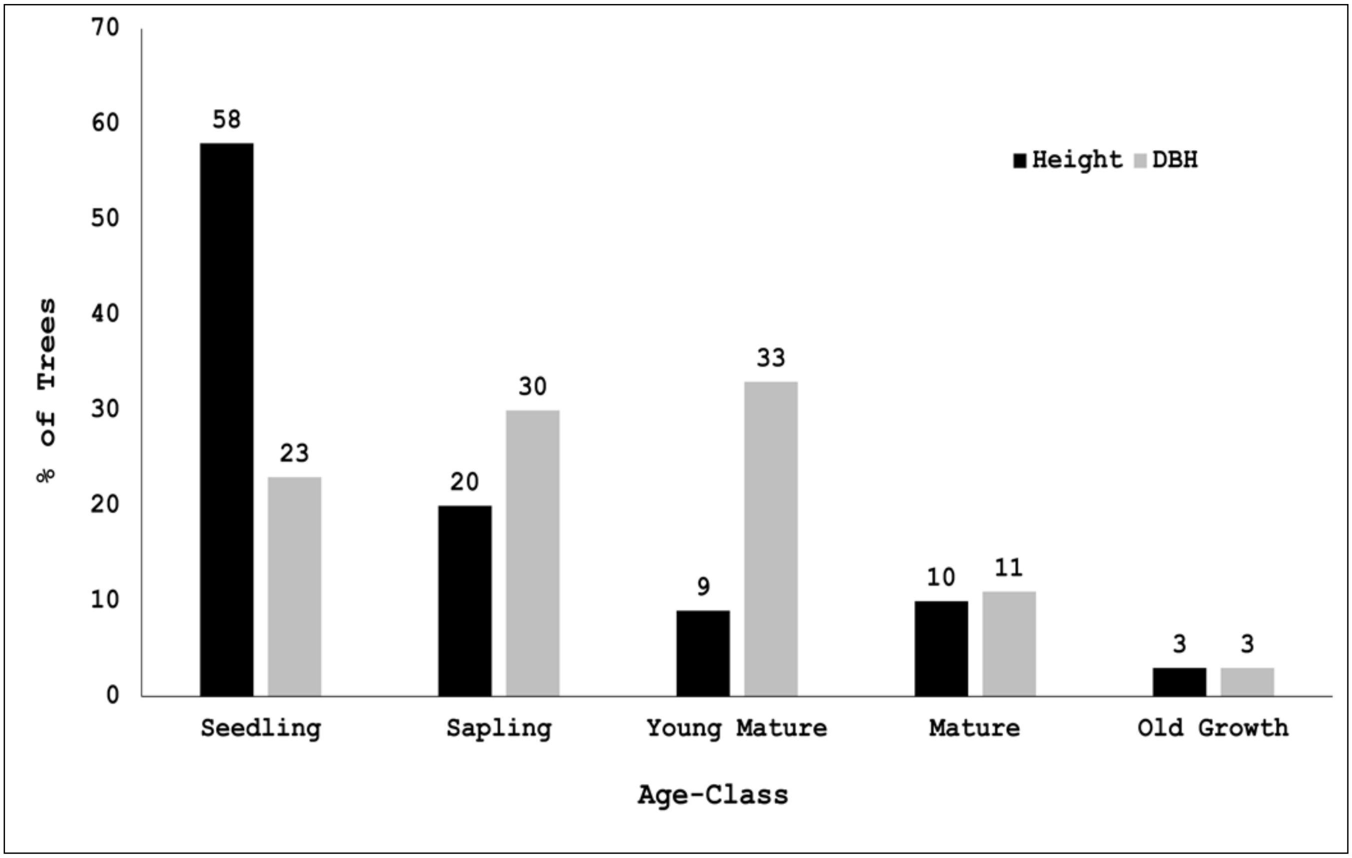


Figure 4.6.4-5. Age class distribution by height and DBH for Arizona walnut during 2011-2012.

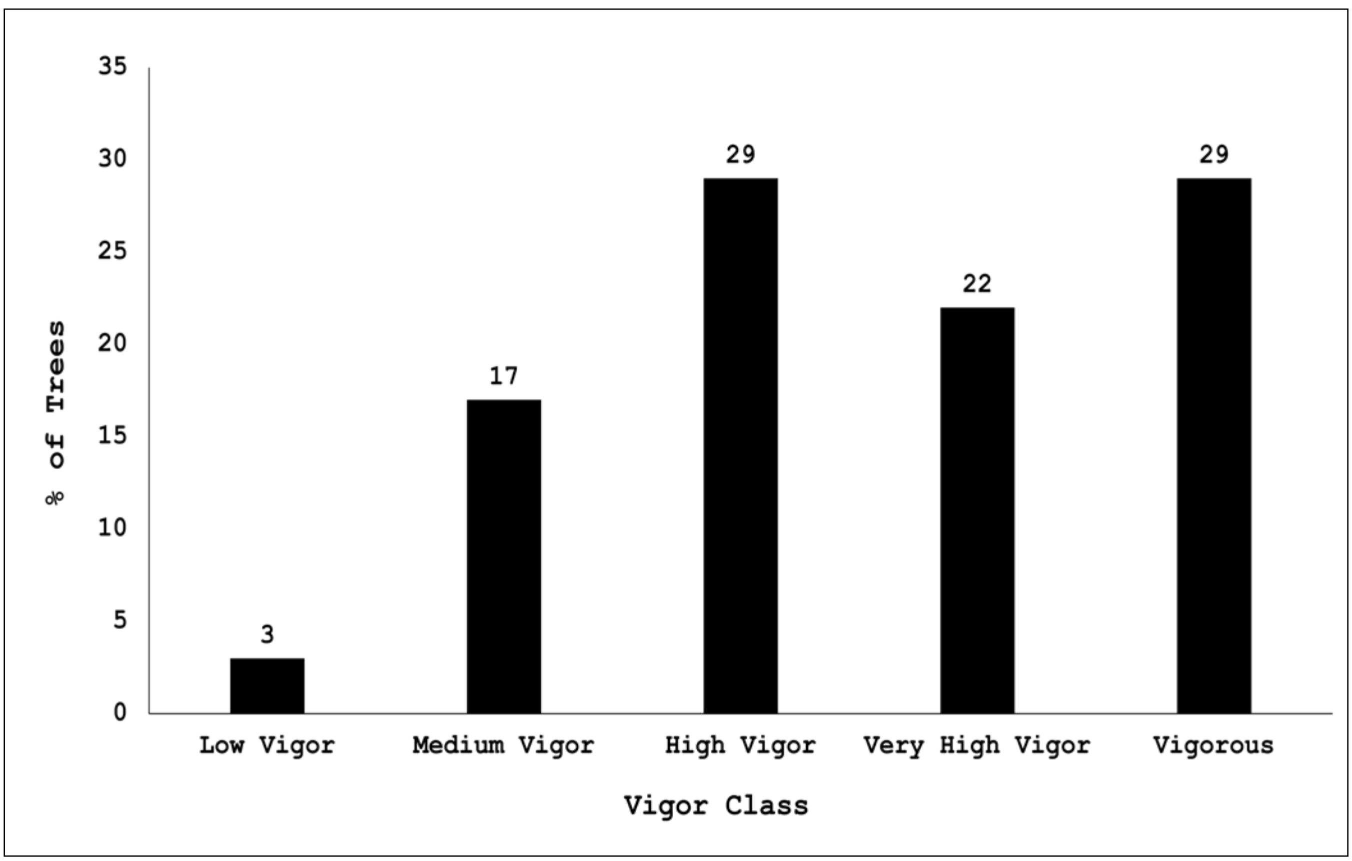


Figure 4.6.4-6. Percent of Arizona walnut trees in each of five vigor categories during 2011-2012.

Arizona Walnut Genetic Diversity

The six measures of genetic diversity in the monument's Arizona walnut population indicate high diversity (Table 4.6.4-2). This was expected for an obligate outcrossing, wind-pollinated species (Allan 2012). Not only was genetic diversity found to be high overall, but the dam does not appear to have affected genetic exchange. The F_{ST} statistics was 0.1, which indicates only a small amount of genetic differentiation on either side of the dam, and both populations exhibited similar amounts of diversity. The amount of diversity partitioned between the two regions was only 2%. Most of the genetic differences were partitioned among individuals across the entire population (79%), which is expected for a healthy and genetically diverse population. The fixation index, f, was also low (0.1). Since overall genetic diversity is high, there are no differences in genetic structure between the two populations separated by the dam, and the level of inbreeding is negligible, we consider the condition for this measure to be good. Confidence in this condition rating is high since data were collected fairly recently (2011) and is representative of the entire Arizona walnut population. Trend does not apply to this measure.

WRD Riparian Condition Assessment

The following measures were used by the WRD to assess the proper functioning of the Walnut Creek #2 reach located upstream and downstream of Third Island Fort. Following these measures we provided WRD's narrative assessment of the Walnut Creek #3 reach located at the confluence of Cherry Creek to the Santa Fe Dam. We did not assign a trend to any of the following measures since this was a one-time assessment. However, confidence in the condition rating is high for each measure since the assessment was conducted in September 2017.

Floodplain

There was no defined channel along the assessment reach, presumably due to the substantial reduction in flow frequencies and volumes after construction of the Upper and Lower Lake Mary Dams. This reach is now best described as a vegetated "canyon bottom" rather than a stream and riparian system. For this reason, WRD responded "not applicable" to this checklist item. Since the lack of a defined stream channel is likely the result of altered flow regimes due to construction of upstream dams, this measure warrants significant concern.

Sinuosity, Width/Depth Ratio, and Gradient

There was no defined stream channel in most of this assessment reach, so WRD could not calculate the channel sinuosity or an average width-to-depth ratio. A number of adverse grade segments occurred on the canyon floor, indicating that mass wasting from the canyon walls overwhelms the ability of current (post-dam) flows to transport this material and maintain the expected channel gradient for this landscape setting. WRD answered "no" for this checklist item. Therefore, we consider this measure to warrant significant concern.

Riparian-Wetland Area

Upland plant species including blue grama (*Bouteloua gracilis*), little bluestem (*Schizachyrium scoparium*), side oats grama (*Bouteloua curtipendula*), smooth brome (*Bromus inermis*) and mountain tail-leaf (*Pericome caudata*) have invaded and now dominate the herbaceous stratum on the canyon floor. Switchgrass (*Panicum virgatum*) was the only herbaceous wetland species observed, and it was restricted to only a few small depressions. Facultative riparian trees such as Arizona walnut (Figure 4.6.4-7) and boxelder were common, and redosier dogwood was also present. However, WRD staff did not observe willows, and observed only a few small cottonwoods (likely re-sprouts) in one location toward the downstream

Table 4.6.4-2. Measures of genetic diversity in the Arizona walnut population.

Area	Statistic	N	N_A	N_E	I	H_O	H_E	f
Population	Mean	13.345	7.382	4.692	1.680	0.696	0.766	0.100
	SE	0.646	0.394	0.243	0.047	0.033	0.010	0.041
Above Dam	Mean	12.725	7.225	4.664	1.660	0.697	0.761	0.094
	SE	0.871	0.485	0.305	0.060	0.041	0.013	0.051
Below Dam	Mean	15.000	7.800	4.864	1.733	0.693	0.780	0.116
	SE	0.000	0.656	0.375	0.073	0.056	0.014	0.067

Source: Tables 5 and 6 in Allan (2012).

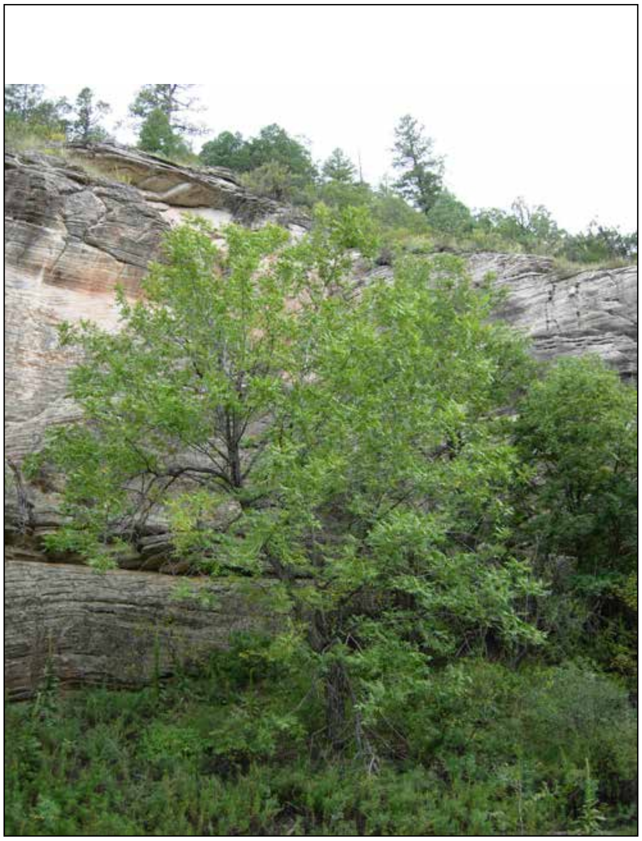


Figure 4.6.4-7. Arizona walnut tree along Walnut Creek. Photo Credit: NPS.

end of the reach. Upland woody species including Rocky Mountain juniper (*Juniperus scopulorum*), New Mexico locust (*Robinia neomexicana*) and Gambel oak (*Quercus gambelii*) were common on the canyon floor. Invasion of the historic riparian-wetland zone by upland species represents a narrowing or diminishment of the riparian-wetland area, so WRD responded "no" to this checklist item. Therefore, this measure warrants significant concern.

Upland Watershed Contribution

Upstream dams have greatly reduced flow frequencies and volumes, which has had adverse effects on channel/floodplain form and degraded riparian-wetland plant communities as described for the previous measures. WRD concluded that the dams in the upper watershed are clearly contributing to riparian system degradation in this assessment reach, so WRD answered "no" for this checklist item. Therefore, this measure warrants significant concern.

Age-class Distribution

Obligate riparian woody species that are very drought-sensitive and that need fluvial processes to create the conditions necessary for their establishment from seed (moist, bare mineral soils) were either not observed on this reach (arroyo willow [*Salix lasiolepis*]) or were only seen at a single location with only one age class that may have been resprouts (narrowleaf cottonwood). Dramatic flow reductions and water table declines after the upstream dams were completed have likely had adverse effects on the establishment and survival of these species. Herbaceous vegetation was dominated by non-wetland species, except for a few isolated pockets of switchgrass. For these reasons WRD answered "no" for this checklist item. Since WRD answered "no" for this checklist item, we consider this measure to warrant significant concern.

However, WRD staff noted that the facultative riparian tree species Arizona walnut and boxelder were common and had multiple age classes in a variety of niches along the reach, indicating their ongoing recruitment despite the highly altered flow regime. Once they are established, these two species are quite drought-tolerant and can thrive under a much wider range of soil moisture conditions (Rosario 1988, Pavek 1993, Schalau 2001) than willows or cottonwoods can tolerate.

Overall Community Composition

The facultative riparian tree species Arizona walnut and boxelder were abundant and existed in several age classes along most of the reach, indicating that they are maintaining their populations under the current, diminished flow regime. However, expected obligate riparian shrubs and trees were either completely absent (arroyo willow) or were observed only in a single location and not reproducing (narrowleaf cottonwood). Herbaceous wetland-riparian vegetation was almost completely absent as previously described. For these reasons, WRD responded "no" to this checklist item, which warrants significant concern.

Wetland Plant Status

As described above, the overwhelming dominance of upland herbaceous plant cover throughout the canyon bottom and the absence of expected obligate riparian trees and shrubs (willows and cottonwoods) in nearly the entire reach led to a "no" response for this checklist item and a condition rating of significant concern.

Streambank Community Composition
WRD responded “not applicable” for this checklist item because there was not a discernible stream channel on the canyon floor, and therefore no streambanks. We also note that the herbaceous vegetation component on the canyon floor was almost entirely comprised of upland species that may not be able to anchor the soil during larger flows. For these reasons, this measure warrants significant concern.

Vigor
Arizona walnuts and boxelders were vigorous and reproducing. However, these relatively drought-tolerant, facultative riparian species are now functioning in a canyon bottom that flows only about once every nine years rather than the pre-dam riparian system that flowed almost every year (Rowlands et al. 1995). WRD did not observe any willows in this reach and only saw a few small cottonwoods in a single location. Both of these obligate riparian species would be expected in this landscape setting if the upstream dams did not exist. Herbaceous vegetation was composed of almost all upland species, with wetland species limited to a few isolated pockets of switchgrass. Since WRD answered “no” for this checklist item, this measure warrants significant concern.

Cover
WRD responded “not applicable” for this checklist item because the frequencies, magnitudes, and durations of flows have been so reduced by the upstream dams that there is no defined stream channel on the canyon floor, and therefore no streambanks. WRD also noted that dominance of the herbaceous stratum by upland species and invasion by upland trees and shrubs reduces the ability of the canyon floor to dissipate the energy of large flows. For these reasons, this measure warrants significant concern.

Floodplain and Channel Characteristics
WRD rated this checklist item as “not applicable” because the stream that flowed annually before construction of the Lower and Upper Lake Mary Dams no longer has a defined channel; therefore, this measure warrants significant concern.

Point Bar Vegetation
WRD rated this checklist item as “not applicable” because the well-defined stream channel that occurred here prior to upstream dam construction (Brian 1992) no longer exists, so there is no lateral channel migration to create and sustain point bar morphology. Therefore, this measure warrants significant concern.

Lateral Stream Movement
Several historical accounts point to an open, intermittent or ephemeral stream channel in Walnut Canyon that flowed almost every year prior to upstream dam construction (Brian 1992, Rowlands et al. 1995). WRD did not observe a defined stream channel in this reach, so there was no evidence of the lateral channel movement that would have been expected under pre-dam conditions. WRD answered “no” for this checklist item, which warrants significant concern.

Vertical Stability of Stream Channel
Bedrock in the canyon bottom provides strong vertical stability in this reach, and there was no evidence of channel incision. WRD responded “yes” for checklist item. This measure is in good condition.

Water/Sediment Balance
A number of adverse grade segments occurred on the canyon floor, indicating that mass wasting from the canyon walls exceeds the ability of post-dam flows to transport this material and maintain the expected channel form and gradient for this landscape setting. This was a clear indication that the water and sediment being supplied by the watershed are not in balance. WRD answered “no” for this checklist item, which warrants significant concern.

Narrative Assessment for Walnut Creek #3: Confluence with Cherry Creek to Santa Fe Dam
At the confluence of Cherry and Walnut Creek (Figure 4.6.1-2), flows have cut into the sediment on the Walnut Canyon floor and formed a moderately incised channel that extends at least 457 m (1,500 ft) downstream. Boxelders covered much of the canyon floor at the confluence, and they occurred sporadically along the channel banks downstream. Box elders also occupied the bases of the canyon walls along much of the reach.

At approximately 213 m (700 ft) downstream from the confluence, there was a small grove of middle-aged narrowleaf cottonwoods on the right overbank area. This appears to be the same location that Phillips (1990) reported “a small area of narrowleaf cottonwood regeneration.” Some of these trees were relatively short in stature and most had at least some dead branches. But overall, they appeared to be in fairly good condition and not in obvious decline, indicating a reliable groundwater source even in dry years. These cottonwoods were the only ones observed along the 1,676 m (5,500 ft) reach between Cherry Canyon and the Santa Fe Dam, and they were not reproducing (no seedlings or saplings). No willows were observed on this entire reach.

Downstream of the cottonwoods the channel gradually became less incised. By about 549-610 m (1,800-2,000 ft) below the confluence, the channel began to transition to more of a vegetated swale. This is likely related to the backwater pool effect and associated sediment accumulation that extends about 1.6 km (1.0 mi) above the Santa Fe Dam after large storms (Soles and Monroe 2012). From this point down to the dam, the canyon bottom was dominated by a mix of native and non-native, early successional herbaceous plant species that are mostly associated with uplands. Native species included western wheatgrass (*Pascopyrum smithii*), blue grama, witchgrass (*Panicum capillare*), Canada wildrye (*Elymus canadensis*), muhly (*Muhlenbergia* spp.), sand dropseed (*Sporobolus cryptandrus*), common sunflower (*Helianthus annuus*), tansy aster (*Dieteria* sp.), goldenrod (*Solidago velutina*), Richardson's geranium (*Geranium richardsonii*), yarrow (*Achillea millefolium*), two species of globe mallow (*Sphaeralcea* spp.), Virginia creeper (*Parthenocissus vitacea*), big bract verbena (*Verbena bracteata*), sage (*Salvia* sp.) and buckwheat (*Polygonum* sp.). Non-native species included white horehound (*Marrubium vulgare*), Russian thistle (*Salsola kali*), Canadian horseweed (*Conyza canadensis*), red root (*Amaranthus retroflexus*), dalmation toadflax (*Linaria dalmatica*), field bindweed (*Convolvulus arvensis*), mullein (*Verbascum thapsus*) and motherwort (*Leonurus cardiaca*). Also, on the original Santa Fe Railroad tract (a private inholding within the monument), WRD observed the non-natives smooth brome, yellow sweetclover (*Melilotus officinalis*) and Scotch thistle (*Onopordum acanthium*).

Periodic pooling above the Santa Fe Dam during the growing season creates harsh conditions for perennial plants. Most perennial grasses and forbs are adversely affected by full submergence for more than a few days, and most upland woody species are intolerant of prolonged flooding. Riparian species like cottonwoods, willows, box elders, redosier dogwoods, and Arizona walnuts are more flood-tolerant than upland trees and shrubs, but even they can be damaged or killed by long-lasting flood events. Deep sediment accumulation in the backwater pool may also exclude riparian-wetland species that rely on groundwater sources that are now buried and inaccessible here. We did not observe any of these woody riparian species or any herbaceous riparian-wetland vegetation in the approximately 457-m (1,500-ft) long canyon bottom segment immediately upstream of the dam. Instead, common sunflower, an annual plant that can colonize the sediment surface quickly after the pooled water recedes, formed a near monoculture in this sub-reach. This contrasted sharply with the dense cover of boxelder, cottonwood, and Arizona walnut in the riparian area immediately below the dam.

From its confluence with Cherry Creek downstream to the Santa Fe Dam, a distance of about 1.6 stream km (1.0 mi), Walnut Creek was clearly in a "Non-Functional Condition." By impounding flows and trapping sediment for more than 100 years, the dam has converted this former riparian system to a lakebed in much of the reach. This impoundment and the flow alterations caused by the Upper and Lower Lake Mary Dams have combined to substantially alter or eliminate expected natural flow regimes, channel forms, riparian-wetland vegetation communities and aquatic habitat characteristics. The WRD team did not fill out a PFC form because it was obvious that this reach was so modified that all checklist items would be answered "no" or "not applicable." Under current conditions, this reach is incapable of supporting a functional riparian system.

Overall Condition and Trend, Confidence Level, and Key Uncertainties

For assessing the condition of the Walnut Creek riparian corridor, we used six indicators with a total of 24 measures, which are summarized in Table 4.6.4-3. Based on the condition rating for these measures, we consider the overall condition of the Walnut Creek riparian corridor to be of significant concern. High confidence was assigned to the majority of measures used in this assessment and the overall condition rating. The trend in the Walnut Creek riparian corridor has deteriorated over time (Figures 4.6.4-8 and -9).

The overwhelming majority of measures used in the PFC method warrant significant concern and the WRD concluded that the Walnut Creek #2 reach is

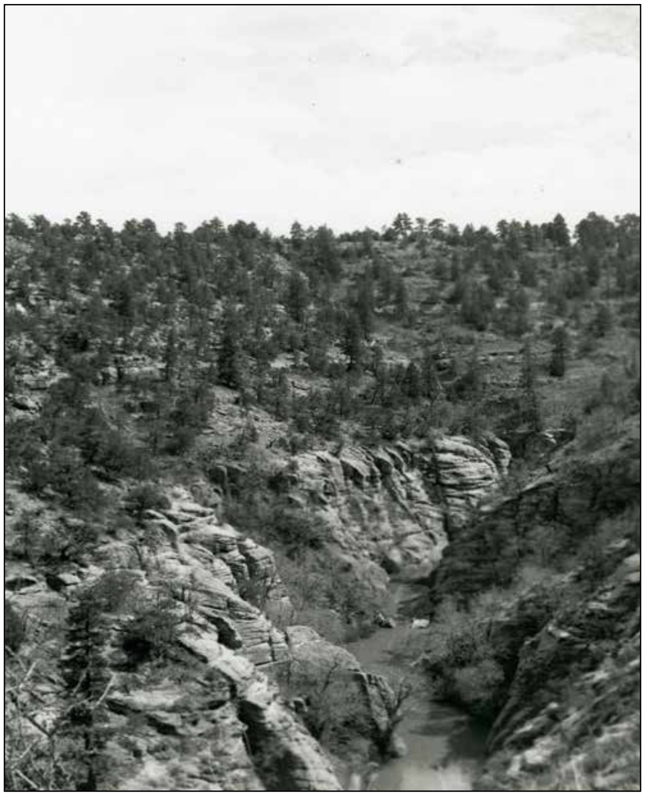


Figure 4.6.4-8. Walnut Canyon in 1941. Photo Credit: © P. Beaubien (Brian 1992).

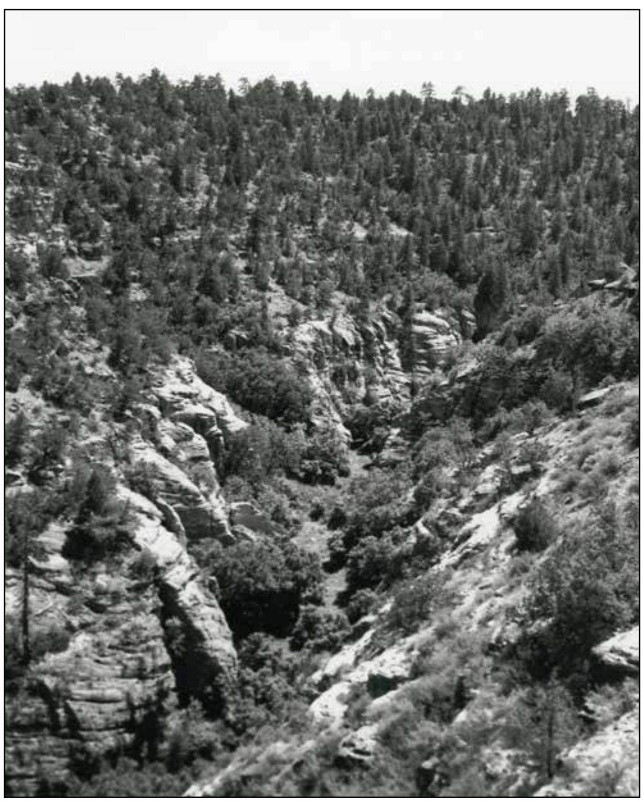


Figure 4.6.4-9. Repeat photo of Walnut Canyon in 1985. Photo Credit: © Brian (1992).

in "Non-Functional Condition." A "Non-Functional Condition" was also assigned to the Walnut Creek #3 reach. Furthermore, the Walnut Creek #1 reach, upstream and outside of the monument, was also assigned a "Non-Functional Condition" rating (see Wagner et al. 2017 for the full assessment of this reach).

Flows for Walnut Creek were absent, with the exception of one flood during the 20-year period. Upstream dam construction has converted the creek from one that flowed seasonally almost every year in response to snowmelt and summer thunderstorms to one that now flows, only rarely, under unusually wet conditions. The WRD team noted: 1) the absence of a well-defined stream channel where one was reported in published historical reviews; 2) the almost total absence of obligate riparian trees and shrubs (willows and cottonwoods), likely due to water table declines and lack of conditions necessary to reproduce from seed; and 3) the invasion of upland trees and the overwhelming dominance by upland species in the herbaceous vegetation layer. The current (post-dam) vegetation, hydrology and erosion/deposition characteristics described above provide substantial evidence that this reach no longer supports a properly functioning riparian system as defined by the PFC method (Prichard et al. 1998). These results are supported by data used to assess the change in age-class distribution for narrowleaf cottonwood and change in importance value of the herbaceous and shrub layer. All four measures used to assess the Arizona walnut were in good condition. Like boxelder, Arizona walnut is considered a facultative or facultative wetland species. This means that it does not necessarily depend on riparian areas and is drought resistant once it becomes established (USDA 2017).

Factors that influence confidence in the condition rating include age of the data (< 5 yrs unless the data are part of a long-term monitoring effort), repeatability, field data vs. modeled data, and whether data can be extrapolated to other areas in the monument. Based on these factors, the measures included in the WRD assessment conducted in September 2017 were assigned high confidence as were the four measures used to assess the condition of the Arizona walnut and the one stream flow measure. However, the three measures of vegetation change from the eight permanent vegetation plots were last sampled more than ten years ago and the sample size may be

Table 4.6.4-3. Summary of Walnut Creek riparian area indicators, measures, and condition rationale.

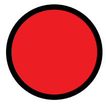
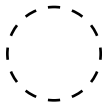
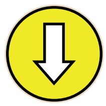
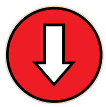
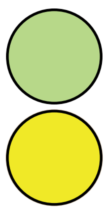
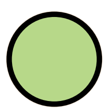
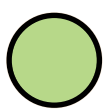
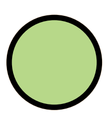
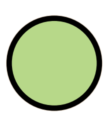
Indicators of Condition	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Water Quantity and Availability	Stream Flow (timing, duration, and magnitude)		Between 1995 and 2016 only one flood was recorded by the stream gage located within the monument. The flood occurred over a six-day period beginning 9 September 2013. There are too few data to assess trend, but this is because the two dams located upstream have inhibited flows since 1904. The lack of flows during the 22-year period warrants significant concern. Confidence in the condition is high.
Vegetation Change	Importance Value for Herbaceous/ Shrub Layer		The six species were not adequately distributed among the eight plots to assess change in importance value over time, so we did not assign a condition rating for this measure. Confidence is low and trend is unknown.
	Boxelder Age-class Structure		Boxelder exhibited fewer individuals in each age-class in 2006 than in 1989, particularly for pole sized trees. These data indicate that recruitment of seedlings and saplings into reproductively mature individuals has declined somewhat. These data warrant moderate concern for this measure. Confidence in these data is medium.
	Narrowleaf Cottonwood Age-class Structure		The low number of narrowleaf cottonwood seedlings in 2006 compared with 1989 and few pole and mature trees warrants significant concern for this species and indicates a deteriorating trend. Confidence in this condition is medium.
	Arizona Walnut Age-class Structure		These data indicate that there has been recruitment of seedlings and saplings into reproductively mature individuals, which indicates good condition, but the slight decline in seedlings and saplings warrants moderate concern. Since the number of poles and mature trees was the same between the two time periods and the number of seedlings and saplings declined only slightly, we assigned an unchanging trend to these data. Confidence in the condition rating is medium.
Current Status of Arizona Walnut	Population Size and Extent		A total of 2,065 Arizona walnut trees were counted within the study area during 2011 and 2012. Trees were distributed throughout the canyon with few gaps between clusters. Since the population is large and trees are well distributed throughout the monument, the condition for this measure is good. Confidence in this condition rating is high since data were collected fairly recently (2011 and 2012). Trend could not be determined.
	Age-Class Distribution		The large proportion of seedlings and saplings by height (81%) and DBH (53%) indicate a healthy Arizona walnut population. Trees in all age classes were well distributed throughout the monument. Since trees from all age classes, including those signifying recruitment and reproduction were present, this measure is in good condition. Confidence in this condition rating is high since data were collected fairly recently (2011 and 2012) and is representative of the entire Arizona walnut population. Trend could not be determined.
	Vigor		Just over half of all walnut trees exhibited very high vigor or were vigorous. Only 20% of trees exhibited medium or low vigor. Since the majority of trees exhibited at least very high vigor, this measure is in good condition. Confidence in this rating is high since data were collected relatively recently (2011-20112), and because the study area included all walnut trees located within the monument. Trend could not be determined.
	Genetic Diversity		Since the overall genetic diversity is high, there are no differences in genetic structure above and below the Santa Fe Dam, and the level of inbreeding is negligible, the condition for this measure is good. Confidence in this condition rating is high since data were collected fairly recently (2011) and is representative of the entire Arizona walnut population. Trend could not be determined.

Table 4.6.4-3 continued. Summary of Walnut Creek riparian corridor indicators, measures, and condition rationale.

Indicators of Condition	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Hydrology	Floodplain	(red circle)	There was no defined channel along Walnut Creek #2, presumably due to the substantial reduction in flow frequencies and volumes after construction of the Upper and Lower Lake Mary Dams. WRD answered "no" for this checklist item, which warrants significant concern. Trend does not apply to this one-time assessment. Confidence in this rating is high.
	Sinuosity, Width/ Depth Ratio, and Gradient	(red circle)	There was no defined stream channel in most of this assessment reach, so WRD could not calculate the channel sinuosity or an average width-to-depth ratio. WRD answered "no" for this checklist item. Therefore, this measure warrants significant concern. Trend does not apply to this one-time assessment. Confidence in this rating is high.
	Riparian-Wetland Area	(red circle)	Upland plant species have invaded and now dominate the herbaceous stratum. Facultative riparian were common, and redosier dogwood was also present. However, WRD staff did not observe willows, and observed only a few small cottonwoods in one location. Upland woody species were common on the canyon floor. Invasion of the historic riparian-wetland zone by upland species represents a narrowing or diminishment of the riparian-wetland area. WRD responded "no" to this checklist item, which warrants significant concern. Trend does not apply to this one-time assessment. Confidence in this rating is high.
	Upland Watershed Contribution	(red circle)	Upstream dams have greatly reduced flow frequencies and volumes, which has had adverse effects on channel/floodplain form and degraded riparian-wetland plant communities as described for the previous measures. WRD concluded that the dams in the upper watershed are clearly contributing to riparian system degradation in this assessment reach, so WRD answered "no" for this checklist item. This measure warrants significant concern. Trend does not apply to this one-time assessment. Confidence in this rating is high.
Vegetation	Age-Class Distribution	(red circle)	Obligate riparian woody species were either not observed on this reach or were only seen at a single location with only one age class. WRD answered "no" for this checklist item, but noted that facultative riparian tree species (Arizona walnut and boxelder) were common and had multiple age classes along the reach, indicating recruitment despite the highly altered flow regime. Since WRD answered "no" for this checklist item, this measure warrants significant concern. Trend does not apply to this one-time assessment. Confidence in this rating is high.
	Overall Community Composition	(red circle)	Facultative riparian tree species (Arizona walnut and boxelder) were abundant and existed in several age classes along most of the reach, indicating that they are maintaining their populations under the current, diminished flow regime. However, expected obligate riparian shrubs and trees were either completely absent or were observed only in a single location and not reproducing. Herbaceous wetland-riparian vegetation was almost completely absent WRD responded "no" to this checklist item, which warrants significant concern. Trend does not apply to this one-time assessment. Confidence in this rating is high.
	Wetland Plant Status	(red circle)	The overwhelming dominance of upland herbaceous plant cover throughout the canyon bottom and the absence of expected obligate riparian trees and shrubs (willows and cottonwoods) in nearly the entire reach led to a "no" response for this checklist item and a condition rating of significant concern. Trend does not apply to this one-time assessment. Confidence in this rating is high.
	Streambank Community Composition	(red circle)	WRD responded "not applicable" for this checklist item because there was not a discernible stream channel on the canyon floor, and therefore no streambanks. WRD also noted that the herbaceous vegetation component on the canyon floor was almost entirely comprised of upland species that may not be able to anchor the soil during larger flows. For these reasons, this measure warrants significant concern. Trend does not apply to this one-time assessment. Confidence in this rating is high.

Table 4.6.4-3 continued. Summary of Walnut Creek riparian corridor indicators, measures, and condition rationale.

Indicators of Condition	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Vegetation	Vigor		Arizona walnuts and boxelders were vigorous and reproducing. However, these relatively drought-tolerant, facultative riparian species are now functioning in a canyon bottom that flows only about once every nine years rather than the pre-dam riparian system that flowed almost every year. No riparian obligate willows and only a few cottonwoods were observed, and herbaceous vegetation was dominated by upland species. WRD answered "no" for this checklist item, which warrants significant concern. Trend does not apply to this one-time assessment. Confidence in this rating is high.
	Cover		WRD responded "not applicable" for this checklist item because the frequencies, magnitudes, and durations of flows have been so reduced by the upstream dams that there is no defined stream channel on the canyon floor, and therefore no streambanks. WRD also noted the dominance of upland species, which reduces the ability of the canyon floor to dissipate the energy of large flows. For these reasons, this measure warrants significant concern. Trend does not apply to this one-time assessment. Confidence in this rating is high.
Erosion/ Deposition	Floodplain and Channel Characteristics		WRD rated this checklist item as "not applicable" because the stream that flowed annually before construction of the Lower and Upper Lake Mary Dams no longer has a defined channel; therefore, this measure warrants significant concern. Trend does not apply to this one-time assessment. Confidence in this rating is high.
	Point Bar Vegetation		WRD rated this checklist item as "not applicable" because the well-defined stream channel that occurred here prior to upstream dam construction no longer exists, so there is no lateral channel migration to create and sustain point bar morphology. Therefore, this measure warrants significant concern. Trend does not apply to this one-time assessment. Confidence in this rating is high.
	Lateral Stream Movement		WRD did not observe a defined stream channel, so there was no evidence of the lateral channel movement that is expected under pre-dam conditions. WRD answered "no" for this checklist item, which warrants significant concern. Trend does not apply to this one-time assessment. Confidence in this rating is high.
	Vertical Stability of Stream Channel		Bedrock in the canyon bottom provides strong vertical stability in this reach, and there was no evidence of channel incision. WRD responded "yes" for checklist item. This measure is in good condition. Trend does not apply to this one-time assessment. Confidence in this rating is high.
	Water/Sediment Balance		A number of locations along the reach had adverse grades, indicating that the water and sediment being supplied by the watershed are not in balance. WRD answered "no" for this checklist item. This measure warrants significant concern. Trend does not apply to this one-time assessment. Confidence in this rating is high.
Overall Condition			The overall condition of the Walnut Creek riparian corridor warrants significant concern with a deteriorating trend and high confidence in the condition rating. The majority of measures warrant significant concern and both stream reaches assessed by the WRD were considered non-functional. Upstream dam construction has converted the creek from one that flowed seasonally almost every year in response to snowmelt and summer thunderstorms to one that now flows, only rarely, under unusually wet conditions.

inadequate for documenting change. Confidence in these measures is low or medium.

In 2011, the U.S. Forest Service completed watershed condition assessments for 6th level watersheds across the U.S. (USFS 2017). The purpose of the classification was to prioritize watersheds for restoration. The classification is a rapid qualitative assessment based on existing data and expert opinion (USFS 2011). Walnut Canyon NM lies within three 6th-level watersheds, all of which were rated as "Functioning at Risk" by the U.S. Forest Service (USFS 2017) (Figure 4.6.4-10). The Walnut Creek-Cherry Canyon Watershed covers much of the monument. Most measures for this watershed were rated as fair, including aquatic habitat, water quantity, and riparian vegetation (USFS 2017). These

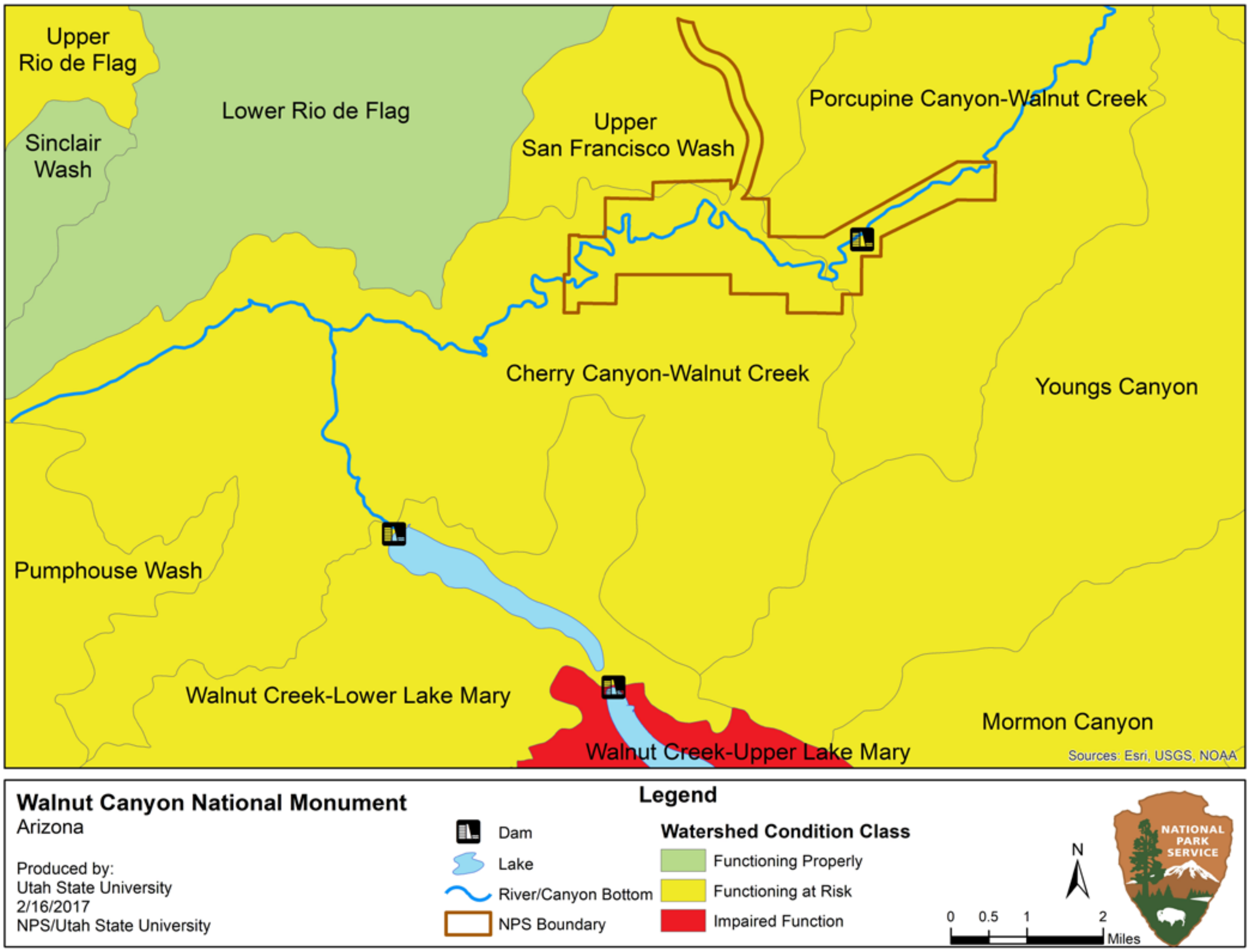


Figure 4.6.4-10. U.S. Forest Service's 2011 watershed condition assessment results. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction.

results contradict those of the WRD assessment, but the watershed assessments cover a much larger area than the areas surveyed by WRD. However, hydrology in the monument is most influenced by the Walnut Creek-Lower Lake Mary Watershed and the Walnut Creek-Upper Lake Mary Watershed, which were rated as "Functional at Risk" and "Impaired Function," respectively. The Upper Lake Mary Watershed exceeded the U.S. Environmental Protection Agency's thresholds for mercury in fish, exhibited diminished aquatic invertebrate and amphibian populations, aquatic habitat was in poor condition, and riparian vegetation vigor and health was reduced (USFS 2017). As described above, the Upper Lake Mary Dam has significantly altered flows downstream and many earthen stock tanks located in the drainage may also influence downstream flows. Furthermore, urbanized lands within this watershed may have reduced watershed function (e.g., wells). Similar results were found for the Lower Lake Mary Watershed, except that aquatic habitat and riparian vegetation were rated as good, which in part led to the higher condition rating (USFS 2017). Overall, these results are consistent with those of the WRD assessments of specific reaches along Walnut Creek and indicate impairment of hydrologic function in and around the monument.

Threats, Issues, and Data Gaps

Much of the damage to Walnut Creek has already occurred and is a direct result of diversion of 90% of the water flowing within Walnut Creek upstream of the monument (Rowlands et al. 1995). Stream flow is rare and the plant community has transitioned from one that was historically dominated by riparian obligate species to one that is now dominated by upland species. Furthermore, several non-native species have invaded the riparian corridor, and stream channel pools that once provided habitat for aquatic invertebrates and amphibians have been filled in by sediments and vegetation in the absence of scouring floods (Holton 2007, Soles and Monroe 2012).

Severe fires within the monument's watershed may impact erosion, patterns of sedimentation, and rill and gully formation as was evident following the Shultz Fire, which burned 6,100 ha (15,073 ac) on the eastern slopes of the San Francisco Peaks (Neary et al. 2011). A study concluded that similar effects are likely to occur in the Upper Lake Mary Watershed given a severe fire, especially since the monument and surrounding area are outside the natural fire regime (Miller 2007). An increase in sedimentation along the canyon bottom may favor non-native plants and kill native vegetation.

NPS staff also cite that exurban development within the Flagstaff city limit in the watershed below Lower Lake Mary may increase storm water run-off floods and non-point source pollution into the canyon upstream from the monument (Flagstaff National Monuments, P. Whitefield, natural resource specialist, comments to draft assessment, 7 March 2017). Furthermore, NPS staff cite that "during high flow events, sediment continues be deposited upstream of the Santa Fe dam, inundating the canyon floor, leaving debris and trash deposits, and increasing habitat for invasive plant species within the canyon bottom upstream of the private Santa Fe Dam inholding" (Flagstaff National Monuments, P. Whitefield, natural resource specialist, comments to draft assessment, 7 March 2017).

The most relevant data gaps include the lack of geomorphic monitoring of the canyon bottom to determine the rate at which the channel is being inundated by colluvial deposits and side channel fan in addition to the lack of recent vegetation monitoring (with the exception of Arizona walnut and the rapid WRD assessment) (Flagstaff National Monuments, P. Whitefield, natural resource specialist, comments to draft assessment, 7 March 2017).

A stream gage that monitors flows to Upper Lake Mary suggests that at least some of the water flowing into the lake would reach the monument in the absence of the two dams (USGS 2017). However, streams in semiarid regions are especially sensitive to changes in precipitation and runoff (Cooper et al. 2012), and climate change may influence the amount of water available for stream flow. Monahan and Fischelli (2014) evaluated which of 240 NPS units have experienced extreme climate changes during the last 10-30 years. The results of this study for Walnut Canyon NM were summarized in NPS (2014). Extreme climate changes were defined as temperature and precipitation conditions exceeding 95% of the historical range of variability. The results of this study indicate a trend toward extreme warm and extreme dry conditions within the monument (Monahan and Fischelli 2014), and are indicative of trends occurring throughout the southwestern U.S. (Prein et al. 2016). These variables of climate change could lead to further changes along Walnut Creek.

4.6.5. Sources of Expertise

The assessment was authored by Lisa Baril, biologist and science writer, Utah State University, WRD staff Joel Wagner (wetland scientist) and Mike Martin (hydrologist), and Christine Taliga (NPS/Natural Resources Conservation Service liaison).

4.7. Ponderosa Pine (*Pinus ponderosa*) Forest

4.7.1. Background and Importance

Walnut Canyon National Monument (NM), located to the east of Flagstaff, encompasses 1,433 ha (3,541 ac) of land. Lands surrounding the national monument consist largely of Coconino National Forest, managed by the U.S. Forest Service (USFS). Ponderosa pine *(Pinus ponderosa)* is the major vegetation community type within the national forest, and fire is an important natural process within much of the landscape surrounding Walnut Canyon NM (NPS 2009aa).

Coniferous forest and woodlands are predominant vegetation types in Walnut Canyon NM (Figure 4.7.1-1a,b and Figure 4.7.1-2). Ponderosa pine dominates the canyon rim terraces on the western half of the monument, and towards the eastern portion of the monument the vegetation transitions into pinyon-juniper woodland and grassland. The south-facing slopes of the canyon are more exposed to the wind and sun, and they are dominated by scattered pinyon pine (*Pinus edulis*) and Utah juniper (*Juniperus osteosperma*) trees with a variety of shrubs, herbaceous species, and succulents in the understory. The more shaded and moist north-facing canyon slopes and tributary canyons are dominated by Douglas-fir-Gambel oak habitat (*Pseudotsuga menziesii-Quercus gambelii*). The canyon bottom and the south-side tributary canyons contain deciduous riparian vegetation. It is the ponderosa pine vegetation on the canyon rim terraces that is the focus of this assessment.

Ponderosa pine was identified as the most common tree within the national monument and immediate vicinity (Hansen et al. 2004). It is present in the mid-elevation ecotonal areas to the highest elevations. The history of fire and land use in a given location significantly influence the density of ponderosa pine, which varies substantially in the area mapped by Hansen et al. (2004).The understory of the ponderosa pine community often includes mountain muhly (*Muhlenbergia montana*), blue grama (*Bouteloua gracilis*), and Gambel oak. In mid-elevations in the park and surrounding area, the canopy is dominated by ponderosa pine, pinyon pine, and Utah juniper woodlands. Ponderosa pine habitats are valuable for their plant species diversity (Patton et al. 2014).

Ponderosa pine habitats are of considerable value to wildlife. At least 250 species of vertebrates inhabit ponderosa pine forests in the Southwest (Allen et al. 2002). Patton et al. (2014) reported 48 mammals, 111 birds, and 47 amphibians and reptiles, as well as 422 arthropods in their database of species found in

Figure 4.7.1-1a. Ponderosa pine. Photo Credit: © Patty Valentine-Darby.

Figure 4.7.1-1b. Gambel oak. Photo Credit: © Patty Valentine-Darby.

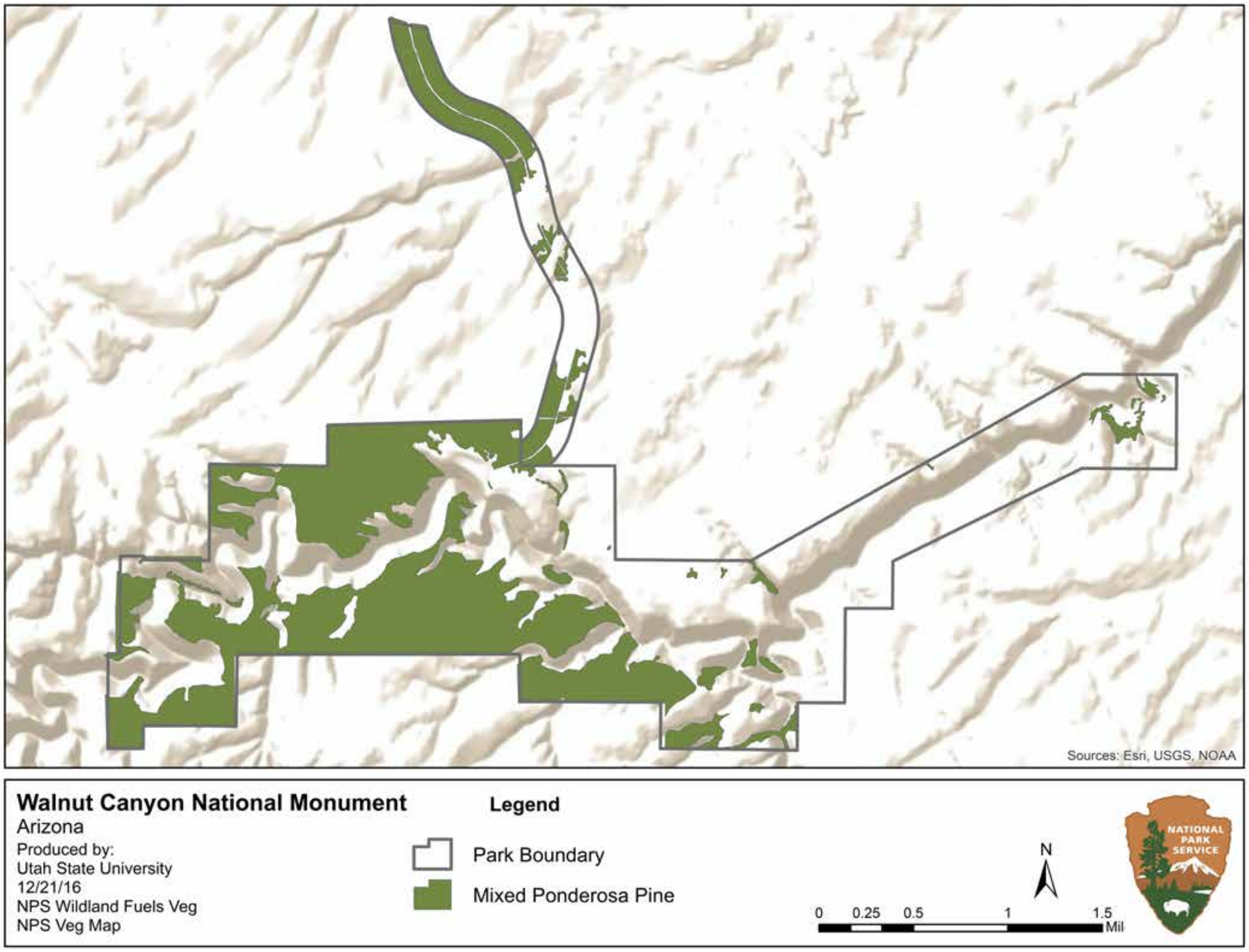


Figure 4.7.1-2. Mixed ponderosa pine vegetation in Walnut Canyon NM. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction.

Arizona ponderosa pine forests. Wildlife species using these habitats include the Abert's squirrel (*Sciurus aberti*), a "distinctive inhabitant" of ponderosa pine forests on the Southern Colorado Plateau (Figure 4.7.1-3; Northern Arizona University [NAU] 2015). This species of squirrel feeds on ponderosa pine seeds and the tree's cambium layer, and the squirrel uses the tree for shelter and nesting. Among the other species that use these forests are mule deer (*Odocoileus hemionus*), elk (*Cervus elaphus*), chipmunks, voles (NAU 2015), and bats (Chung-MacCoubrey 1996). Many different bird species also use ponderosa pine habitats, such as Steller's Jay (*Cyanocitta stelleri*), brown creeper (*Certhia americana*), white-breasted nuthatch (*Sitta carolinensis*), dark-eyed junco (*Junco hyemalis*), and western tanager (*Piranga ludoviciana*) (NAU 2015), all of which are known to occur at Walnut Canyon NM (Short 2002, Holmes et al. 2011). Short (2002) reported 42 species in ponderosa pine habitat during surveys south of the canyon, and Holmes et al. (2011) reported 62 species during their surveys both to the north and south of the canyon.

4.7.2. Data and Methods

To assess condition of ponderosa pine forests at Walnut Canyon NM, we used three indicators, fire regime, stand structure, and status/health of trees, focusing on different ecological and structural aspects of this resource. These indicators had a total of four measures. We also included a fourth indicator, presence & composition of understory vegetation and soil surface features, (with three measures) for informational purposes, but the indicator was not used to evaluate condition. This is described in greater detail later in this section. We based the assessment on several studies that have been conducted within the national monument, as well as the 2009 Fire Management Plan (FMP; i.e., NPS 2009a). The main

Figure 4.7.1-3. Abert's squirrel (*Sciurus aberti*) is a distinctive species of ponderosa pine forests on the Southern Colorado Plateau. Photo Credit: © Robert Shantz.

studies are described as needed in this section; they include: Davis (1987), Swetnam et al. (1990), Menzel (1996), and Parker et al. (2003a a,b). We also used data provided by the Southern Colorado Plateau Network (SCPN), collected under their integrated upland monitoring program (DeCoster et al. 2012) for informational purposes. The vegetation mapping report for the park (Hansen et al. 2004) was also used.

Departure from Natural Historical Fire Regime: Fire Regime Condition Class

Ponderosa pine forests have existed in northern Arizona for at least 4,000 years (Cole 1990 as cited by Menzel 1996). Over this time, the ponderosa pine has adapted to conditions in its environment, including frequent wildfires. Surface fires of low severity occurred in Southwestern ponderosa pine forests on the order of every 2-26 years (Reynolds et al. 2013). These fires served to maintain forest composition, structure, and spatial patterns (Reynolds et al. 2013). They seldom killed large trees but maintained an open forest structure by thinning out regenerating vegetation. European settlement in the middle to late 1800s, however, brought changes to the ponderosa pine forests due to livestock grazing, fire suppression, logging activities, and introduction of exotic species (Allen et al. 2002). Relative to historical reference conditions, current stands of old-growth trees have decreased. Dense stands of young trees are common, in some places species composition has shifted, grasses and forbs in the understory have declined in diversity and abundance, and in some cases, wildlife species are thought to have declined in abundance due to habitat changes (Allen et al. 2002). These forests are now more vulnerable to large, stand-replacing crown fires that represent a threat to both ecological communities and human communities (Allen et al. 2002). Efforts have been underway to restore the ecology of Southwestern ponderosa pine forests, and a substantial number of publications are available on the topic (e.g., Moore et al. 1999, Allen et al. 2002, Ecological Restoration Institute 2005, Reynolds et al. 2013).

We based this measure that focuses on fire on the results of a Fire Regime Condition Class (FRCC) analysis conducted by NPS (2009). NPS (2009) conducted a FRCC analysis as part of its fire management planning process. The analysis "characterizes the degree of historic change in vegetation as a result of the disruption from its natural fire regime. The results can help identify appropriate management strategies and can help prioritize areas for restoring vegetation and natural ecological process" (NPS 2009aa). Methods used for the analysis are described in Appendix A of the FMP (NPS 2009aa) and are entitled "Project Scale Fire Regime and Condition Class (FC) Methods, FIREMON Draft v1.1, 3-16-2003.

NPS conducted the initial assessment in 2003 using the vegetation maps from Hansen et al. (2004) and studies in the park that provided information on the natural historical fire regime, reference vegetation, and present day vegetation (Davis 1987, Swetnam et al. 1990, Knox 2004, Menzel 1996, and Parker et al. 2003b). NPS (2009) separated the national monument's fire-prone vegetation types into one of five natural historical fire regime categories with related fire return intervals and burn severity descriptions. The ponderosa pine vegetation community fell into fire regime I, with a fire return interval of 0-35 years and a burn severity of low.

Ponderosa pine vegetation was also separated into two vegetation-wildland fuel types: 1) Mixed

Ponderosa-Pinyon - Juniper-Gambel Oak-Blue Grama Woodland; and 2) Prescribed Burn Areas 1987-1999: Mosaic of Ponderosa Pine-Dominated and Pinyon-Juniper-Dominated Vegetation (NPS 2009aa). These two types were made up of the same ponderosa pine vegetation classes from Hansen et al. (2004, which were combined into one group in Figure 4.7.1-2). However, the second type consisted of areas that had received prescribed burn treatments between 1987 and 1999 (NPS 2009aa).

The purpose of the stand structure indicator is to assess the current stand structure of ponderosa pine forests in the national monument. We focus here on ponderosa pine trees, but some information is also presented on other species (e.g., Gambel oak, pinyon pine, and juniper). The information and data sources used here are generally the same as for the first indicator.

<u>Ponderosa Pine Stem Densities by Size Class</u>

To assess condition under this measure, we used information and analysis from the FMP (NPS 2009aa). In turn, the FMP analysis was based on data collected largely from two studies- Menzel (1996) and Parker et al. (2003b).

Ponderosa pine stands in the Flagstaff area were logged starting around 1880 (NPS 2009aa). Ponderosa pine stands prior to this time were described by Covington and Moore (1994 as cited by NPS 2009aa) based on studies in central and northern Arizona analyzing existing trees and cut stumps. Stands that exist today generally have many more small-diameter trees and canopies that are more closed. Few trees remain that are in the 50.8 to more than 76.2 cm (20 to more than 30 in) diameter range.

Menzel (1996) studied ponderosa pine tree stands within a 15.5 km^2 (6 mi^2) area along the north Walnut Canyon rim-Campbell Mesa area; the study area included land managed by the USFS, the State of Arizona, and NPS. The study area included two sections of ponderosa pine in the northwest corner of the national monument. Menzel reconstructed the tree stands within this area (to ~1876) using dendroecological techniques (Menzel 1996). The author also provided 1994 data on stand composition and structure.

More recently, Parker et al. (2003a,b) studied ponderosa pine stands within the park, on both the north rim (one study site) and south rim (two study sites) of the canyon, to examine the effects of prescribed burns on drought-related tree mortality. Each stand was about 15 ha (37 ac) in size, and each was located in the ecotone between the higher elevation ponderosa pine forest and the lower elevation pinyon-juniper woodland. The researchers describe the stands as being representative of the rim terrace ponderosa stands within the park. Data from this study are available on stand composition, basal area, stem density, and size classes. It should be noted that the Parker et al. (2003a,b) sites on the north rim were "slightly farther east" than Menzel's, and Parker et al.'s sites on the south rim (where Menzel did not sample) may have been farther into the pinyon-juniper ecotone (NPS 2009aa).

Menzel (1996) found that the forests and woodlands on the north rim of Walnut Canyon were probably similar in appearance to those in other parts of northern Arizona around 1876. He also concluded that the increases by 1994 in basal area and density (for ponderosa pine and other species) within the forests in the Walnut Canyon area were not as great as they were for other areas (e.g., North Kaibab Plateau). He attributed this to poorer site quality and regeneration potential in the national monument area, along with the effects of thinning through heavy logging that kept densities of smaller trees lower than in the other areas. It should be noted that land in Walnut Canyon NM was never open to harvest, but stumps from the late 1800s/early 1900s exist in the park and indicate that timber trespass occurred (Menzel 1996). Knox (2004) suggested lower ponderosa pine densities in the national monument may be due to their lower elevation within the park compared to in other areas, transitioning into pinyon-juniper and drier conditions.

We assessed this measure using information from NPS (2009), which was based on the Menzel (1996) data for 1876 and 1994 and the Parker et al. (2003a,b) data for 2003. Data from the 1876 stands (Menzel 1996) and 1880 stands (Knox 2004) indicated that the stands were relatively open with an uneven age structure (NPS 2009a). Table 4.7.2-1 shows the desired density of ponderosa pine trees per 100 acres for trees that are 9 in (22.9 cm) or greater in DBH. A desired range is shown for each diameter class starting with 9 in (22.9 cm). Aspects of the table are described in the notes under the table. Also note that while metric units are typically presented first throughout all sections of the overall document, for this and other measures in this assessment we present the English units first (for diameter classes) to be consistent with NPS (2009) and to avoid conversion and rounding differences. In an effort to keep the table somewhat easy to read, we included only the number of stems per acre and desired range of trees per 100 acres (rather than also in hectares).

To assess condition, we compared the data for 2003 to the desired range of trees (minimum/maximum average numbers) shown in the last column of Table 4.7.2-1. Specific thresholds to assess condition are provided in the Reference Condition section, and they are based on how much the measured stem densities differ or depart from the desired ranges. It is important to note that the thresholds in the reference conditions are somewhat subjective. We also compared the 1994 data to the desired range in the number of trees, but we did not use these data to assess condition because they are now more than 20 years old.

Presence and Persistence of Large Trees

The previous measure under this indicator focused on ponderosa pine stem densities in the ponderosa pine forests at Walnut Canyon NM. That measure includes information on large ponderosa pine trees, but this measure focuses more on large ponderosa pine individuals and their importance in the ponderosa pine community using some of the data from Menzel (1996) and Parker et al. (2003 a,b). Prior to European settlement, ponderosa pine forests above the rim of Walnut Canyon had fewer but larger ponderosa pine trees (NPS 2009a).

Old ponderosa pine trees are of value and interest for a number of reasons, including their scarcity on the landscape, the unique wildlife habitat they provide, the information they provide on past disturbance and changes in climate, their aesthetic and spiritual meaning to people, their resilience to

Table 4.7.2-1. Desired ponderosa pine stem densities by size class for Walnut Canyon NM (in FMU-2) based on estimated trees per acre in 1876.

Diameter Class (inches) [1]	Diameter Class (cm)	Density (# tree stems per acre), 1876	Adjustment above 1876 density [2]	Desired range (#) of trees 9+ inch (22.9+ cm) DBH per 100 acres [3]
0.1 - 2.9 [4]	0.2 - 7.4	unreliable data	–	ensure regeneration; no specific target provided
3.0 - 8.9 [4]	7.6 - 22.6	unreliable data	+ 0 to 100%	360 to 720 (conservative estimate)
9.0 - 11.9	22.9 - 30.2	5.0	+ 30 to 40%	675 - 725
12.0 - 15.9	30.5 - 40.4	5.0	+ 20 to 30%	600 - 650
16.0 - 18.9	40.6 - 48.0	3.0	+ 10 to 20%	330 - 360
19.0 - 23.9	48.3 - 60.7	2.3	+ 10 to 20%	250 - 280
24.0 - 26.9	61.0 - 68.3	1.6	+ 0 to 20%	160 - 190
27.0 - 31.9	68.6 - 81.0	1.0	+ 0 to 20%	100 - 120
32.0 - 35.9	81.3 - 91.2	0.2	+ 0%	20
36.0 - 39.9	91.4 - 101.3	0.1	+ 0%	10
40.0 - 43.9	101.6 - 111.5	0	–	–
9+ DBH Total	22.9+ DBH Total	18.2	–	2,115 - 2,325

Source: NPS 2009a.

[1] Numbers in this document are typically presented in metric units first, followed by English units. However, we present data and discussion for this measure in English units first to follow NPS (2009) and avoid rounding issues. However, metric units are shown in the table.

[2] Adjustments above the 1876 density were made to account for the possibility that: smaller trees were underrepresented or underestimated in the 1876 study area; and 20th century conditions (e.g., wetter climate) may have been more conducive to tree survival and growth than for the reference stand (NPS 2009a).

[3] Desired tree densities are shown per 100 acres to allow for management of tree groups across a project area rather than on a per acre basis (NPS 2009a).

[4] The first two size classes are for seedlings and saplings, respectively. The numbers of ponderosa pine in these classes are highly variable among locations regionally because densities fluctuate over short time scales due to regeneration and mortality events (NPS 2009a).

low/mod-severity fire, and their ability to sequester carbon (multiple authors as reviewed in Kolb et al. 2007). For example, in Walnut Canyon NM and the general vicinity, large ponderosa pine trees are used for nesting by the northern goshawk (*Accipiter gentilis*), a "species of greatest conservation need" in Arizona (Arizona Game and Fish Department [AGFD] 2012; see the Birds assessment in this report). In the western U.S., old ponderosa pine trees are under threat from fire, stress from competition with mid- or under-story trees, drought, and related bark beetle attacks (Kolb et al. 2007). Kolb et al. (2007) notes that what is described as old-growth ponderosa pine forest varies somewhat according to management entity and researcher, but old trees are the common theme (Kaufmann et al. 1992). In Arizona and New Mexico, the average age of ponderosa pine trees in stands of old growth is 279 years (Swetnam and Brown 1992 as cited by Kolb et al. 2007). In these same two states, old-growth stands are said to include trees at least 160 years old and with a DBH greater than 46 cm (18 in; Mehl 1992 as cited by Kolb et al. 2007).

Old, larger stands of ponderosa pine within Walnut Canyon NM are managed for northern goshawk and Mexican spotted owl (*Strix occidentalis lucida*; as well as for other wildlife), to restore a frequent, low-severity fire regime, and to reduce the risk of high-severity stand replacing wildfire (Paul Whitefield, Natural Resource Specialist, Flagstaff Area NMs, pers. comm.).

Extent/Proportion of Conifer Mortality

A substantial, but unmeasured, proportion of conifers have died within Walnut Canyon NM since around 2002 (NPS 2009a). This mortality includes older ponderosa and pinyon trees in the ponderosa-pinyon-juniper ecotone, older trees in the eastern pinyon-juniper woodlands, and patches of mature Douglas-fir on north-facing slopes. This measure will focus on the mortality of conifers within the ponderosa pine forests in the national monument. The main sources of information used are data from Parker et al. (2003a, b) and USFS (2004, 2014a, 2014b, 2016b).

Mortality of trees has increased across the western U.S. (van Mantgem et al. 2009). For example, in northern Arizona, mortality was monitored in ponderosa pine and mixed-conifer forests from 1997-2007 (Ganey and Vojta 2011). These researchers found that mortality occurred on nearly all of their 1-ha (2.5 ac) mixed-conifer and ponderosa pine plots (100 and 98%, respectively). In most cases the mortality was due to forest insects attacking drought-stressed trees. The number of ponderosa pine trees that died from 2002 to 2007 was 74% greater than the number that died in the earlier years of the study period; the proportions were even greater in the mixed-conifer forest. For both forest types, the magnitude of mortality varied spatially. The largest size classes were affected the most, especially in the mixed-conifer forest.

To assess condition under this measure, we used data from Parker et al. (2003a,b) from their two prescribed burn plots and one control plot within the park. All three plots were transitional between ponderosa pine and pinyon-juniper communities. The overall dataset was used for other measures in the assessment, but this measure uses data on dead trees in particular. Our other main source of data for this measure is from the USFS Forest Health Monitoring (FHM) Program (USFS 2004, 2014a, 2014b, 2016b). The FHM Program conducts annual aerial detection surveys across the United States to document tree mortality as a result of bark beetle infestation and other insects and diseases (Potter and Conkling 2016). Surveyors document visible damage to tree crowns and identify, when possible, the damage agent, usually by identifying the host-tree species (Potter and Conkling 2016). The data used in the assessment are from 2001-2004 (encompassing the period that the Parker et al. study was conducted and a period of observed mortality) and 2013-2015, the most recent few years. The data for these years, provided by the USFS to Flagstaff Area NMs, are specifically for the national monument.

Bark beetles (Coleoptera: Curculionidae, Scolytinae) are a group of native insects composed of many species that live between the bark and wood of host trees and feed on the tree's phloem tissues (Bentz et al. 2010). Their feeding habits interrupt the flow of nutrients and water in the tree, eventually leading to tree death. Bark beetles preferentially attack weakened trees. Although bark beetle outbreaks are a natural ecosystem process, climate change has increased drought stress on western coniferous forests making many millions of hectares of trees available to bark beetle infestation (Bentz et al. 2010). Widespread bark beetle infestation may have undesirable effects on vegetation structure and composition, fire behavior and occurrence, and carbon storage (Jenkins et al. 2012, Ghimire et al. 2015, and Potter and Conkling 2016).

Functional Group Cover
Species Cover & Frequency
Soil Surface Features Cover
Under the presence & composition of understory vegetation and soil surface features indicator, we include data for three measures that have been collected by the SCPN at Walnut Canyon NM as part of their integrated upland monitoring program within the network's parks. We present these data for informational purposes only, as monitoring data have been validated and summarized only one time to date and are considered baseline data. The summarized and validated data are from 2014; data were collected again in 2016, but they were not available at the time of writing this assessment. No reference conditions by which to judge condition have been developed by SCPN or by us for this assessment. The summarized data were provided in advance of a monitoring report that will be produced by SCPN. The data were provided in December 2016 by Jim DeCoster, Plant Ecologist, with SCPN.

The SCPN implemented an integrated upland monitoring program to monitor vegetation and soils within the predominant upland vegetation types in the network's parks (DeCoster et al. 2012). Vegetation and soils are considered overall indicators of upland ecosystem integrity (Thomas et al. 2006, as cited by DeCoster and Swan 2016). Below we provide a condensed excerpt from DeCoster et al. (2012) regarding the importance of vegetation and soils.

> Vegetation... is the dominant biological feature of terrestrial ecosystems and provides habitat upon which all animals depend. Moreover, in dryland ecosystems, vegetation stabilizes soil and enhances the capture and retention of soil resources. In fire-adapted systems, fuel loading and fuel connectivity are largely controlled by vegetation structure, thus vegetation structure affects fire return intervals and fire severity.
>
> Soil was identified as a vital sign because erosion is a significant threat to many dryland ecosystems. Soil is a thin layer of mineral and organic matter that supports both flora and fauna, and consequently determines ecosystem health. Soil regulates hydrologic processes and the cycling of mineral nutrients.

At Walnut Canyon NM, the SCPN selected one ecosystem, or ecological site, to monitor-- Ponderosa Pine. Note that the SCPN refers to the sites they monitor as ecological sites, but that they "do not exactly conform to the concept of ecological sites as described by the U.S. Natural Resource Conservation Service" (DeCoster and Swan 2016).

Sampling was conducted within 12 plots within the park (Figure 4.7.2-1). Each of the 12 permanently-marked plots are 0.5 ha (1.2 acres) in size. The sampling design includes various measurements, including those we have included here. Centered within each 0.5 ha (1.2 acre) plot are three 50 m (164 ft) transects (DeCoster et al. 2012). SCPN collects the following data from within five 10 m^2 quadrats placed along each transect: 1) cover of all herbaceous and shrub species, 2) frequency of all herbaceous and shrub species in 5 nested quadrats, 3) cover of plant functional categories, 4) cover of soil surface features (in 1 m^2 quadrats), and 5) counts of tree seedlings by size class (which we do not present in this assessment). For a full description of the sampling process, see DeCoster et al. (2012).

4.7.3. Reference Conditions

Table 4.7.3-1 summarizes the condition thresholds for measures in good condition, those warranting moderate concern, and those warranting significant concern. For the ponderosa pine stem densities by size class measure, we provided additional buffers around the desired ranges in the number of trees to account for the possibility that there could have been differences in the number of trees historically in the different areas sampled for ponderosa pine within the park.

For this assessment, it is also valuable to include a discussion of the reference period for assessing condition and the natural historical fire regime. For both of these topics, we provide text directly from NPS (2009).

> Reference Period:
>
> The period from 1680 to 1880 is proposed as a reference period for establishing fire and vegetation restoration objectives for Walnut Canyon NM. Climate variation and extreme

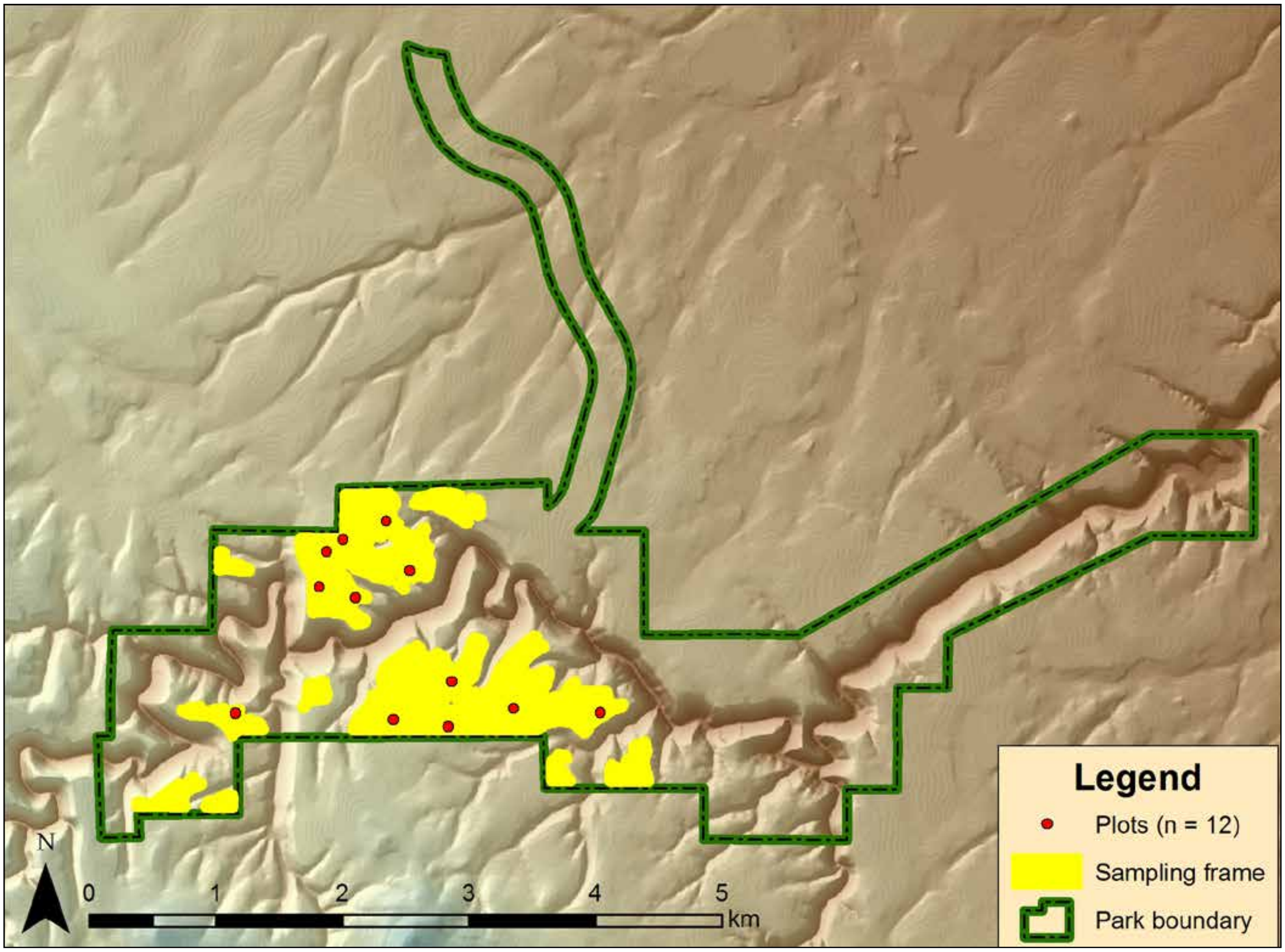


Figure 4.7.2-1. The location of 12 plots (red dots) being sampled as part of the upland integrated monitoring program of the SCPN. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction. Figure Credit: NPS SCPN.

climatic episodes are comparable over the last 12-22 centuries, although mean annual temperatures are steadily rising and may exceed the historic range of variation over the next 50 to 100 years.... Robust fire records are available from 1700 to the present. By 1680 A.D. the ponderosa stands surrounding Walnut Canyon had recovered from the Sunset Crater Volcano eruption for about six centuries, and from intensive land use by the Sinagua Culture for about four centuries. It is reasonable to assume that by 1700, tree composition, population structure, and distribution patterns were in equilibrium with the natural historical fire regime. Between 1680 and 1880, the ponderosa stands in the Walnut Canyon area had been shaped by a frequent fire regime for at least two centuries. This is also the period in which most of the oldest living ponderosa pines in the contemporary stands around Walnut Canyon germinated. Beginning around 1880, logging of the local stands initiated long term changes in tree density, size-classes, and canopy cover. The natural fire regime was also altered around 1880 as livestock grazing and logging activities reduced the continuity of the herbaceous understory.

Natural Historical Fire Regime:

Davis (1987) collected fire-scarred wedges from 27 ponderosa pines and developed a fire chronology for the rim terraces of Walnut Canyon NM. Eighteen of Davis' tree wedges were reanalyzed by Swetnam et al. (1990).

Table 4.7.3-1. Reference conditions used to assess ponderosa pine forests in Walnut Canyon NM.

Indicator	Measure	Good	Moderate Concern	Significant Concern
Fire Regime	Departure from Natural Historical Fire Regime: FRCC	Fire regimes are within an historical range, and the risk of losing key ecosystem components is low. Vegetation attributes (species composition and structure) are intact and functioning within an historical range.	Fire regimes have been moderately altered from their historical range. The risk of losing key ecosystem components is moderate. Fire frequencies have departed from historical frequencies by one or more return intervals (either increased or decreased). This results in moderate changes to one or more of the following: fire size, intensity and severity, and landscape patterns. Vegetation attributes have been moderately altered from their historical range.	Fire regimes have been significantly altered from their historical range. The risk of losing key ecosystem components is high. Fire frequencies have departed from historical frequencies by multiple return intervals. This results in dramatic changes to one or more of the following: fire size, intensity, severity, and landscape patterns. Vegetation attributes have been significantly altered from their historical range.
Stand Structure (i.e., size/age structure)	Ponderosa Pine Stem Densities by Size Class	Ponderosa pine stem densities fall within or close to the desired range of trees equal to and greater than 9 in (22.9 cm) DBH per 100 acres. "Close to" is within 10% of the minimum or maximum value.	Ponderosa pine stem densities fall outside of but between 10 and 30% of the desired range of trees 9 in (22.9 cm) and greater DBH per 100 acres.	Ponderosa pine stem densities fall outside of the desired range of trees 9 in (22.9 cm) DBH and greater per 100 acres by more than 30%.
	Presence and Persistence of Large Trees	Ponderosa pine stands contain large trees in desirable numbers (based on historical estimates and desired range; see measure above).	Large trees exist in the stands, but occur in lower than desired numbers (based on historical estimates and desired range; see measure above).	Presence of large trees is substantially less than desired numbers (based on historical estimates and desired range; see measure above).
Status / Health of Trees	Extent/Proportion of Conifer Mortality	Extent of conifer mortality in the monument is very small or nonexistent.	Extent of conifer mortality in the monument is relatively small to moderate.	Extent of conifer mortality in the monument is moderate to substantial and/or may continue to increase.
Presence & Composition of Understory Vegetation & Soil Surface Features	Functional Group Cover	No reference conditions were developed.	No reference conditions were developed.	No reference conditions were developed.
	Species Cover & Frequency	No reference conditions were developed.	No reference conditions were developed.	No reference conditions were developed.
	Soil Surface Features Cover	No reference conditions were developed.	No reference conditions were developed.	No reference conditions were developed.

Knox (2004) augmented Davis' and Swetnam's work with additional samples. While one tree was old enough to have evidence of fire dating to the 1580s A.D., fires were not recorded on more than 25% of the samples until about 1700. Frequent fires are evident throughout the record until 1889. For the period from 1700 to 1880, Knox excluded fires recorded only on single trees, and calculated a mean fire return interval of 8.2 years, with a minimum/maximum range from 1 to 11 years. Because of the frequent fire return interval along the Walnut Canyon rim, and because the scarred trees survived multiple fires, the stands are assigned to Natural Historical Fire Regime I [with a fire return interval of 0-35 years and a burn severity of low].

4.7.4. Condition and Trend

Departure from Natural Historical Fire Regime: Fire Regime Condition Class

There are two vegetation-wildland fuel types that include ponderosa pine vegetation. The table below (Table 4.7.4-1) shows the FRCC results for the ponderosa pine-dominated areas within the national monument from NPS (2009). As seen, a majority of the ponderosa pine vegetation at Walnut Canyon NM was placed into condition class 2 in the 2003 assessment. This condition class corresponds to our NRCA condition of moderate concern. The areas dominated by ponderosa pine vegetation (as well as some dominated by pinyon-juniper vegetation) that were treated with prescribed burns from 1987-1999 were placed into condition class 1, which corresponds to an NRCA condition of good. It should be noted that this assessment was conducted in 2003, and the FMP (dated 2009) maintained the conclusions. However, the document also notes that "recent changes in the spread of exotics and insect outbreaks may have changed these condition assessments and they will need re-examination in the future. After reviewing these tables and recent analyses, it appears that there may be condition class 3 areas in these monuments [meaning all three Flagstaff Area NMs], but confirmation awaits updated assessments and additional analysis" (NPS 2009a). The FMP does not indicate in which areas in the three parks this might be the case.

Although the information about to be presented is not based on monitoring data, we use it to consider the trend in condition for this measure. The FMP describes management strategies for the two condition classes of ponderosa pine vegetation. For the condition class 1 areas (areas that have recently been managed with prescribed fire; those in good condition in our assessment), the management strategy states:

> These areas of fire-dependent vegetation have little departure from the range of natural variation. Wildland fires will be managed utilizing the appropriate management response. Natural conditions in these areas can be maintained with prescribed fire. Manual vegetation thinning and fuels reduction treatments may be used on a limited basis to protect site-specific sensitive resources.

Table 4.7.4-1. Fire regime condition class assessment results for ponderosa pine at Walnut Canyon NM.

Vegetation-Wildland Fuel Type	Total ha (acres)	Fire Regime	Condition Class
Mixed Ponderosa-Pinyon-Juniper-Gambel Oak-Blue Grama Woodland	394 (973)	I	2
Prescribed Burn Areas 1987-1999: Mosaic of Ponderosa Pine Dominated and Pinyon-Juniper Dominated Vegetation	163 (402)	I	1

Source: NPS 2009a.

For the condition class 2 areas (the majority of the ponderosa pine vegetation in the park; considered of moderate concern), the management strategy states:

> These areas of fire-dependent vegetation have moderate departure from the range of natural variation. Wildland fires will be managed utilizing the appropriate management response. The areas can be restored to the natural fire regime with manual vegetation thinning and fuel reduction treatments, followed by prescribed fire. Localized areas within condition class 2 may need more intensive manual vegetation thinning and fuels removal before they can be managed with prescribed fire.

Another important aspect of the fire management program at Walnut Canyon NM is the Fire Management Unit (FMU). FMUs are geographic planning units for actual implementation of fire program activities (NPS 2009a). Four FMUs have been defined, with ponderosa pine vegetation falling into three FMUs (FMU-1, FMU-2, and FMU-4) at the national monument (Figure 4.7.4-1). FMU-1 consists of "developed areas and areas of heavy visitor use within fire-prone vegetation where human safety and protection of public or private property are paramount values." FMU-2 consists of "areas of vegetation that are adapted and dependent upon a frequent fire regime." FMU-4 includes "areas with a variety of vegetation, fuels, fire regimes, resources at risk, and topographic features." This FMU includes areas that NPS "will either be required to or be able to manage with more passive strategies than the other FMUs" (NPS 2009a). Management objectives are described for all of the

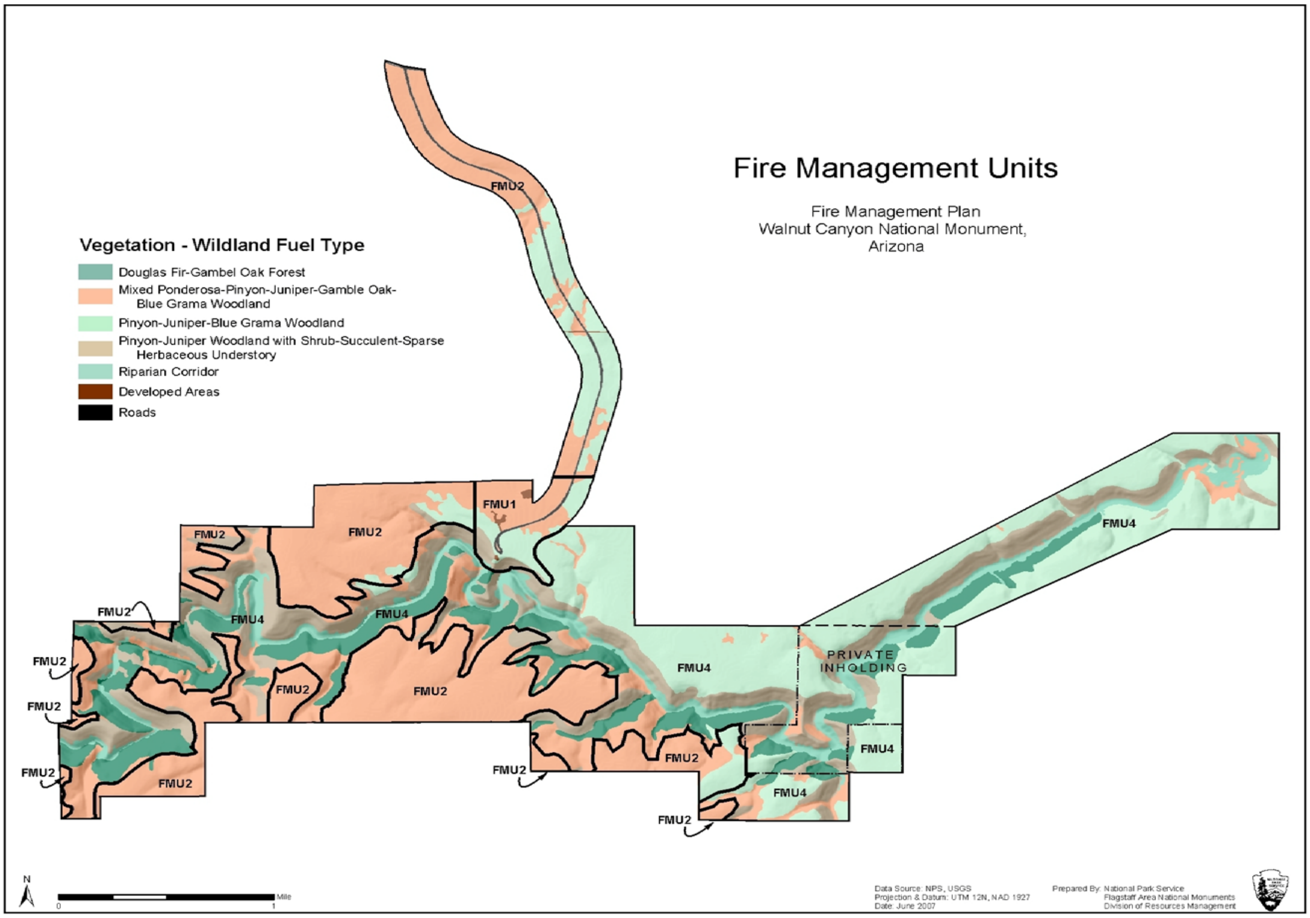


Figure 4.7.4-1. Fire Management Units within Walnut Canyon NM. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction. Figure Credit: NPS.

FMUs, with fire management activities described for both condition class 1 and 2 areas within FMUs 1 and 2. Twenty-four hectares (59 ac) of ponderosa pine vegetation are included in FMU-1, 398 ha (983 ac) are included in FMU-2, and 141 ha (349 ac) are included in FMU-4. The prescribed and lightning-ignited fires that have occurred at the park since 1986 are shown in Figure 4.7.4-2.

This information was presented on the fire management program because it shows that natural resource managers at Walnut Canyon NM are making efforts to allow for a more natural fire regime in ponderosa pine stands where possible within the park, and to allow these forests to receive the ecological benefits of fire. Based on the information presented here, and the reference conditions described in Table 4.7.3-1, we consider condition under this measure to be good to of moderate concern. This range, or split, in condition corresponds to some of the ponderosa pine within the monument being placed into condition class 1 (i.e., good condition), and some being placed into condition class 2 (i.e., moderate concern). Although it is possible the trend in condition is improving (with prescribed fires and efforts to allow a more natural fire regime), we have no data in the assessment to support this, and so we conclude a trend of unknown at this time. Because the FRCC analysis was conducted in 2003 and NPS (2009) suggested some areas within the park may fall into condition class 3 (and we do not know where those areas are), we have medium confidence in the measure.

Ponderosa Pine Stem Densities by Size Class

We assessed condition under this measure using information from NPS (2009), which was based on the Menzel (1996) data for 1876 and 1994 and the Parker et al. (2003a,b) data for 2003. We compared the density of ponderosa pine stems from the Menzel (1996) and Parker et al. (2003a,b) studies to the NPS (2009) desired densities for stems 9 in (22.9 cm) and greater in DBH. Smaller size classes were not used in the measure

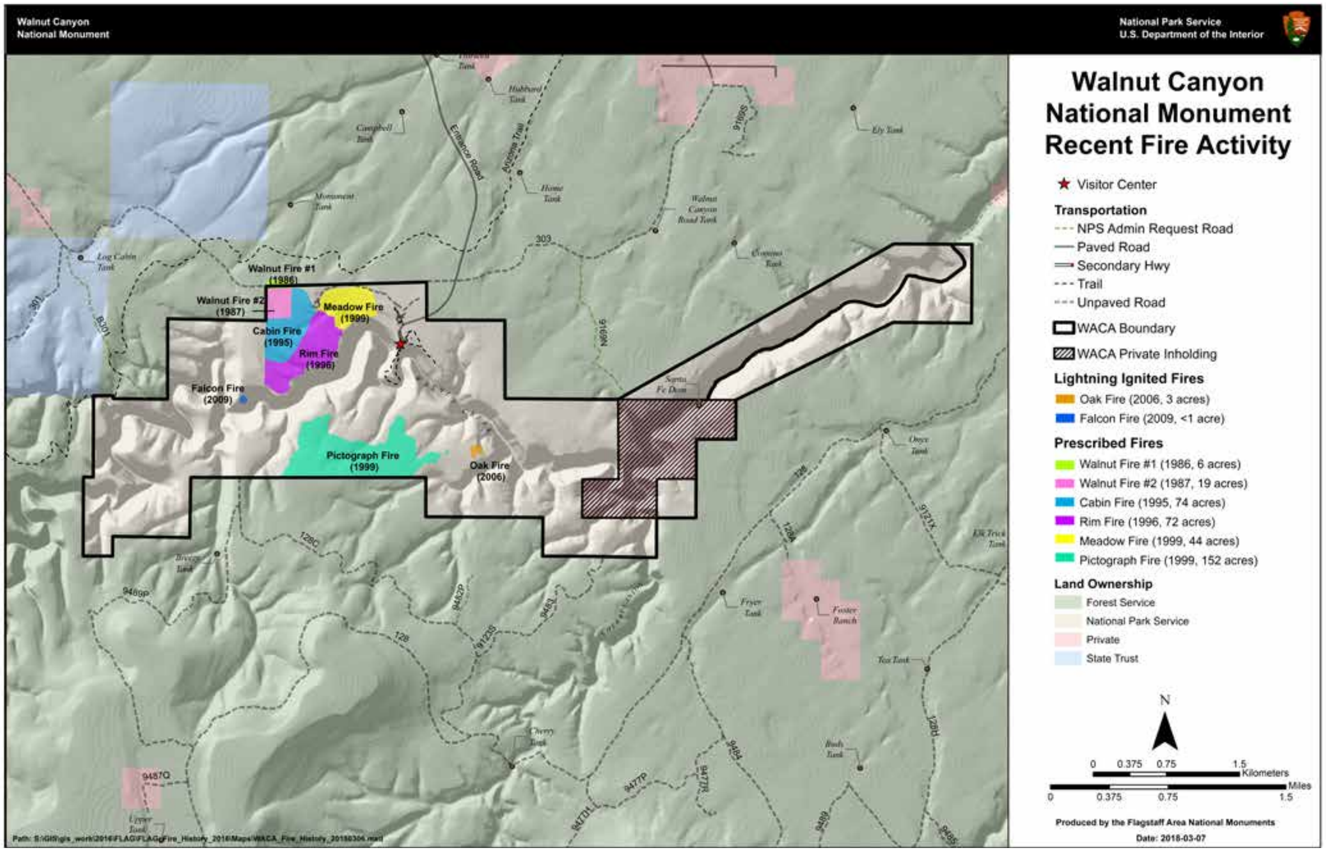


Figure 4.7.4-2. Prescribed and lightning-ignited fires at Walnut Canyon NM since 1986. Figure Credit: NPS 2014.

because data were either not available or considered unreliable by NPS (2009), but available information on these size classes is shown in the table (see below). As previously mentioned, note that we provide English units first for this measure to be consistent with NPS (2009).

For this measure, we used the most recent data only to assess condition, but we also show the data from 1994 and departures from the desired ranges of trees per size class. As seen from Table 4.7.4-2, densities in the eight size classes for which we have data fell both over, under, and within the desired minimum and maximum ranges (see fifth and seventh columns in table).

For the 1994 data, the number of trees (calculated for 100 ac) was greater than the desired range for four size classes, within the range for one size class, and less than the range for three size classes. Observed densities were greater than the desired range primarily for the relatively smaller size classes in the comparison (i.e., the 9-11.9, 12-15.9, and 16-18.9 in [22.9-30.2, 30.5-40.4, and 40.6-48.0-cm] DBH size classes). No trees were reported in the 32-35.9 in (81.3-91.2 cm) and 36-39.9 in (91.4-101.3 cm) DBH size classes. The greatest departure from the desired range was for the 9-11.9 in DBH size class. If these data were more recent and we were using them to judge condition, the stem densities would be of significant concern using the reference conditions.

For the 2003 data, the number of trees (calculated for 100 ac) was greater than the desired range for one size class (but only by <1%), within the range for one size class, and less than the range for six size classes. The greatest departure from the desired range was for the 36-39.9 in (91.4-101.3 cm) DBH size class, followed by the 32.0-35.9 in (81.3-91.2 cm) size class and the 16.0-18.9 in (40.6-48.0-cm) size class. If we consider the departures for the individual size classes, using our reference conditions we would consider the condition good for three of the size classes (i.e., those within 10% of the minimum or maximum number of trees), of moderate concern for two of the size classes (those with departures from the desired range of between 10 and 30%), and of significant concern for three of the size classes (those with departures >30%). To judge overall condition, however, we determined an

Table 4.7.4-2. Desired and actual ponderosa pine stem densities by size class for Walnut Canyon NM.

Diameter Class (inches) [1]	Diameter Class (cm)	Desired range (#) of trees 9+ inch (x cm) DBH per 100 acres [2]	# Trees per acre in 1994 (north rim)	Minimum Difference between 1994 and desired range (and % departure) [3]	# Trees / acre in 2003 (both rims)	Minimum Difference between 2003 and desired range (and % departure) [3]
0.1 - 2.9	0.2 - 7.4	no specific target provided	64.0	–	no data	–
3.0 - 8.9	7.6 - 22.6	conservative estimate provided- did not use	32.7	–	58.9	–
9.0 - 11.9	22.9 - 30.2	675 - 725	17.5	over by 1,025 (141%)	7.3	over by 5 (0.7%)
12.0 - 15.9	30.5 - 40.4	600 - 650	9.8	over by 330 (51%)	5.5	under by 50 (8.3%)
16.0 - 18.9	40.6 - 48.0	330 - 360	6.8	over by 180 (50%)	1.8	under by 150 (45%)
19.0 - 23.9	48.3 - 60.7	250 - 280	2.7	within desired range	2.1	under by 40 (16%)
24.0 - 26.9	61.0 - 68.3	160 - 190	1.0	under by 60 (37.5%)	1.6	within desired range
27.0 - 31.9	68.6 - 81.0	100 - 120	1.7	over by 50 (42%)	0.8	under by 20 (20%)
32.0 - 35.9	81.3 - 91.2	20	0	under by 20 (100%)	0.1	under by 10 (50%)
36.0 - 39.9	91.4 - 101.3	10	0	under by 10 (100%)	0	under by 10 (100%)
40.0 - 43.9	101.6 - 111.5	–	0	–	0	–
9+ DBH Total	22.9+ DBH Total	–	–	average minimum difference = 65%	–	average minimum difference = 30%

Source: NPS 2009a. Based on data from 1876, 1994, and 2003.

[1] Numbers in this document are typically presented in metric units first, followed by English units. However, we present data and discussion for this measure in English units first to follow NPS (2009) and avoid rounding issues. However, metric units are shown in the table.

[2] Desired tree densities are shown per 100 acres to allow for management of tree groups across a project area rather than on a per acre basis (NPS 2009a).

[3] The percent departure was calculated from the closest part of the range (i.e., departure from the minimum or maximum value).

average minimum departure or difference for the eight size classes; that figure amounts to 30%. Using our reference conditions, this leads to a condition of moderate concern (but 31% would have been considered significant concern based on our reference condition cut-off). We have only low to medium confidence in the measure because: differences may have existed between stand densities historically in the Menzel (1996) and Parker et al. (2003a,b) plots; the data are now 13 years old; the additional loss of trees after 2003 may have occurred (which would affect stem densities); and our reference condition thresholds were subjective. Some of these factors also contribute to our conclusion of an unknown trend.

Data are also available on stem densities for Gambel oak and pinyon pine and juniper species from Menzel (1996) and Parker et al. (2003a,b) for 1876, 1994, and 2003. We did not include these species in a measure because no target densities were available for them from NPS (2009). However, because the data are of interest and they are natural components of the ponderosa pine community, we present the densities of these trees below. As seen from the table, the total densities and the densities for many individual size classes were much higher for the 1994 stands than for the 1876 stands (Table 4.7.4-3). The total densities and the densities for many of the size classes for the 2003 stands were intermediate between the 1876 and 1994 stands.

Presence and Persistence of Large Trees

This measure focuses on the presence and persistence of large ponderosa pine trees in the ponderosa pine community at Walnut Canyon NM. The Data and Methods section included some discussion of the importance of these large trees. Among the values is their use for habitat and nesting for species such as the northern goshawk. It is important to again mention that the timber harvesting that began in the 1800s focused on the removal of large trees. NPS (2009) reported that stands were logged between the 1880s and 1920s (and some again in the 1960s). The data and information sources we used on large ponderosa pine trees in the national monument were primarily Menzel (1996), Parker et al. (2003a,b), and NPS (2009).

Table 4.7.4-3. Gambel oak and pinyon-juniper stem densities by size class in Walnut Canyon NM .

Diameter Class (inches) [1]	Diameter Class (cm)	Gambel Oak: Density (stems/acre), 1876	Gambel Oak: Density (stems/acre), 1994	Gambel Oak: Density (stems/acre), 2003	Pinyon-Juniper: Density (stems/acre), 1876	Pinyon-Juniper: Density (stems/acre), 1994	Pinyon-Juniper: Density (stems/acre), 2003 [2]
0.1 - 2.9	0.2 - 7.4	7.2	30.3	9.8	0.9	28.0	–
3.0 - 8.9	7.6 - 22.6	2.2	27.0	19.2	1.1	13.2	16.1
9.0 - 11.9	22.9 - 30.2	0.7	5.4	1.6	1.0	7.8	3.0
12.0 - 15.9	30.5 - 40.4	0.4	0.7	0.2	0.7	3.0	1.6
16.0 - 18.9	40.6 - 48.0	0.2	0.7	0.1	0.5	1.7	0.2
19.0 - 23.9	48.3 - 60.7	0.1	0.7	0.1	0.1	1.0	0.3
24.0 - 26.9	61.0 - 68.3	0	0	0	0.1	0	0.1
27.0 - 31.9	68.6 - 81.0	0	0.3	0	0.2	0.3	0.2
32.0 - 35.9	81.3 - 91.2	0	0	0	0.1	0	0.1
36.0 - 39.9	91.4 - 101.3	0	0	0	0.1	0	0
40.0 - 43.9	101.6 - 111.5	0	0	0	0.1	0	0
Total	Total	10.8	65.1	31.0	4.7	55.0	21.6

Source: NPS (2009) original sources: Menzel 1996 and Parker et al. 2003a,b.

[1] Numbers in this document are typically presented in metric units first, followed by English units. However, we present data and discussion for this measure in English units first to follow NPS (2009) and avoid rounding issues. However, metric units are shown in the table for size class.

[2] Pinyon-juniper data for 2003 did not include the smallest diameter size class. Therefore, the total number of stems for this year is not entirely comparable to the other two years.

In Arizona and New Mexico, stands of old-growth ponderosa pine include trees at least 160 years old and with a DBH greater than 46 cm (18.1 in; Mehl 1992 as cited by Kolb et al. 2007). According to Table 4.7.4-2, this falls into the tree size range (at the upper end) listed as 16.0-18.9 in (40.6-48.0 cm) in DBH (see Table 4.7.4-4, a modified version of 4.7.4-2).

Comparing the data from Menzel (1996) from 1876 to 1994, densities in three of the six size classes shown (excluding the largest, which had no trees recorded) increased; these classes are the two smallest and the fourth smallest. Densities in three of the size classes decreased; these are the two largest and the third smallest. These densities were directly comparable because the study areas were the same. This comparison also generally holds if one compares the desired range and the 1994 densities, except that the second smallest category of those shown was within the desired range in 1994. The largest size class of trees in 1994 was the 27-31.9 in (68.6-81 cm) DBH class.

Comparing the 2003 densities to the desired range of trees leads to somewhat different results. For five of the six size classes, the 2003 densities were lower than the desired range of trees. The one exception was for the third smallest size class shown. The largest size class of trees in the 2003 stand was the 32.0-35.9 in (81.3-91.2 cm) DBH class.

Based on the 2003 data, it appears that trees in the larger size classes (16.0-18.9 in [40.6-48.0 cm] DBH and greater) occur in fewer numbers on the landscape than desired at Walnut Canyon NM. As with the previous measure, we calculated an average minimum difference from the desired range; that figure is 38.5%. Using our reference conditions, this leads to a condition of significant concern. Because of the history of logging in the area, potential historical differences between the Parker et al. stands and the Menzel stands that were used to develop the desired range in the number of trees, as well as the fact that the data are now 13 years old, we consider the confidence level to be low to medium. With the availability of more widespread and current data, it is possible we would conclude a different condition. The trend is unknown.

It must also be acknowledged that the NPS, as well as other agencies (such as the USFS) have discussed the need to protect and manage for large ponderosa pine trees. Flagstaff Area NMs has specific management objectives and guidelines in place to manage for these large trees (NPS 2009a). For example, within FMU-2, the oldest ponderosa pines surviving from the 1880s

Table 4.7.4-4. Desired and actual ponderosa pine stem densities by size class for the larger size classes.

Diameter Class (inches) [1]	Diameter Class (cm)	# Trees per acre in 1876 (north rim)	Desired range (#) of trees 16+ inch (40.6+ cm) DBH per 100 acres [2]	# Trees per acre in 1994 (north rim)	Minimum Difference between 1994 and desired range (and % departure) [3]	# Trees per acre in 2003 (both rims)	Minimum Difference between 2003 and desired range (and % departure) [3]
16.0 - 18.9	40.6 - 48.0	3.0	330 - 360	6.8	over by 180 (50%)	1.8	under by 150 (45%)
19.0 - 23.9	48.3 - 60.7	2.3	250 - 280	2.7	within desired range	2.1	under by 40 (16%)
24.0 - 26.9	61.0 - 68.3	1.6	160 - 190	1.0	under by 60 (37.5%)	1.6	within desired range
27.0 - 31.9	68.6 - 81.0	1.0	100 - 120	1.7	over by 50 (42%)	0.8	under by 20 (20%)
32.0 - 35.9	81.3 - 91.2	0.2	20	0	under by 20 (100%)	0.1	under by 10 (50%)
36.0 - 39.9	91.4 - 101.3	0.1	10	0	under by 10 (100%)	0	under by 10 (100%)
16+ DBH Total	40.6+ DBH Total	–	–	–	average minimum difference = 55%	–	average minimum difference = 38.5%

Source: NPS 2009a.

[1] Numbers in this document are typically presented in metric units first, followed by English units. However, we present data and discussion for this measure in English units first to follow NPS (2009) and avoid rounding issues. However, metric units are shown in the table. The metric units were calculated based on the data in inches shown; the diameter classes in centimeters are not the exact categories shown in the original data sources.

[2] Desired tree densities are shown per 100 acres to allow for management of tree groups across a project area rather than on a per acre basis (NPS 2009a).

[3] The percent departure was calculated from the closest part of the range (i.e., departure from the minimum or maximum value).

stand (trees greater than 16 in [40.6 cm] DBH) are protected with manual thinning treatments (NPS 2009a [Appendix K-6]).

<u>Extent/Proportion of Conifer Mortality</u>

The Parker et al. (2003a,b) study provides data on tree mortality in the ponderosa pine forests of Walnut Canyon NM. Their study site on the north side of Walnut Canyon (referred to as the Cabin stand), experienced a prescribed fire in 1998 (see Figure 4.7.4-2). Of the two sites on the south side of the canyon (referred to as the Pictograph stand and the Control stand), the first was burned in 1999 (see Figure 4.7.4-2). Although the original intent of the Parker et al. (2003a,b) work was to examine the relationship between prescribed fire, drought, and tree mortality (for which statistical analyses were inconclusive; Parker et al. 2003a,b), the project resulted in a useful dataset on these forest stands within the park.

Although the focus of this measure is on conifer mortality, we also include some data on Gambel oak. In the three stands studied by Parker et al. (2003a, b), ponderosa pine accounted for the greatest proportion of the trees in each stand (i.e., 70-80%; Table 4.7.4-5). Either Gambel oak or junipers (juniper species were combined) made up the next greatest proportion in all three stands. In each of the three stands, the proportion of the ponderosa pine trees present that were dead ranged from 21-41%. In one stand, 40% of the junipers were dead, and on two stands 25% of the Gambel oaks were dead. The Pictograph stand (south rim) had the greatest overall mortality of all species combined (i.e., 39%, compared to 20 and 25%).

Ponderosa pine mortality was also examined according to size class, with five size classes used (Table 4.7.4-6). The percentage of trees dead was as high as 67% for trees in the 24-38 in (61.0-96.5 cm) DBH class in one of the stands, and 45% of trees in the 16-24 in (40.6-61.0 cm) DBH class in another stand. We calculated an average percent mortality by size class for the three stands (last column) and found that mortality was greatest in the 24-38 in (61.0-96.5 cm) DBH class; mortality decreased with DBH of the size class.

Table 4.7.4-5. Species composition and tree mortality in 2003 in ponderosa pine plots at Walnut Canyon NM.

Common Name	Pictograph Stand (on south rim)		Cabin Stand (on north rim)		Control Stand (on south rim)	
	% of all trees	% of these trees that were dead	% of all trees	% of these trees that were dead	% of all trees	% of these trees that were dead
Ponderosa pine	80	41	74	21	70	27
Colorado pinyon pine	0	0	5	14	12	18
Juniper species *	5	40	18	18	10	15
Gambel oak	16	25	3	25	8	18
All species mortality	39		20		25	

Source: Parker et al. 2003b Table 2.

* Parker et al. (2003a,b) combined juniper species into one group.

Table 4.7.4-6. Ponderosa pine size class and mortality in 2003 in Walnut Canyon NM.

Diameter breast height (DBH) in inches (and cm) [1]	Pictograph Stand (on south rim)		Cabin Stand (on north rim)		Control Stand (on south rim)		Average mortality by size class [2]
	% of all trees	% of these trees that were dead	% of all trees	% of these trees that were dead	% of all trees	% of these trees that were dead	
> 38 (>96.5)	0	0	1	0	0	0	0
24-38 (61.0-96.5)	24	67 [3]	25	30	28	30	42.3
16-24 (40.6-61.0)	15	33 [3]	26	33	31	45	37
8-16 (20.3-40.6)	29	35 [3]	24	0	26	20	18.3
<8 (<20.3)	32	31	21	17	14	0	16

Source: Parker et al. 2003b Table 4.

[1] Numbers in this document are typically presented in metric units first, followed by English units. However, we present data and discussion for this measure in English units first to follow Parker et al. (2003a,b) and NPS (2009).

[2] Data not provided by Parker et al. (2003b).

[3] The numbers shown here are from Parker et al. (2003b); the same table appears in Parker et al. (2003a), but the values for these categories are different.

It was not clear to Parker et al. (2003a,b) how the trees died and why so many more trees died in the Pictograph stand (Figure 4.7.4-3). However, they noted that bark beetles were invading stands of ponderosa pine in this part of Arizona, and that they had noticed "a large number of beetle holes on the bark of large dead trees at the Pictograph site..." It was difficult to make conclusions at the time because of the lack of post-fire monitoring and information on the intensity of the prescribed fire (Parker et al. 2003a).

Some additional information is available for the national monument from around the same time period from the USFS Forest Health Monitoring Program. Data from the USFS program indicates that a substantial area of the park was affected by bark beetles in 2002-2003 (Table 4.7.4-7). A total of 560 ha (1,383 ac) was affected in 2002, and a total of 749 ha (1,850 ac) was affected in 2003. The numbers were low in 2004, but in that year 128 ha (317 ac) were reported as affected by drought.

In comparing the early period shown in the table to the more recent period, a much larger area of the park was affected by bark beetles in 2001-2004 than in 2013-2015. In 2001-2004, hundreds of hectares were affected by the ponderosa pine *Ips* (and 18 ha [45 ac] were affected by the pinyon pine *Ips*); this is in comparison to a total of 6 ha (14 ac) in 2013-2015 (and none in the last two years). It should be noted that the table shows all of the data on the park for these years from the FHM Program (and some of the categories shown do not directly apply to this assessment [e.g., the area for Douglas-fir beetle]).

Figure 4.7.4-3. Large, dead ponderosa pine trees in the stand south of the canyon where the Pictograph burn was conducted. Photo Credit: NPS.

Based on the information presented here from the FHM Program for the last three years, we would consider the current extent of conifer mortality within the national monument to be low (equating to a good condition). However, because of the mortality that occurred in the early 2000s, we consider condition to be of moderate concern in the recognition that the loss of so many larger trees in the park will be noticeable for many years to come. National monument personnel have been attempting to protect the larger, older trees (NPS 2009a). We consider the overall trend unknown, although it appears to be unchanging at least over the last few years (with no or very low levels of new, dead trees). We have moderate confidence in the assessment. The continuing threat of drought and climate change is addressed in the Threats section.

Functional Group Cover

As described in the Data and Methods section, under this indicator and its three measures, we present data from the SCPN integrated upland monitoring program. To date, data are available for one sampling period at Walnut Canyon NM, representing the first year of baseline conditions for monitoring vegetation and soils in the Ponderosa Pine ecological site.

Table 4.7.4-8 shows the results of the 2014 baseline monitoring for functional group cover. Perennial grasses and forbs dominated the understory of the Ponderosa Pine ecological site. The mean total live foliar cover was 6.0%. Mean covers of standing dead herbaceous plants and standing dead shrubs were 3.1% and 0.01%, respectively. These plots were sampled for the second time in 2016 (data not yet available). Long-term monitoring of the plots will allow for the assessment of trends in functional group cover in the future.

Species Cover & Frequency

Results of the SCPN upland monitoring at the park in 2014 indicated that the most dominant herbaceous/shrub species recorded was *Bouteloua gracilis* (blue grama; 2.63%), followed by *Penstemon linarioides* (toadflax beardtongue; 0.51%), *Muhlenbergia montana* (mountain muhly; 0.38%), *Elymus elymoides* (squirreltail; 0.25%), *Heterotheca villosa* (hairy false goldenaster; 0.19%), and *Eriogonum racemosum* (redroot buckwheat; 0.17%) (Table 4.7.4-9). Many of the dominant species had high quadrat and plot frequencies, indicating that they were abundant at multiple scales and that they were relatively evenly dispersed (e.g., DeCoster and Swan 2016). A large standard deviation (compared to the associated mean)

Table 4.7.4-7. Area of forest affected by bark beetles and drought in 2001-2004 and 2013-2015 at Walnut Canyon NM.

Year	Ponderosa pine *Ips* ha (ac)	Pinyon pine *Ips* ha (ac)	Western pine beetle ha (ac)	Douglas-fir beetle ha (ac)	Drought ha (ac)	Total ha (ac)
2001	0	0	2 (5 ac)	0	0	2 (5)
2002	560 (1,383)	0	0	0	0	560 (1,383)
2003	731 (1,805)	18 (45)	0	0	0	749 (1,850)
2004	5 (13)	0	0	6.5 (16)	128 (317)	140 (346)
2013	6 (14)	0	0	0	0	6 (14)
2014	0	0	0	0	0	<0.4 (<1) *
2015	0	0	0	0	0	0

Sources: Data taken from USFS 2004, 2013, 2014, and 2015.

* No specific bark beetle was named in USFS (2014).

Table 4.7.4-8. Functional group cover for 12 plots at Walnut Canyon NM.

Functional Groups	Mean (%)	Standard deviation
Total live foliar cover	5.96	3.66
Perennial grasses	4.27	2.65
Forbs	1.48	0.94
Shrubs	0.11	0.18
Cacti/Succulents	0.00	0.01
Standing dead herbaceous	3.06	1.90
Standing dead shrubs	0.01	0.02

Source: SCPN, December 2016.

Table 4.7.4-9. Foliar cover and frequency of the 17 most abundant shrub and herbaceous species in 12 plots at Walnut Canyon NM.

Dominant species	Foliar cover		Frequency (%)	
	Mean (%)	SD	Quadrat	Plot
Bouteloua gracilis	2.63	2.14	100.0	69.2
Penstemon linarioides	0.51	0.47	100.0	70.0
Muhlenbergia montana	0.38	0.52	75.0	25.0
Poa fendleriana	0.35	0.32	100.0	70.8
Elymus elymoides	0.25	0.13	100.0	85.0
Heterotheca villosa	0.19	0.43	50.0	17.5
Eriogonum racemosum	0.17	0.14	75.0	61.7
Erigeron flagellaris	0.12	0.15	91.7	45.8
Carex geophila	0.11	0.32	25.0	15.0
Koeleria macrantha	0.10	0.14	66.7	20.8
Lotus wrightii	0.09	0.06	100.0	58.3
Aristida purpurea	0.08	0.23	50.0	9.2
Hymenopappus filifolius	0.07	0.06	83.3	39.2
Erigeron divergens	0.04	0.04	91.7	46.7
Gutierrezia sarothrae	0.04	0.07	58.3	20.8
Cirsium wheeleri	0.04	0.06	58.3	22.5
Robinia neomexicana	0.04	0.11	16.7	7.5

Source: SCPN, December 2016.

indicates large variability among plots. These plots were sampled for the second time in 2016 (data not yet available). Again, long-term monitoring of the plots will allow for the assessment of trends in the future.

Soil Surface Features Cover

The final measure/information from SCPN's upland monitoring program included in our assessment is cover of soil surface features. Duff/litter was the dominant soil surface feature in the plots, with a mean cover of 74.79% (Table 4.7.4-10). Undifferentiated crust had the next highest cover (8.68%), followed by woody debris (3.14%) and bare ground (2.81%). Coverages of the remaining soil surface features are shown in the table. A large standard deviation (compared to the associated mean) indicates large variability among plots. Note that the soil surface features do not add up to 100%, because the calculations were made from cover class midpoints (DeCoster and Swan 2016). These plots were sampled again in 2016 (data not yet available). Again, the long-term monitoring of the plots will allow for the assessment of trends in soil surface features in the future.

Table 4.7.4-10. Cover of soil surface features for 12 plots at Walnut Canyon NM.

Functional Groups	Mean (%)	Standard deviation
Bare ground	2.81	4.18
Coarse gravel	0.42	0.39
Cobble	1.10	1.12
Cyanobacteria	0.37	0.68
Dead herbaceous base	1.44	1.12
Dead woody base	0.03	0.06
Duff / litter	74.79	7.60
Fine gravel	0.38	0.43
Lichen	0.15	0.42
Live plant base	0.95	0.62
Moss	0.03	0.05
Stone / Bedrock	0.89	1.60
Undifferentiated crust	8.68	7.11
Woody debris	3.14	2.58

Source: SCPN, December 2016.

Overall Condition, Trend, Confidence Level, and Key Uncertainties

Overall, we consider the condition of ponderosa pine forests to warrant moderate concern in Walnut Canyon NM. This condition rating was based on three indicators with a total of four measures, which are summarized in Table 4.7.4-11. Two measures (ponderosa pine stem densities by size class, and extent of conifer mortality) were judged to be of moderate concern, one measure (departure from natural historical fire regime) was judged to be in good to moderate concern condition, and one measure (presence and persistence of large trees) was judged to be of significant concern. We considered the overall trend as unknown. Regarding the less than desired number of large ponderosa pine trees within the

Table 4.7.4-11. Summary of indicators, measures, and condition rationale used to assess ponderosa pine forests in Walnut Canyon NM.

Indicators of Condition	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Fire Regime	Departure from Natural Historical Fire Regime: Fire Regime Condition Class		According to the 2003 FRCC assessment, the majority of the ponderosa pine vegetation in the park falls into condition class 2, which corresponds to an NRCA condition of moderate concern. A substantial area, however, (treated with prescribed burns from 1986-1999), was placed into condition class 1 (which corresponds to an NRCA condition of good). Therefore, we consider condition under this measure to be of good to moderate concern. Although it is possible the trend in condition is improving (with prescribed fires and efforts to allow a more natural fire regime), we have no data in the assessment to support this, and so we conclude a trend of unknown at this time. Because the assessment was conducted in 2003, and NPS (2009) notes the potential for some needed updates to the conclusions, we have medium confidence in the measure.
Stand Structure (i.e., size/age structure)	Ponderosa Pine Stem Densities by Size Class		Based on the data sources used in the assessment, ponderosa pine stem densities in 2003 departed from the target range by an average of 30%, leading to a condition of moderate concern. The number of trees was greater than the desired range for one size class, within the range for one size class, and less than the range for six size classes. The greatest departure from the desired range was for the 36-39.9 in (91.4-101.3 cm) DBH size class. Trend is unknown. Confidence in the measure is low to medium because the data are 13 years old and there are potential differences in the reference stands and the 2003 stands.
	Presence and Persistence of Large Trees		Based on 2003 data and the desired range of trees based on the 1876 stand data, it appears that trees in the larger size classes (16.0-18.9 inch [40.6-48.0 cm] DBH and greater) occur in fewer numbers than desired at the park (average departure from the target range was 38.5%). Condition is of significant concern. Because of the history of logging in the area and uncertainties with the data (e.g., potential differences between 1876 and 2003 stands, a lack of current data), the confidence level is low to medium. The trend is unknown.
Status / Health of Trees	Extent/Proportion of Conifer Mortality		In the Parker et al. (2003a,b) stands, the proportion of ponderosa pine trees present that were dead ranged from 21-41%. In one stand, 40% of the junipers were dead. Among the ponderosa pine size classes studied, mortality was greatest in the 24-38 inch (61.0-96.5 cm) size classes; the average percent mortality of the three stands for this size class was 42%. Data from the USFS FHM Program indicated a substantial area of the park was affected by bark beetles in 2002-2003 (a total of 1,309 ha (3,233 ac). For the 2013-2015 period, only about 6 ha (14-15 ac) were affected. Although mortality in the park appears to have been low for the last few years, we consider condition to be of moderate concern to recognize the mortality that occurred in the early 2000s. The loss of so many larger trees in the park will be noticeable for many years to come. We consider the overall trend unknown, and we have medium confidence in the assessment.
Presence & Composition of Understory Vegetation & Soil Surface Features	Functional Group Cover		Data on ponderosa pine and soils were collected in the park as part of the SCPN upland monitoring program for the first time in 2014. Because no reference conditions have been developed the condition is unknown.
	Species Cover & Frequency		Data on ponderosa pine and soils were collected in the park as part of the SCPN upland monitoring program for the first time in 2014. Because no reference conditions have been developed the condition is unknown.
	Soil Surface Features Cover		Data on ponderosa pine and soils were collected in the park as part of the SCPN upland monitoring program for the first time in 2014. Because no reference conditions have been developed the condition is unknown.

Table 4.7.4-11 continued. Summary of indicators, measures, and condition rationale used to assess ponderosa pine forests in Walnut Canyon NM.

Indicators of Condition	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Overall Condition		(yellow circle)	Overall, we consider the condition of ponderosa pine forests in Walnut Canyon NM to warrant moderate concern. The assessment was based on three indicators with four measures, two of which were of moderate concern, one of which was good to moderate concern, and one of which was of significant concern. We also included an additional indicator with three measures, but because the information was collected for the first time by SCPN in 2014 and no reference conditions have been developed, we did not use it to judge condition at this time. We did not assign an overall trend for this assessment, but it should be recognized that under the FMP the park is restoring the fire-adapted ponderosa pine stands to the extent possible and protecting ponderosa pines in the larger size classes. Confidence in the overall condition rating is medium.

park, it is estimated that it will take 50 to 100 years for adequate numbers of trees in the vicinity of Walnut Canyon to grow into the 24-30 in (61-76.2 cm) and larger diameter size class (USFS 2006 as cited by NPS 2009a).

Although ponderosa pine densities have been described as much higher than they were historically in forests across the region, Menzel (1996) reported that they were not as great in the Walnut Canyon area in 1994 as has been reported for forests elsewhere. However, the densities he reported for 1994 stands in the park were greater than for the same stands in 1876. Data from 2003 in other ponderosa pine stands (near Menzel's and across the canyon), indicated densities were lower for those stands than in 1994. A substantial but unknown number of trees died within the park in the early 2000s due to drought conditions (Parker et al. 2003a,b, NPS 2009a). In the last few years, a relatively low number of trees have died from insects and disease in the park (USFS 2014a, 2014b, 2016b).

There are several factors that influence confidence in the condition rating. The first is the age of the data; the most recent ponderosa pine stand data used to assess condition are from 2003 (i.e., Parker et al. 2003a,b), except for the recent aerial survey data from USFS. A second factor is that we compared stand data from Menzel (1996) for 1876 to that of Parker et al. (2003a,b) that was not in the same location within the park. The Parker et al. data were also described as being located in the ecotone between ponderosa pine forest and pinyon-juniper woodland (although Parker et al. 2003b described them as being representative of the ponderosa stands in the park). Also, the Parker et al. (2003a,b) data were collected during the period of drought-induced conifer mortality. It would have been very interesting to have 2003 (or more recent) stand data for the Menzel (1996) plots. Finally, the conifer mortality in the early 2000s may also influence the FRCCs we used from NPS (2009) for the first indicator. Drought, climate change, and conifer mortality are discussed in more detail below in the Threats and Issues section.

It should also be noted that while we did not use the SCPN integrated upland plot data to judge condition at this point in time, these data will be useful for this purpose in the future. SCPN is planning to sample the plots every two years and will use the data to monitor for changes in vegetation over time. However, there are two caveats to consider with this monitoring data (Jim DeCoster, Plant Ecologist, SCPN, pers. comm). First, the monitoring is designed to examine changes over long periods of time. Over the first several sampling events, the data may show temporary changes representing episodic events. It may take 20 or more years to begin to detect long-term trends and directional change. The second caveat is that to date there are not enough data to conduct power analysis for determining levels of change detection. The relatively small sample size of 12 plots at the national monument will likely not have the same statistical power as many of the other upland ecosystems that SCPN monitors (e.g., 10% change in species frequency for the 4 most common species, and 20% change in frequency for another 8-10 species). Relatively small changes in the data over time may be evident, but they may not always be statistically significant; the changes may only be described in more general and qualitative terms.

SCPN's workload is such that establishing additional monitoring plots does not appear feasible at this time (Jim DeCoster, Plant Ecologist, SCPN, pers. comm).

Threats and Issues

Some of the main threats to ponderosa pine forests within Walnut Canyon NM and the region include drought, bark beetle infestations, and uncontrolled or severe wildfire. An overarching threat is from climate change. These are threats to all trees and ecosystem components within the forest, but they may be of particular concern for older, larger ponderosa pine trees, which are rarer/fewer on the landscape but suffered higher mortality rates during drought conditions in the early 2000s (Parker et al. 2003b, USFS 2004).

Predictions have been made that temperature in the Southwest will rise by more than 3 degrees Fahrenheit (up to 9 degrees Fahrenheit) by 2100 (Kent 2015). It is harder to predict precipitation in the Southwest, and predictions to date vary (Kent 2015). However, droughts are projected to be more intense and last longer in the coming century (Kent 2015). Within Walnut Canyon NM, "recent climatic conditions are already shifting beyond the historical range of variability" (Monahan and Fisichelli 2014). In their analysis for the park and vicinity, three temperature variables were found to be "extreme warm" (annual mean temperature, maximum temperature of the warmest quarter, and mean temperature of the coldest quarter), and three precipitation variables were found to be "extreme dry" (annual precipitation, precipitation of the driest month, and precipitation of the driest quarter) for the most recent time period (2003-2012). This was in comparison to data for the entire period of analysis, 1901-2012. None of the temperature variables were considered "extreme cold," and none of the precipitation variables were considered "extreme wet."

The Walnut Canyon NM Foundation Document (NPS 2015a) stated that fire vulnerability is high due to the dead and downed trees in the park and warming temperatures associated with climate change. The fire vulnerability is also largely due to conditions at the landscape scale. The Coconino NF environmental assessments for the Eastside and Marshall Forest Health and Fuels Reduction Treatments immediately adjacent to Walnut Canyon estimate there is a risk of severe, stand-replacing fire on about 1/3 of the planning area. The most intense fires observed in northern Arizona since 2002, such as the 2010 Schultz Fire, would completely burn an area four or five times the size of Walnut Canyon in a single 24 hour period.

Under some modeled climate change scenarios, fire frequencies could increase up to 25% by 2100 (NPS 2015a). Climate change might influence fire activity in three different ways: changes in fuel loading; changes in fuel condition (fuel moisture); and changes in fuel ignition (Hessl 2011 as cited by Kent 2015). Changes in fuel loading, for example, could occur due to mortality of trees and loss of vegetation cover, changes in regeneration patterns, range shifts, and disturbances such as severe fire and insect outbreaks (Kent 2015). Kent (2015), however, reports that a sound strategy for combatting these potential changes includes the actions that managers can and do already take for ecological restoration and fuel hazard reduction--using thinning and prescribed burning practices.

4.7.5. Sources of Expertise

No outside experts were consulted for this assessment, but the assessment is largely dependent upon information contained in the Flagstaff Area NMs' Fire Management Plan. Jim DeCoster, Plant Ecologist with SCPN, provided the integrated upland monitoring data on vegetation and soils from their 2014 monitoring within Walnut Canyon NM (in advance of their report). The assessment author is Patty Valentine-Darby, science writer, Utah State University. Lisa Baril, science writer, Utah State University, contributed text on bark beetles and the FHM program.

4.8. Non-native Invasive Plants

4.8.1. Background and Importance

Vegetation in Walnut Canyon is composed of a diverse mix of open woodlands, dense forests, small meadows, and sparse shrublands (Hansen et al. 2004). This diversity is partly attributed to the steep gradient in elevation from the canyon bottom to the uplands (NPS 2015a). This steep gradient has resulted in a plant community that is ecotonal in nature, which has allowed for intermixing of species that do not usually occur together (Hansen et al. 2004).

Walnut Creek flows intermittently through Walnut Canyon, the monument's prominent geologic feature (Soles and Monroe 2015). Historically, periodic floods scoured the canyon bottom and limited the density of vegetation there (Brian 1992, Rowlands et al. 1995). However, the upper Walnut Creek watershed has been damned to provide water to the City of Flagstaff, Arizona (Soles and Monroe 2015). Reduced flows have led to a riparian plant community that is denser than historic conditions would have allowed (Brian 1992). Today, the canyon floor is a complex mix of shrublands and woodlands composed of box elder (*Acer negundo*), dogwood (*Cornus stolonifera*), New Mexican olive (*Forestiera pubescens*), Arizona walnut (*Rosa arizonica*), narrowleaf cottonwood (*Populus angustifolia*), New Mexican locust (*Robinia neomexicana*), Arizona rose (*Rosa arizonica*), and snowberry (*Symphoricarpos rotundifolius*) among other species (Hansen et al. 2004).

While dense vegetation occurs in the canyon bottom, the canyon walls are sparsely vegetated (Hansen et al. 2004). On the plateau above the canyon, ponderosa pine (*Pinus ponderosa*) woodlands represent the most common vegetation type in the monument (Hansen et al. 2004) (Figure 4.8.1-1). Pinyon pine (*Pinus edulis*) and Utah juniper (*Juniperus osteosperma*) are also common woodland tree species and usually occur lower in elevation than ponderosa pine woodlands. In more mesic areas Douglas-fir (*Pseudotsuga menziesii*) and Rocky Mountain juniper (*Juniperus scopulorum*) form dense forests (Hansen et al. 2004). Small patches of grasslands occur adjacent to woodlands and forests and depending on elevation, soil moisture, and disturbance regime are a mix of blue grama (*Bouteloua eriopoda*), mountain muhly (*Muhlenbergia montana),* muttongrass (*Poa fendleriana*), little bluestem (*Schizachyrium scoparium*), squirreltail (*Elymus elymoides*), Walnut Canyon fringed brome (*Bromus ciliatus*), and Fendler's threeawn (*Aristida purpurea*) (Hansen et al. 2004).

The introduction of non-native species, however, may alter ecosystem structure and function in Walnut Canyon NM. At least 36 non-native species are known to occur within the monument, many of which are of

Figure 4.8.1-1. Native ponderosa pine forest in Walnut Canyon NM. Photo Credit: NPS.

management concern including cheatgrass (*Bromus tectorum*), dalmation toadflax (*Linaria dalmatica*), and prickly Russian thistle (*Salsola tragus*) (NPS 2009bb). In areas outside the monument, non-native species have been directly linked to the replacement of dominant native species (Tilman 1999), the loss of rare species (King 1985), changes in ecosystem structure, alteration of nutrient cycles and soil chemistry (Ehrenfeld 2003), shifts in community productivity (Vitousek 1990), reduced agricultural productivity, and changes in water availability (D'Antonio and Mahall 1991).

The damage caused by these species to natural resources is often irreparable, and our understanding of the consequences incomplete. Non-native species are second only to habitat destruction as a threat to wildland biodiversity (Wilcove et al. 1998). Consequently, the dynamic relationships among plants, animals, soil, and water established over many thousands of years are at risk of being destroyed in a relatively brief period. For the National Park Service (NPS), the consequences of these invasions present a significant challenge to the management of the agency's natural resources "unimpaired for the enjoyment of future generations" (NPS 2006). National parks, like land managed by other organizations, are deluged by new non-native species arriving through predictable (e.g., road, trail, and riparian corridors), sudden (e.g., long-distance dispersal through cargo containers and air freight), and unexpected anthropogenic pathways (e.g., weed seeds in restoration planting mixes). Non-native plants claim an estimated 1,862 ha (4,600 ac) of public land each year in the United States (Asher and Harmon 1995), significantly altering local flora. For example, non-native plants comprise an estimated 43% and 36% of the flora of the states of Hawaii and New York, respectively (Rejmanek and Randall 1994). Non-native plants infest an estimated 1 million ha (2.6 million ac) of the 33.5 million ha (83 million ac) managed by the NPS (Welch et al. 2014). Prevention and early detection are the principal strategies for successful invasive non-native plant management. While there is a need for long-term suppression programs to address high-impact species, eradication efforts are most successful for infestations of less than one hectare (2.5 ac) in size (Rejmanek and Pitcairn 2002).

4.8.2. Data and Methods

Several studies have reported on vegetation in Walnut Canyon NM (Brian 1992, Hansen et al. 2004, Hiebert and Hudson 2010, Menzel 1996, NPS 2009bb, Schelz et al. 2008, and others), but only three of them specifically documented non-native plant presence in the park (Hiebert and Hudson 2010, Schelz et al. 2008, NPS 2009bb). Using these three reports, we developed a comprehensive list of all non-native plant species known to occur in the monument. We drafted an initial list using the Invasive Plant Management Plan and Environmental Assessment (IPMPEA) developed for the three Flagstaff, Arizona national monuments (Walnut Canyon NM, Sunset Crater Volcano NM, and Wupatki NM) (NPS 2009bb) and then supplemented this list with additional non-native species described in Schelz et al. (2008) and Hiebert and Hudson (2010). The list generated from this effort represents the most current list of non-native plants found within the monument and was used to evaluate non-native plants that occur there. We used three indicators, with a total of seven measures, to determine the current condition of non-native plants at Walnut Canyon NM.

<u>NatureServe Invasive Species Impact Rank</u>

The NatureServe database (NatureServe Explorer 2016), which is based on the Invasive Species Assessment Protocol developed by Morse et al. (2004), is a ranking system that categorizes and lists non-native plants for large areas, such as regions (e.g., Great Plains) or states (e.g., Arizona) according to their overall impact on native biodiversity. The invasiveness ranking protocol assesses four major categories for each plant (ecological impact, current distribution and abundance, trend in distribution and abundance, and management difficulty) for a total of 20 questions (Morse et al. 2004). A subrank score is developed for each category then an overall Invasive Species Impact Rank or I-Rank score is developed for each species. Based upon the I-Rank value, each species is then placed into one of four categories: species that cause high, medium, low, or insignificant negative impacts to native biodiversity within the area of interest (Morse et al. 2004).

<u>AZ-WIPWG Ecological Impact Rank</u>

The Arizona Wildlands Invasive Plant Working Group (AZ-WIPWG) developed a ranking system that was adapted from the NatureServe I-rank system (Warner et al. 2003). AZ-WIPWG categorized and listed non-native plants occurring in Arizona that are most threatening to wildlands. The final list of species evaluated included invasive, non-native species that threaten wildlands, which are defined as plants that are "(1) not native to, yet can spread into, the wildland ecosystems under consideration, and that also (2) do any of the following within wildland ecosystems - "displace native species, hybridize with native species, alter biological communities, or alter ecosystem processes," (Warner et al. 2003). The criteria for evaluating a species were ecological impact, invasiveness potential, ecological amplitude and distribution, and rating level of documentation for a total of thirteen questions. As with NatureServe's system, a subrank score was developed for each category and an overall Ecological Impact Rank was developed for each species. Each species was then placed into one of three categories: species that cause high, medium, and low ecological impacts on ecosystems and biotic communities. A fourth category termed "evaluated but not listed," includes those species for which the sum effects fall below the thresholds for ranking or for which current information was inadequate to assign a ranking. A total of 75 species were evaluated and 71 species were ranked (AZ-WIPWG 2005).

To assess the prevalence of non-native plants we relied on data provided in Schelz et al. (2008) and Hiebert and Hudson (2010). These two reports describe non-native plants in two regions within the monument: high use areas (Schelz et al. 2008) and low use areas (Hiebert and Hudson 2010) (Figure 4.8.2-1). High use areas included the main road corridor leading into the monument; administrative areas including the visitor center, residences, and the area between the residences and the old ranger cabin; and the Island Trail and Rim Trail (Schelz et al. 2008). Low use areas included most of the Resource Preservation Zone (Hiebert and Hudson 2010). The Resource Preservation Zone is a 1,248 ha (3,085 ac) area that is closed to general public access in order to protect sensitive habitat and cultural resources (NPS 2007aa). This zone comprises 93% of the monument. Between these two studies, nearly all areas of the monument were surveyed for non-native plants. The methods used to describe non-native plants differed by study and are described below.

<u>Schelz et al. (2008)</u>
Non-native plants were mapped during August and September 2008 in each of 55 plots, which covered approximately 291 ha (718 ac). The plots covered the entire high use area shown in Figure 4.8.2-1. Although some plots extended outside of the monument's boundary, especially near the road corridor, only those plot areas located inside the boundary were surveyed with the exception of two plots that contained scotch thistle (*Onopordum acanthium*). Because of this plant's ability to rapidly invade, it was mapped wherever it was found. Each plot was surveyed by walking transects of variable distance depending on terrain and density of vegetation cover. Transects were as narrow as 20 m (66 ft) in densely vegetated areas and as wide as 50 m (164 ft) in sparsely vegetated areas. Plot searches were conducted so that surveyors were at least 90% confident that all non-native plants measuring at least 0.004 ha (0.01 ac) were detected. Non-native plants with a high probability of occurring in the monument were targeted; however, all non-native plants encountered were mapped. Non-native plants covering ≤ 0.2 ha (≤ 0.05 ac) were mapped at single point features and infestations > 0.2 ha (> 0.05 ac) were mapped as line or polygon features depending on plant configuration. Infestations that were separated by more than 25 m (82 ft) were mapped as separate features. Field data were collected using a handheld Triple GeoXT 2005 global positioning system.

<u>Hiebert and Hudson (2010)</u>
Non-native plants were sampled during September and October 2008 in each of 106, 150 m x 150 m (492 ft x 492 ft) grid cells located within the Resource Preservation Zone. Grid cells were randomly selected from a gridded map of the entire study area. Grid cells located on the private inholding or on slopes > 25% were eliminated. Observers made four passes through each grid cell in order to capture all non-native plants present. Quantitative data were collected in belt transects located at the center of each grid cell. Belt transects measured 50 m x 6 m (20 ft x 164 ft).

<u>Overall Frequency (%)</u>
In the Resource Preservation Zone frequency data were collected in both the grid cells and the belt transects within grid cells; however, we only report frequency data for the larger grid cells because this captures non-native plants found within belt transects since the entire grid cell was searched for non-native plants (Hiebert and Hudson 2010). Frequency was calculated as the proportion of total grid cells in which a particular species occurred. Frequency data were not presented in Schelz et al. (2008).

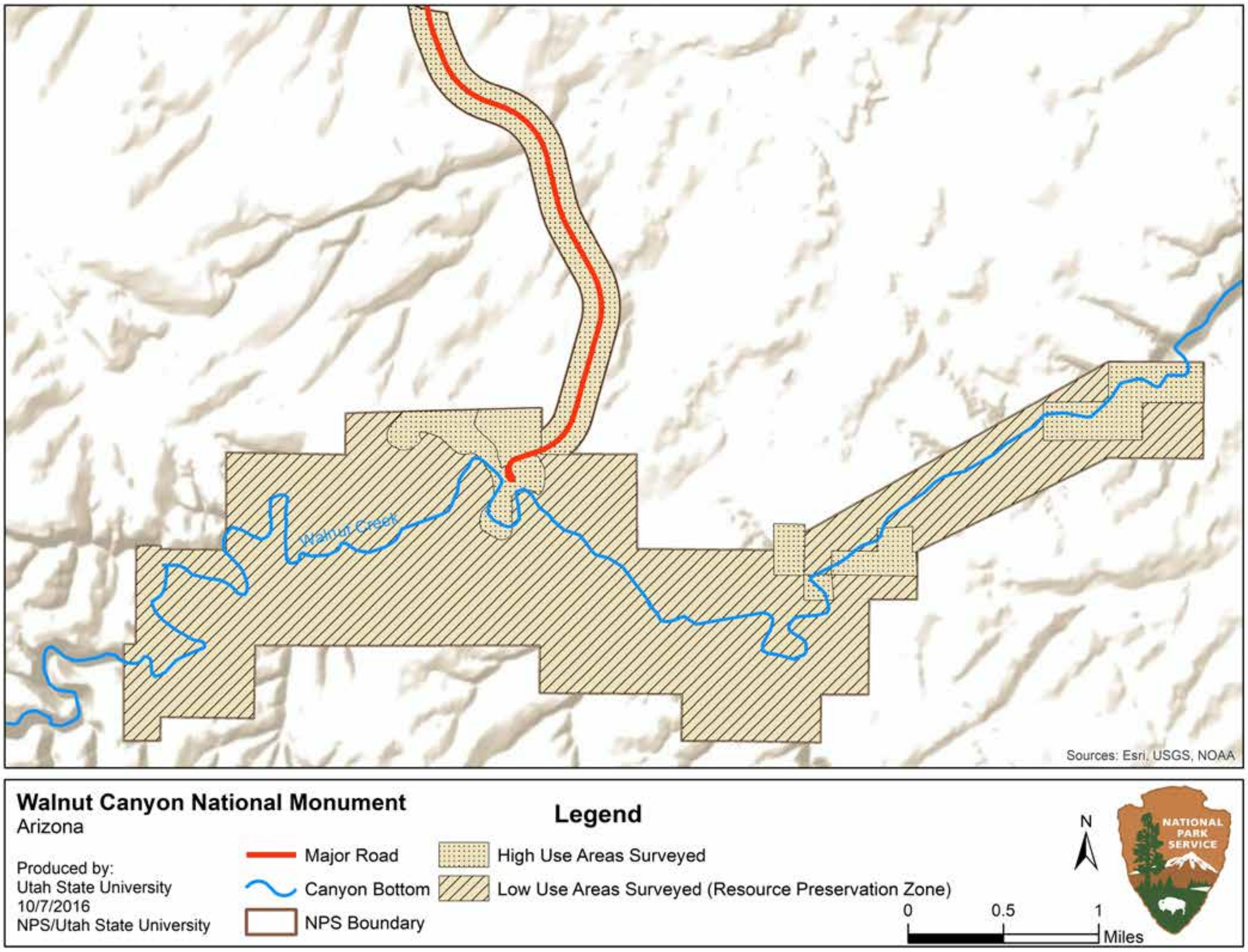


Figure 4.8.2-1. Locations of non-native and invasive plants monitoring locations in Walnut Canyon NM. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction.

Overall Cover (%)

In the Resource Preservation Zone, average percent cover and percent cover by species was estimated in each belt transect and then averaged across all belt transects. Foliar cover was estimated by taking the mid-point in each of seven classes as follows: <0.1%, 0.1-1%, 1-5%, 5-10%, 10-25%, 25-50%, and >50% (Hiebert and Hudson 2010).

In high use areas, percent cover was calculated by dividing the total area mapped for each species by the total area surveyed and then multiplying by 100. Total cover was calculated by summing the total area mapped for all species then dividing by the total area surveyed and then multiplying by 100. The number of acres mapped is presented in Table 2 in Schelz et al. (2008).

Frequency by Habitat Type and Area (%)

In the Resource Preservation Zone the 106 grid cells were stratified by habitat type and area (Hiebert and Hudson 2010). Some species may be more likely to invade certain habitat types or the different habitat types may vary in their susceptibility to invasion by non-native species. The habitat types were riparian (n = 7), pinyon-juniper woodland (n = 20), ponderosa pine forest (n = 54), and sparse vegetation (n = 25). Grid cells were also stratified by canyon side (north versus south). The south side of the canyon has a northern aspect and is generally more mesic than the north side, which has a southern aspect. In Walnut Canyon the north side of the canyon is also closer to the road corridor, which is a mechanism of dispersal. The authors did not indicate the sample size for north and south sides of the canyon (Hiebert and Hudson 2010). Finally, grid cells were stratified by three areas of the monument that were added at different times.

These areas were the original 1915 boundary (*n* = 40), the 1938 expansion area (*n* = 28), and the 1996 expansion area (*n* = 38). Stratifying by boundary age may reveal patterns of invasion based on length of time of resource protection. Prior to inclusion as part of the monument, the different boundaries were subject to grazing, logging, and off-road vehicle use (Hiebert and Hudson 2010). The 1938 boundary was fenced in 1973, and the 1996 boundary was fenced in 2004 and 2005 (Hiebert and Hudson 2010). Sample sizes varied by strata because the stratification by habitat type and area occurred after the random sample was generated.

Cover by Habitat Type and Area (%)

Cover by habitat type and area were collected as described for the measure of overall cover in the Resource Preservation Zone. The habitats and areas within which cover data were collected were the same as described for the measure of frequency by habitat type and area.

Percent and Area Removed

We report the proportion of individual non-native plants removed by species and the total proportion removed in high use areas after they were mapped (Schelz et al. 2008). We also include geographic information system data provided by Walnut Canyon NM staff. These data include the areas manually treated for select non-native plants during 2014 and 2015. The areas treated were the Island Trail, the canyon rim area, the area around the sewage lagoons, and along abandoned or closed road corridors.

4.8.3. Reference Conditions

Table 4.8.3-1 summarizes the condition thresholds for measures in good condition, those warranting moderate concern, and those warranting significant concern. Reference conditions were developed jointly by Natural Resource Condition Assessment staff, NPS staff, and staff from the Southern Colorado Plateau Network Inventory and Monitoring Program.

Table 4.8.3-1. Reference conditions used to assess non-native plants in Walnut Canyon NM.

Indicator	Measure	Good	Moderate Concern	Significant Concern
Potential to Alter Native Plant Communities	NatureServe Invasive Species Impact Rank	No non-native species with a high innate ability to alter ecosystem structure and function and/or only a few species with a medium or low ability to alter ecosystem structure and function are present.	Many non-native species with medium or one or two species with a high ability to alter ecosystem structure and function are present.	Many non-native species with medium or many species with a high ability to alter ecosystem structure and function are present.
	AZ-WIPWG Ecological Impact Rank	Insignificant - Low	Medium	High
Prevalence of Non-native Plants	Overall Frequency (%)	Non-native plants are found in <25% of all plots surveyed.	Non-native plants are found in 25%-50% of all plots surveyed.	Non-native plants are found in >50% of all plots surveyed.
	Overall Cover (%)	0% over several years.	1% and 4% over several years.	>5% over several years.
	Frequency by Habitat Type and Area (%)	Non-native plants are found in <25% of all plots surveyed.	Non-native plants are found in 25%-50% of all plots surveyed.	Non-native plants are found in >50% of all plots surveyed.
	Cover by Habitat Type and Area (%)	0% over several years.	Between 1% and 4% over several years.	>5% over several years.
Control Effort	Non-native Plants Removed (% and ha)	> 50% (of target area or individual plants with a high invasiveness ranking were treated/controlled/confined).*	20% to 50% (of target area or individual plants with a high invasiveness ranking were treated/controlled/confined).*	< 20% (of target area or individual plants with a high invasiveness ranking were treated/controlled/confined).*

4.8.4. Condition and Trend

Table 4.8.4-1 lists the total non-native plant species known to occur in Walnut Canyon NM. The list includes species identified in the IPMPEA (NPS 2009bb), Schelz et al. (2008), and Hiebert and Hudson (2010). Table 2 of the IPMPEA lists 36 species for Walnut Canyon NM (NPS 2009b). Between the two other studies, we found an additional seven species, although, *Tamarix chinensis* was mistakenly listed in Hiebert and Hudson (2010), resulting in a total of six. All of these species were not listed in the IPMPEA and one species was listed as occurring in Wupatki NM, but not in Walnut Canyon NM. This resulted in a total of 42 non-native species known to occur in Walnut Canyon NM. However, the two species of sweetclover (*Melilotus* spp.), which were listed as distinct species by AZ-WIPWG as well as in the IPMPEA, were listed as synonyms of the same species in the United States Department of Agriculture's PLANTS Database (USDA 2016). Furthermore, desert wheatgrass (*Agropyron desertorum*) was listed as a subspecies of crested wheatgrass (*Agropyron crystatum*) in the USDA PLANTS Database (USDA 2016). Crested wheatgrass was listed in the IPMPEA, but desert wheatgrass was not (NPS 2009b). For all species added to the initial IPMPEA list, we searched the USDA PLANTS database for plant name synonyms to ensure the genus or species name had not changed, which could have accounted for these differences (USDA 2016). While searching for plant name synonyms, we found that Canadian horseweed (*Conyza canadensis*) and redroot pigweed (*Amaranthus retroflexus*) were both listed as native to Arizona (USDA 2016) but were considered non-native by Schelz et al. (2008).

<u>NatureServe Invasive Species Impact Rank</u>

Of the 42 non-native species listed in Table 4.8.4-1, 20 have not been assessed by NatureServe. Many of the remaining 23 species were assigned mixed rankings (e.g., high/medium, medium/low, low/insignificant). Cheatgrass was the only species with a high ranking. An additional five species were ranked as high/medium or medium. These were diffuse knapweed (*Centaurea diffusa*), desert wheatgrass, Kentucky bluegrass (*Poa pratensis*), Siberian elm (*Ulmus pumila*), and common mullein (*Verbascum thapsus*). Each of these species, except for desert wheatgrass and Kentucky bluegrass, were listed as management priorities in the IPMPEA (NPS 2009b). The remaining 16 species were ranked as high/low (1), medium/low (9), medium/insignificant (2), low (2), or low/insignificant (2). Since the majority of species were assigned at least a medium ranking and one species was ranked as high, we consider this measure to warrant moderate concern. Confidence in this rating is high. We could not determine trend since species are assessed only once.

<u>AZ-WIPWG Ecological Impact Rank</u>

Fifteen species listed in Table 4.8.4-1 were evaluated by AZ-WIPWG, including common mullein, which was evaluated but not listed and indicates low potential for invasion by this species. However, this species was listed as a management priority in the IPMPEA. Of the remaining 14 species that were ranked, two were ranked high, 10 were ranked medium, and two were ranked low. As expected, species with a high AZ-WIPWG ranking were also considered management priorities in the monument. These were red brome (*Bromus rubens*) and cheatgrass. Many of the medium ranked species were also listed as a management priority in the IPMPEA. Six species were considered a management priority in the park but were not ranked by AZ-WIPWG. It's important to note that not all species known to occur in Walnut Canyon NM were included in the IPMPEA and several were therefore, not assigned a management priority. In general, the NatureServe and AZ-WIPWG ranking systems were consistent. Species ranked medium to low or insignificant by NatureServe were generally not evaluated by AZ-WIPWG, and species ranked medium or high by NatureServe were assigned a similar rank by AZ-WIPWG. Since 35.7% of plants listed in Table 4.8.4-1 were evaluated by AZ-WIPWG and 12 species were given a high or medium ecological impact rank, we consider this measure to warrant moderate concern. Confidence in this rating is high. We could not determine trend since species are assessed only once.

<u>Overall Frequency (%)</u>

A total of 20 non-native species were detected in the Resource Preservation Zone (Table 4.8.4-2). Slender Russian thistle (*Salsola collina*) was also identified as occurring in this zone, but the authors note that this species may have been incorrectly identified as *S. tragus* (prickly Russian thistle) in some areas, particularly in the northeastern section where all *Salsola* observations were recorded as *tragus*. This brings the total to 21 non-native species in the Resource Preservation Zone.

Of the 106 grid cells surveyed in the Resource Preservation Zone, 105 contained at least one

Table 4.8.4-1. List of non-native plant species documented in Walnut Canyon NM.

Scientific Name	Common Name	Invasive Plant Management Plan	NatureServe Invasive Species Impact Rank	AZ-WIPWG Ecological Impact Rank
Agropyrun cristatum	Crested wheatgrass	Priority	Medium/Low	NA
Agropyron desertorum	Desert wheatgrass	Not Listed in Plan	Medium	NA
Amaranthus albus	Prostrate Pigweed	–	NA	NA
Amaranthus blitoides	Mat amaranth	Not Listed for Park	NA	NA
Amaranthus retroflexus	Redroot pigweed	Not Listed in Plan	NA	NA
Bromus diandrus	Ripgut brome	Priority	NA	Medium
Bromus rubens	Red Brome	Priority	NA	High
Bromus tectorum	Cheatgrass	Priority	High	High
Centaurea diffusa	Diffuse knapweed	Priority	High/Medium	Medium
Chenopodium album	Lambsquarters	–	NA	NA
Cirsium vulgare	Bull thistle	Priority	Medium/Low	Low
Convolvulus arvensis	Field bindweed	–	Medium/Low	Medium
Conyza canadensis	Canada horseweed	Not Listed in Plan	NA	NA
Descurainia sophia	Tansy mustard	Not Listed in Plan	Medium/Low	NA
Erodium cicutarium	Storksbill	–	Medium/Low	Medium
Erysimum repandum	Spreading wallflower	–	NA	NA
Galium aparine	Bedstraw	–	NA	NA
Kochia scoparia	Mexican burning bush	–	Low	NA
Lactuca serriola	Prickly lettuce	Priority	Low/Insignificant	NA
Leonurus cardiaca	Common motherwort	–	NA	NA
Linaria dalmatica	Dalmatian toadflax	Priority	NA	Medium
Malus pumila	Paradise apple	–	Medium/ Insignificant	NA
Marrubium vulgare	Horehound	Priority	Medium/Low	NA
Medicago lupulina	Alfalfa	Not Listed in Plan	Medium/ Insignificant	NA
Melilotus alba	White sweetclover	Priority	Medium/Low	Medium
Melilotus officinalis	Yellow sweetclover	Priority	Medium/Low	Medium
Onopordum acanthium	Scotch thistle	Priority	NA	Low
Parthenocissus quinquefolia	Virginia creeper	–	NA	NA
Plantago lanceolata	Lanceleaf plantain	–	High/Low	NA
Poa pratensis	Kentucky bluegrass	–	Medium	NA
Polygonum aviculare	Knotweed	Not Listed in Plan	Low	NA
Portulaca oleracea	Purslane	Priority	NA	NA
Potentilla norvegica	Norwegian cinquefoil	–	NA	NA
Rumex crispus	Curly dock	–	Low/Insignificant	NA
Salsola collina	Slender Russian thistle	Priority	NA	Medium
Salsola kali	Russian thistle/tumbleweed	Priority	NA	NA
Salsola tragus	Prickly Russian thistle	Priority	NA	Medium
Sisymbrium altissimum	Tumble mustard	–	NA	NA
Taraxacum officinale	Dandelion	–	NA	NA
Tragopogon dubius	Common salsify	–	Medium/Low	NA
Ulmus pumila	Siberian elm	Priority	Medium	Medium
Verbascum thapsus	Common mullein	Priority	Medium	Evaluated But NA

Note: NA indicates that the plant has not been assessed.

Table 4.8.4-2. Frequency of non-native plants detected in the Resource Preservation Zone in Walnut Canyon NM.

Common Name	Frequency (%)
Dalmatian toadflax	87.74
Common mullein	83.02
Chenopodium spp.	62.26
Common salsify	29.25
Purslane	24.53
Cheatgrass	20.75
Horehound	17.92
Tansy mustard	13.21
Dandelion	12.26
Prickly lettuce	12.26
Tumble mustard	10.38
Prickly Russian thistle	6.6
Common motherwort	5.66
Yellow sweetclover	2.83
Bull thistle	1.89
Mexican burning bush	1.89
Alfalfa	0.94
Desert wheatgrass	0.94
Mat amaranth	0.94
Scotch thistle	0.94
Overall Frequency	99

Source: Hiebert and Hudson (2010).

non-native species. This indicates that non-native plants are widespread in this area despite limited access. Plants with the highest frequencies include dalmatian toadflax (87.74%) and common mullein (83.02%). *Chenopodium* spp. was also widespread; however, the authors note that they were unable to distinguish between the non-native *C. album* from the native *C. berlandieri (*Hiebert and Hudson 2010*)*. Dalmatian toadflax was ranked as medium by AZ-WIPWG and common mullein was evaluated by not listed by AZ-WIPWG. Common salsify (*Tragopogon dubius*), purslane (*Portulaca oleracea)*, and cheatgrass each occurred in at least 20% of all grid cells. Cheatgrass was ranked as high by both NatureServe and AZ-WIPWG. While only moderately widespread as of 2008, this species has high potential to continue spreading to other areas of the monument. Species with low frequencies but of management priority, and at least a medium ranking by either NatureServe or AZ-WIPWG, include prickly Russian thistle and yellow sweetclover. Their low frequencies suggest they are not yet widespread (at least as of 2008), but their ranking indicate the potential to alter native plant communities if they should spread. Since 99% of all grid cells sampled contained at least one non-native species and several of them are of management concern, we consider the condition for this measure to warrant significant concern. We assigned a low confidence in this condition rating since data were collected eight years ago. We could not determine trend based on one year of data.

<u>Overall Cover (%)</u>

A total of 28 non-native species were detected between high use areas and the Resource Preservation Zone (Table 4.8.4-3). As expected, there were more non-native species detected in high use areas (24) than in Resource Preservation Zone belt transects (16). However, an additional four species were detected in the larger grid cells of the Resource Preservation Zone that were not detected in the belt transects. These were: bull thistle (*Cirsium vulgare*), alfalfa (*Medicago lupulina*), mat amaranth (*Amaranthus blitoides*), and scotch thistle. Thus, 20 species were found in the Resource Preservation Zone versus 24 in high use areas. If including slender Russian thistle, which may have been confused with prickly Russian thistle in the Resource Preservation Zone, the total is 21 non-native species for this region. Table 4.8.4-4 shows the species that occur in either one zone or the other but not both.

Non-native plants represented 9.3% of the total high use area (Table 4.8.4-3). Mean cover in the low use Resource Preservation Zone averaged 1.75%. Because sampling methods differed between these areas it is difficult to make direct comparisons. Nevertheless, these results indicate much lower non-native plant cover in the low use Resource Preservation Zone than in the high use area.

In high use areas dalmatian toadflax, common mullein, and purslane exhibited the highest cover (3.10%, 2.57%, and 1.32%, respectively). All other species exhibited less than 1% cover. In the Resource Preservation Zone, common motherwort (*Leonurus cardiacus*) exhibited the highest cover, but this species is not considered a management priority by the park nor was it ranked by AZ-WIPWG or NatureServe. Purslane and common mullein averaged 3.51% and 3.18% cover, respectively. Common mullein is considered problematic as indicated by NatureServe's medium ranking. All other species sampled in the Resource Preservation Zone exhibited ≤ 2% cover. In

Table 4.8.4-3. Percent cover of non-native species detected in Wupatki NM.

Common Name	High Use Areas[1]	Resource Preservation Zone[2]
	Total Cover (%)	Mean Cover (%)
Bull thistle	< 0.01	–
Canada horseweed	0.06	–
Cheatgrass	0.02	0.05
Chenopodium spp.[3]	0.26	0.45
Common motherwort	–	7.50
Common mullein	2.57	3.18
Common salsify	0.14	0.05
Dalmatian toadflax	3.10	2.01
Dandelion	0.01	0.05
Desert wheatgrass	–	0.05
Diffuse knapweed	< 0.01	–
Field bindweed	0.08	–
Horehound	0.40	0.05
Knotweed	< 0.01	–
Mexican burning bush	–	0.05
Prickly lettuce	0.08	0.05
Prickly Russian thistle	0.16	0.16
Purslane	1.32	3.51
Red Brome	< 0.01	–
Redroot pigweed	0.05	–
Ripgut brome	0.01	–
Scotch thistle	0.01	–
Siberian elm	< 0.01	–
Storksbill	0.02	–
Tansy mustard	–	0.05
Tumble mustard	< 0.01	0.05
White sweetclover	0.86	–
Yellow sweetclover	0.19	0.05
Total or Mean Cover	Total = 9.3	Mean = 1.75

[1] Schelz et al. (2008).

[2] Hiebert and Hudson (2010).

[3] Identified as *C. album* in Schelz et al. (2008) and *C.* spp. in Hiebert and Hudson (2010).

combination with frequency data, these results indicate that although non-native plants are widespread in the Resource Preservation Zone, they are not abundant. The results for the Resource Preservation Zone warrant moderate concern, while results from high use areas warrant significant concern. However, non-native plant cover could change substantially over several years, but these studies represent only one year of data that were collected eight years ago. Given these factors, we assigned a low confidence to this condition rating. Trend is unknown since data were collected during one year only.

Table 4.8.4-4. Species that occur in only high use areas or the Resource Preservation Zone.

Common Name	
High Use Areas	Resource Preservation Zone
Diffuse knapweed	Alfalfa
Field bindweed	Desert wheatgrass
Canada horseweed	Mat amaranth
Knotweed	Mexican burning bush
Red brome	Slender Russian thistle
Redroot pigweed	Tansy mustard
Ripgut brome	*Chenopodium* spp.*
Siberian elm	–
Storksbill	–
White sweetclover	–

* This species may either be the non-native *C. album* or the non-native *C. berlandieri*. *C. album* was recorded in high use areas.

<u>Frequency by Habitat Type and Area (%)</u>

When stratified by habitat type, six species occurred in only one of the four habitat types (Table 4.8.4-5). Bull thistle and common motherwort occurred only in riparian areas, desert wheatgrass and mat amaranth occurred only in pinyon-juniper woodlands, alfalfa was found exclusively in ponderosa pine forests, and scotch thistle was restricted to sparse vegetation. Roughly the same number of species occurred within each habitat type. However, comparisons across habitat types are difficult due to variability in sample size. Nevertheless, excluding species that occurred in only one habitat type, eight of the remaining 14 species exhibited their highest frequency in riparian habitat. Furthermore, average frequency in the riparian areas was about twice as high as in each of the three other habitat types. This suggests that riparian habitat in Walnut Canyon may be particularly vulnerable to invasion by non-native species.

As the monument expanded, the number of non-native plants increased from 13 in the 1915 boundary to 18 species within the 1996 expansion area. Only one species (alfalfa) was found in the 1915 boundary but not within the subsequent two boundaries. Five species were found within the 1996 boundary that were not found within either of the two previous boundaries. These were: bull thistle, desert wheatgrass, mat amaranth, Mexican burning bush (*Kochia scoparia*), and prickly Russian thistle. Contrary to expectations,

Table 4.8.4-5. Frequency of non-native plants by habitat type and area in the Resource Preservation Zone in Walnut Canyon NM.

Common Name	Riparian (*n* = 7)	Pinyon-juniper Woodland (*n* = 20)	Ponderosa Pine Forest (*n* = 54)	Sparse Vegetation (*n* = 25)	1915 Boundary (*n* = 40)	1938 Expansion (*n* = 28)	1996 Expansion (*n* = 38)	North Side Canyon (South Facing)	South Side Canyon (North Facing)
Alfalfa	–	–	1.85	–	2.50	–	–	–	2.00
Bull thistle	28.57	–	–	–	–	–	5.26	–	–
Cheatgrass	57.14	20.00	11.11	32.00	17.50	25.00	21.05	22.45	14.00
Chenopodium spp.	71.43	90.00	42.59	80.00	60.00	64.29	63.16	67.35	56.00
Common motherwort	85.71	–	–	–	5.00	7.14	5.26	–	–
Common mullein	100.00	55.00	88.89	88.00	97.50	75.00	73.68	79.59	84.00
Common salsify	85.71	30.00	27.78	16.00	27.50	28.57	31.58	24.49	26.00
Dalmatian toadflax	100.00	70.00	96.30	80.00	97.50	85.71	78.95	85.71	88.00
Dandelion	85.71	–	11.11	4.00	15.00	14.29	7.89	4.08	10.00
Desert wheatgrass	–	5.00	–	–	–	–	2.63	2.04	–
Horehound	57.14	40.00	7.41	12.00	12.50	14.29	26.32	22.45	8.00
Mat amaranth	–	5.00	–	–	–	–	2.63	–	2.00
Mexican burning bush	–	5.00	–	4.00	–	–	5.26	4.08	–
Prickly lettuce	28.57	5.00	3.70	32.00	15.00	17.86	5.26	12.24	10.00
Prickly Russian thistle	–	10.00	1.85	16.00	–	–	18.42	8.16	6.00
Purslane	–	60.00	7.41	40.00	10.00	32.14	34.21	28.57	24.00
Scotch thistle	–	–	–	4.00	–	3.57	–	2.04	–
Tansy mustard	–	15.00	7.41	28.00	17.50	14.29	7.89	12.24	16.00
Tumble mustard	42.86	25.00	1.85	8.00	5.00	3.57	21.05	12.24	4.00
Yellow sweetclover	14.29	–	–	8.00	–	3.57	5.26	2.04	2.00
Average Frequency	37.86	21.75	15.46	22.60	29.42	27.81	23.10	24.38	23.47
Total Species	12	14	13	15	13	14	18	16	15

Source: Hiebert and Hudson (2010).

average frequency was highest for the 1915 boundary and lowest in the 1996 expansion area. Approximately the same number of species occurred on the north (16) and south (15) sides of the canyon. Alfalfa and mat amaranth occurred only on the south side while desert wheatgrass, Mexican burning bush, and scotch thistle occurred only on the north side. Species that occurred on both sides of the canyon, however, exhibited similar frequencies. Differences in frequency between the two canyon sides may indicate a preference for aspect-dependent characteristics (e.g., soil moisture, shade, solar radiation) or be the result of proximity to the road; however, the number of species and average frequency was only slightly higher for the south side as opposed to the north side of the canyon, which is farther from the road.

These data indicate that non-native plants occur in all habitat types and areas surveyed. Non-native species occurred in more than 25% but less than 50% of plots located in the riparian area, the original 1915 boundary, and the 1938 expansion area. This warrants moderate concern for these locations. Average frequency was less than 25% in the remaining habitat types and areas, which indicates good condition for these locations. We assigned low confidence to this condition rating since data were collected eight years ago. We could not determine trend based one year of sampling.

Cover by Habitat Type and Area (%)

Average cover in each of the four habitat types was low and did not exceed 1% (Table 4.8.4-6). Cover in the riparian habitat averaged 0.53%, and this was the highest cover of non-native plants among the four habitat types. Within riparian habitat, common mullein exhibited the greatest cover at 3.58%. Common mullein also exhibited the greatest cover in sparse vegetation while dalmatian toadflax (1.84%) and common mullein (1.08%) accounted for the majority of non-native plant cover in ponderosa pine forests. Purslane (1.43%) represented the highest cover in pinyon juniper woodlands. Within each of the three boundary areas, average cover was low and did not exceed 0.5%. Dalmatian toadflax and common mullein exhibited greater cover in the 1915 boundary than in the 1938 or 1996 expansion areas. Still, cover did not exceed 2% by species in any of the three boundaries. Dalmatian toadflax and common mullein exhibited similar and the highest cover on the north and south sides of the canyon while purslane cover was greater on the north vs. south side. Although 17 species were recorded in belt transects across the

Table 4.8.4-6. Cover of non-native plants by habitat type and area in the Resource Preservation Zone in Wupatki NM.

Common Name	Riparian (*n* = 7)	Pinyon-juniper Woodland (*n* = 20)	Ponderosa Pine (*n* = 54)	Sparse Vegetation (*n* = 25)	1915 Boundary (*n* = 40)	1938 Expansion (*n* = 28)	1996 Expansion (*n* = 38)	North Side Canyon (South Facing)	South Side Canyon (North Facing)
Cheatgrass	0.01	< 0.01	< 0.01	0.01	< 0.01	< 0.01	0.01	< 0.01	–
Chenopodium spp.	0.01	0.16	< 0.01	0.25	0.02	0.11	0.16	0.17	0.03
Common motherwort	1.07	–	–	–	–	0.27	–	–	–
Common mullein	3.58	–	1.08	1.12	1.33	0.50	1.16	0.84	0.91
Common salsify	0.01	< 0.01	< 0.01	–	< 0.01	–	< 0.01	< 0.01	< 0.01
Dalmatian toadflax	0.08	0.14	1.84	0.15	1.89	0.31	0.59	1.02	1.12
Dandelion	0.01	–	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	–
Desert wheatgrass	–	< 0.01	< 0.01	0.01	–	–	–	–	–
Horehound	–	–	–	< 0.01	–	< 0.01	–	< 0.01	–
Mat amaranth									
Mexican burning bush	–	0.03	–	0.02	–	–	0.03	–	< 0.01
Prickly lettuce	0.01	–	–	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	–
Prickly Russian thistle	–	0.03	< 0.01	< 0.01	–	–	0.02	< 0.01	0.01
Purslane	–	1.43	–	0.12	–	0.09	0.76	0.52	0.12
Tansy mustard	–	–	< 0.01	–	< 0.01	< 0.01	–	–	< 0.01
Tumble mustard	–	< 0.01	–	–	–	–	<0.01	< 0.01	–
Yellow sweetclover	0.01	–	–	< 0.01	–	–	–	–	–
Average Cover	0.53	0.20	0.33	0.14	0.41	0.13	0.25	0.24	0.28

Source: Hiebert and Hudson (2010).

various habitat types and areas, most exhibited < 0.01% cover and average cover did not exceed 0.6% in any strata. Since cover did not exceed 1% in any habitat type or area we consider the condition for this measure to be good. As with overall cover, cover by habitat type could change substantially over several years, but these studies represent one year of data that were collected eight years ago. Given these factors, we assigned a low confidence to this condition rating. We could not determine trend based on one year of sampling.

Non-native Plants Removed (% and area)

In 2008, nearly 19% of all non-native plants mapped in high use areas were removed (Table 4.8.4-7). All knotweed and tumble mustard plants were removed and 81.95% of common salsify plants removed. None of these species were evaluated by AZ-WIPWG and only knotweed was assigned a rank (low) by NatureServe. Red brome, cheatgrass, and diffuse knapweed are among the species with the highest management priority and those with the highest rankings by NatureServe and AZ-WIPWG, but none of these species were removed from high use areas in 2008. However, these species were among the species with the lowest cover (4.8.4-3). Similarly, the species removed also exhibited relatively low cover.

During 2014 and 2015, 9.9 ha (25.5 ac) were surveyed and manually treated for common mullein, horehound (*Marrubium vulgare*), dalmatian toadflax, cheatgrass, and scotch thistle (Figure 4.8.4-1). Of these cheatgrass and dalmatian toadflax have the highest invasiveness rankings.

Since less than 20% of non-native plants were removed during 2008 and none were ranked high or medium by either AZ-WIPWG or NatureServe, we consider this measure to warrant significant concern. However, confidence is low since these data are eight years old. Although high use areas are currently targeted and control efforts occurred as recently as 2015, no data on the proportion of the target area controlled were available. Therefore, we consider the condition for this measure to be unknown with low confidence in the condition rating. No data on trend were available.

Overall Condition, Trend, Confidence Level, and Key Uncertainties

Overall, we consider the condition of non-native and invasive plants to warrant moderate concern in Walnut

Table 4.8.4-7. Percent of non-native species removed in Walnut Canyon NM.

Common Name	% Removed
Knotweed	100
Tumble mustard	100
Common salsify	81.95
Canada horseweed	25.64
Dalmatian toadflax	16.39
Common mullein	12.81
Horehound	11.64
Dandelion	8.37
Prickly lettuce	4.25
Purslane	4.02
Chenopodium spp.	2.98
Bull thistle	2.78
Prickly Russian thistle	2.35
Yellow sweetclover	2.16
Redroot pigweed	1.72
Storksbill	1.59
Ripgut brome	0.97
Field bindweed	0.6
White sweetclover	0.13
Total	18.7

Source: Schelz et al. (2008).

Canyon NM. This condition rating was based on three indicators and seven measures, which are summarized in Table 4.8.4-8. Since the majority of data used in this assessment were for one season only (2008), we could not determine trend in non-native plant cover, frequency, or control effort. However, the two studies used in this assessment provided broad coverage of nearly all areas of the monument. In Schelz et al. (2008) non-native plants were mapped throughout high use areas, and in Hiebert and Hudson (2010) grid cells were widely distributed throughout the Resource Preservation Zone. Together, these two studies provide excellent baseline information on non-native plant occurrence in the monument.

Those measures for which confidence in the condition rating was high were weighted more heavily in determining the overall condition than measures with medium or low confidence. Factors that influence confidence in the condition rating include age of the data (<5 yrs unless the data are part of a long-term monitoring effort), repeatability, field data vs. modeled data, and whether data can be extrapolated to other areas in the monument. Based on these factors,

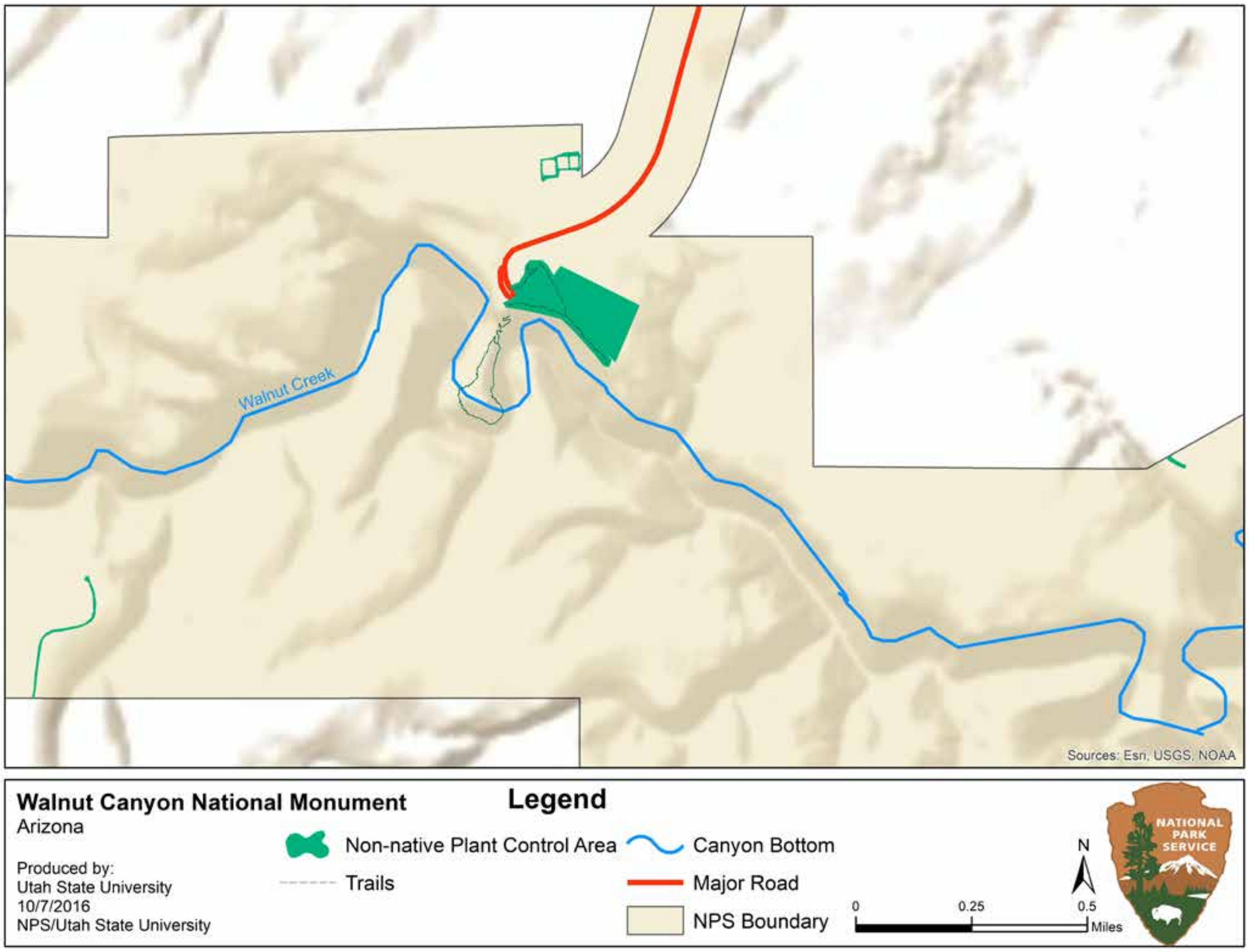


Figure 4.8.4-1. Locations of non-native and invasive plant control efforts in Walnut Canyon NM. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction.

we assigned high confidence to the NatureServe and AZ-WIPWG ranking measures. The data used to assess measures of frequency, cover, and the proportion of non-native plants removed were eight years old. Therefore, we assigned medium confidence to the condition for these measures. Key uncertainties of these studies include how non-native plant cover and frequency have changed over time and whether the control treatments were effective. Controlling non-native plants reduces the likelihood that they will spread into more remote areas of the monument. The goal has been to control the spread of non-plants since eliminating most species is probably unrealistic (Paul Whitefield, pers. comm., Natural Resource Specialist, Flagstaff Area National Monuments). While targeted efforts such as those described in this assessment can be effective, the effectiveness of these efforts is difficult to determine without follow-up surveys.

Threats, Issues, and Data Gaps

Of all the stressors on native vegetation, climate change has the most potential to influence community composition, vegetation structure, and species richness (Schweiger et al. 2010). And climate change can, in turn, influence the spread of invasive plants (Hellmann et al. 2008). Monahan and Fischelli (2014) evaluated which of 240 NPS units have experienced extreme climate changes during the last 10-30 years. The results of this study for Walnut Canyon NM were summarized in NPS (2014). Extreme climate changes were defined as temperature and precipitation conditions exceeding 95% of the historical range of variability. The results of this study indicate a trend toward extreme warm and extreme dry conditions within the monument (Monahan and Fisichelli 2014), and are indicative of trends occurring throughout the southwestern U.S. (Prein et al. 2016). In Walnut Canyon NM non-native plant growth tends to occur

Table 4.8.4-8. Summary of indicators, measures, and condition rationale used to assess non-native and invasive plants in Walnut Canyon NM.

Indicators of Condition	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Potential to Alter Native Plant Communities	NatureServe Invasive Species Impact Rank		Of the 42 non-native species found in Walnut Canyon NM, 20 have not been assessed by NatureServe. Species with a high rank was cheatgrass. An additional five species were ranked as high/medium or medium. The remaining 16 species were ranked as high/low (1), medium/low (9), medium/insignificant (2), low (2), or low/insignificant (2). Since the majority of species were ranked at least medium and one species were ranked as high, we consider this measure to warrant moderate concern. Trend could not be determined. Confidence in this condition rating is high.
	AZ-WIPWG Ecological Impact Rank		Sixteen of the 42 species found in Walnut Canyon NM were evaluated by AZ-WIPWG. Two were ranked high, 10 were ranked medium, two were ranked low, and one was evaluated but not ranked. Since 35.7% of plants listed in Table 4.8.4-1 were evaluated by AZ-WIPWG and 12 species were given a high or medium ecological impact rating, we consider this measure to warrant moderate concern. Trend could not be determined. Confidence in this condition rating is high.
Current Prevalence of Non-native Plants	Overall Frequency (%)		Since 99% of grid cells contained at least one non-native species and several are of management concern, we consider the condition for this measure to warrant significant concern. Trend could not be determined. Confidence in this condition rating is low since these data are eight years old.
	Overall Cover (%)		Non-native plants represented 9.3% of the total high use area and mean cover in the Resource Preservation Zone averaged 1.75%.The data for the Resource Preservation Zone warrants moderate concern, while data from high use areas warrants significant concern. Trend could not be determined. Confidence in this condition rating is low since data are for one season eight years ago.
	Frequency by Habitat Type and Area (%)		Non-native species occurred in more than 25% but less than 50% of plots located in the riparian area, the original 1915 boundary, and the 1938 expansion areas. This warrants moderate concern for these locations. Average frequency was less than 25% in the remaining habitat types and areas, which indicates good condition for these locations. Trend could not be determined. Confidence in this condition rating is low since these data are eight years old.
	Cover by Habitat Type and Area (%)		Average cover did not exceed 1% in any of the four habitat types, three boundaries, or by canyon side, which indicates good condition for this measure. Trend could not be determined. Confidence in this condition rating is low since these data represent one season and are eight years old.
Control Effort	Non-native Plants Removed (% and ha)		Since less than 20% of non-native plants were removed during 2008 and none were ranked high or medium by either AZ-WIPWG or NatureServe, we consider this measure to warrant significant concern. However, confidence is low since these data are eight years old. Although high use areas are currently targeted and control efforts occurred as recently as 2015, no data on the proportion of the target area controlled were available. Therefore, we consider the condition for this measure to be unknown with low confidence in the condition rating. Trend could not be determined.
Overall Condition			Overall, we consider the condition for non-native and invasive plants in Walnut Canyon NM to warrant moderate concern. Frequency data indicate that non-native plants are widespread, but cover data indicate low abundance. The number of non-native plants with high invasiveness rankings indicate the potential for a number of species to significantly alter native plant communities in the monument. While control efforts are ongoing, several species of concern were not controlled and treatment effectiveness is unknown. Confidence is low primarily due to age of data.

in pulses (P. Whitefield, pers. comm. Natural Resource Specialist, Flagstaff Area National Monuments). However, native vegetation in the monument is dense and highly productive; thus, non-natives tend to be out-competed by native species within about five years (Paul Whitefield, pers. comm., Natural Resource Specialist, Flagstaff Area National Monuments). Changes in patterns of precipitation and temperature, though, may result in non-native plants gaining the competitive edge over native species.

The introduction and spread of invasive plants is also influenced by road corridors, trails, and disturbances. While access in much of Walnut Canyon is restricted, the monument is a small, highly linear park, which increases the monument's susceptibility to invasion by non-native species (Hiebert and Hudson 2010). Not surprisingly, the highest number and cover of non-native species was found in Walnut Canyon NM's high use areas compared to the Resource Preservation Zone (Hiebert and Hudson 2010). Although non-native plants were less common in backcountry areas, they were still widespread, perhaps because the Resource Preservation Zone was designated only recently in 2007 (NPS 2007a). In other words, the area was previously open to access, providing a mechanism for invasive plant seed transport. Furthermore, the boundary of the monument has expanded twice since its initial designation in 1915. Land use patterns in the expansion areas prior to their addition to the monument likely contributed the introduction and spread of non-native plants there (Hiebert and Hudson 2010).

Walnut Canyon NM was managed by the U.S. Forest Service until 1934 (Menzel 1996). The monument's boundary was expanded in 1938 and then again in 1996 (Menzel 1996). Prior to its establishment, parts of the monument were logged and evidence suggests that illegal logging occurred even after timber harvest was prohibited within the monument's boundary (Menzel 1996). In addition to timber harvest, sheep and cattle were grazed in portions of the monument until a boundary fence was erected in 1974, but grazing continued in the 1996 expansion area before it was added to the monument (Menzel 1996). In 2004 and 2005 the boundary fence was expanded to include the 1996 expansion area (Hiebert and Hudson 2010).

The disruption of natural processes including fire and periodic floods in Walnut Creek may have also influenced non-native plant frequency and cover in the monument. A long history of fire suppression has led to an altered forest structure (Menzel 1996). Ponderosa pine forests historically exhibited an open, parklike structure with an herbaceous understory, but without the natural disturbance of fire, ponderosa pines have increased in density, Gambel oak and pinyon juniper trees have increased in frequency, and the herbaceous understory has been lost (Menzel 1996). This latter effect is also attributed to past cattle and sheep grazing within the monument (Menzel 1996). Although forest structure has shifted as a result of an altered disturbance regime, little is known about how or if fire suppression has influenced the occurrence and spread of non-native plants in the monument.

Periodic floods in Walnut Creek historically maintained an open riparian habitat structure. Today, flows in Walnut Creek are restricted by two dams located in the Upper Walnut Creek Watershed (Soles and Monroe 2015). The dams, which were constructed in 1904 and 1941, divert much of the water that would otherwise flow through the monument (Soles and Monroe 2015). Since construction of the dams, upland plants have encroached and the density of vegetation has increased in the riparian area (Brian 1992). As with fire suppression, little is known about the effects this has had on the spread of non-native plants, but data used in this assessment suggest that non-native plants are more prevalent in riparian areas than in other habitat types in the monument (Hiebert and Hudson 2010). Reduced flows may be partially responsible. The interruption of natural disturbances, past grazing effects, illegal timber harvest, and climate change may all be contributing factors to non-native plant occurrence in Walnut Canyon NM.

4.8.5. Sources of Expertise

No outside experts were consulted for this assessment. Assessment author was Lisa Baril, science writer, Utah State University.

4.9. Birds

4.9.1. Background and Importance

The National Park Service's mission is to manage park resources "unimpaired for future generations." Protecting and managing some of our nation's most significant natural resources requires basic knowledge of the condition of ecosystems and species that occur in national parks. Birds are a highly visible component of many ecosystems (Figure 4.9.1-1). They are considered good indicators of ecosystem health because they can respond quickly to changes in resource and environmental conditions (Canterbury et al. 2000, Bryce et al. 2002). Relative to other vertebrates, birds are also highly detectable and can be efficiently surveyed with the use of numerous standardized methods (Bibby et al. 2000, Buckland et al. 2001). Changes in bird population and community parameters can be an important element of a comprehensive, long-term monitoring program. Another compelling reason to monitor birds is that they are inherently valuable. The high aesthetic and spiritual values that humans place on native wildlife are acknowledged in the agency's Organic Act: "to conserve . . . the wildlife therein . . . unimpaired for the enjoyment of future generations." Bird watching, in particular, is a popular, longstanding recreational pastime in the United States and forms the basis of a large and sustainable industry (Sekercioglu 2002). Hundreds of species of birds occur in the American Southwest, as do some of the best birdwatching opportunities.

A substantial number of bird species are present at Walnut Canyon NM because of the diversity of plant communities and the variety of geological and physical features present (Haldeman and Clark 1969). Vegetation communities within the national monument include Douglas-fir forests, ponderosa pine forests, pinyon-juniper woodlands, and wooded riparian habitat along the canyon floor. Ledges, holes, and recesses in and on the canyon walls provide nesting sites for some species (Haldeman and Clark 1969). Ponderosa pine habitat, dominated by ponderosa pine (*Pinus ponderosa*) is located on the level terraces above the canyon. The north-facing slopes of Walnut Canyon and tributary canyons, protected from the wind and sun, are dominated by Douglas-fir-Gambel oak habitat (*Pseudotsuga menziesii-Quercus gambelii*) (Holmes et al. 2011). In contrast, south-facing slopes of the canyon are more exposed to the wind and sun, and they are dominated by pinyon pine (*Pinus edulis*) and Utah juniper (*Juniperus osteosperma*) trees; the understory of this habitat type has a diverse understory of herbaceous, shrub, and succulent species. The canyon bottom, and the south-side tributary canyons, contain deciduous riparian vegetation. Stands of box

Figure 4.9.1-1. Ash-throated flycatcher, a common bird species at Walnut Canyon NM. Photo Credit: © Robert Shantz.

elder (*Acer negundo*) and Arizona walnut (*Juglans major*) dominate the riparian corridor, but a diversity of plant species is present.

Although Southern Colorado Plateau Network (SCPN) monitoring of birds within Walnut Canyon NM is not conducted on a regular basis, some surveys and studies of birds within the national monument have been and are conducted. The most recent species-wide effort was an inventory of birds in two of the main habitat types in the park in 2009-2010 (Holmes et al. 2011). The two habitats inventoried were ponderosa pine and riparian habitat, and the inventory was conducted between mid-May and mid-July of 2009 and 2010.

The earliest publication/report we reviewed for this assessment was Haldeman and Clark (1969), which discussed bird species occurrence in the national monument in relation to the plant communities present. The authors provided a substantial species list of birds that had been recorded at the park by 15 different observers over the course of 34 years. Few details on the observers were provided. The list includes observations made throughout the year, so the list includes species that nest in the area, as well as spring and fall migrants.

Information on birds within Walnut Canyon NM is also available from study conducted in 1999-2001 in ponderosa pine habitat. The purpose of the study was to determine the effects of low-severity prescribed fires in ponderosa pine forests on vegetation, breeding birds, and arthropods (Short 2002). The researcher had study sites in three national park units, with one being Walnut Canyon NM.

Although not part of the inventory surveys conducted in 2009-2010 by Holmes et al. (2011), some work has been conducted on birds in pinyon-juniper habitat in the national monument. Van Riper and Crow (2006) conducted a study focusing on the relationship between pinyon-juniper density and/or maturity and bird species distribution in the areas studied. The purpose was partially to provide information to managers on how activities affecting pinyon-juniper density (e.g., prescribed fires and mechanical fuels reductions) might affect birds. The researchers found that the number of bird species present was related to the characteristics of pinyon-juniper and the type of management treatment that had been conducted (hand cut, chained, or not treated). Modeled relationship results (for relationships between characteristics of the vegetation and occupancy/relative abundance) were provided for 14 species.

Other efforts to study and/or monitor birds within the park include those focusing on individual species of interest. Species that have been studied or monitored on an individual basis include a number of raptor species- the Mexican spotted owl (*Strix occidentalis lucida*), northern goshawk (*Accipiter gentilis*), peregrine falcon (*Falco peregrinus*), golden eagle (*Aquila chrysaetos*), and great horned owl (*Bubo virginianus*). Monitoring of these species is discussed in the condition assessment, although the federally threatened Mexican spotted owl is the subject of a separate assessment.

This condition assessment addresses birds at Walnut Canyon NM through the use of data from the 2009-2010 avian inventory in ponderosa pine and canyon riparian habitats, as well as through the use of other studies and surveys that have been conducted in the park. Information is presented on the overall number and types of species that have been recorded in the park, including any species that are federally listed as endangered or threatened or otherwise considered sensitive species. We also address the status of the raptor species, which are monitored in the park. Threats faced by birds in Walnut Canyon NM are addressed primarily in the last section of this condition assessment.

4.9.2. Data and Methods

For this assessment of birds at Walnut Canyon NM, we used two indicators of condition, species occurrence and status of selected species. The first indicator's measures are species presence/absence and the occurrence of species of conservation concern (described in more detail below). The second indicator has three measures, each focusing on the status of a different raptor species that occurs at the park.

Species Presence/Absence

To assess species presence/absence at Walnut Canyon NM, we used the surveys of Holmes et al. (2011) and Short (2002). We also used the species list from Haldeman and Clark (1969), although it should be noted that this list is not based on standardized surveys as are the results of Holmes et al. (2011) and Short (2002). We created a list of species from these survey/research efforts, as well as the NPSpecies list for the park (NPS 2016b) to obtain a complete list of species for the park. The NPSpecies list contained a small number of species that were not reported by the other sources. Because two of the resources used to compile the list (Haldeman and Clark 1969, and NPS 2016b) included records throughout the year (and because some species detected could just be passing through the park), the list of species is not confined to species that breed within the park.

The comprehensive list of species we compiled indicates in which survey/study effort each species was recorded. We also noted, for the most recent inventory (2009-2010), in which habitat type each species was recorded. This information also allows the reader to see which species were recorded by one or more survey/study efforts. It is of interest to see where (i.e., in which habitat type) and when species were recorded. Finally, it should be remembered that the list of Haldeman and Clark (1969) was an overall list of birds recorded in the park, while Short (2002) conducted her work in ponderosa pine habitat, and Holmes et al. (2011) surveyed for birds in ponderosa pine and riparian habitat.

Presence of Species of Conservation Concern

The second measure used in this assessment focused on the species that occur or have occurred at Walnut Canyon NM that are considered species of conservation concern at either national or regional scales. Note that we use the phrase "species of conservation concern" in a general sense; it is not specifically tied to use by any one agency or organization. We took the overall list of species for the national monument previously described (based on the two survey efforts [Short 2002, and Holmes et al. 2011] and two lists [Haldeman and Clark 1969, and NPS 2016b]), and compared it to multiple species of conservation concern lists (e.g., a federal list of endangered and threatened species, those of Greatest Conservation Need in Arizona). The specific lists we used are described below.

Species of Conservation Concern Background

There have been a number of agencies and organizations that focus on the conservation of bird species. Such organizations may differ, however, in the criteria they use to identify and/or prioritize species of concern based on the mission and goals of their organization. They also range in geographic scale from global organizations, such as the International Union for Conservation of Nature (IUCN), who maintains a "Red List of Threatened Species," to local organizations or chapters of larger organizations. This has been, and continues to be, a source of potential confusion for managers and others who need to make sense of and apply the applicable information. In recognition of this, the U.S. North American Bird Conservation Initiative (NABCI) was created in 1999; it represents a coalition of government agencies, private organizations, and bird initiatives in the United States working to ensure the conservation of North America's native bird populations. Although there remain a number of sources at multiple geographic and administrative scales for information on species of concern, several of which are presented below, the NABCI has made great progress in developing a common biological framework for conservation planning and design.

One of the developments from the NABCI was the delineation of Bird Conservation Regions (BCRs) (U.S. North American Bird Conservation Initiative 2014). Bird Conservation Regions are ecologically distinct regions in North America with similar bird communities, habitats, and resource management issues (Figure 4.9.2-1). Walnut Canyon NM and Sunset Crater Volcano NM are both within the Sierra

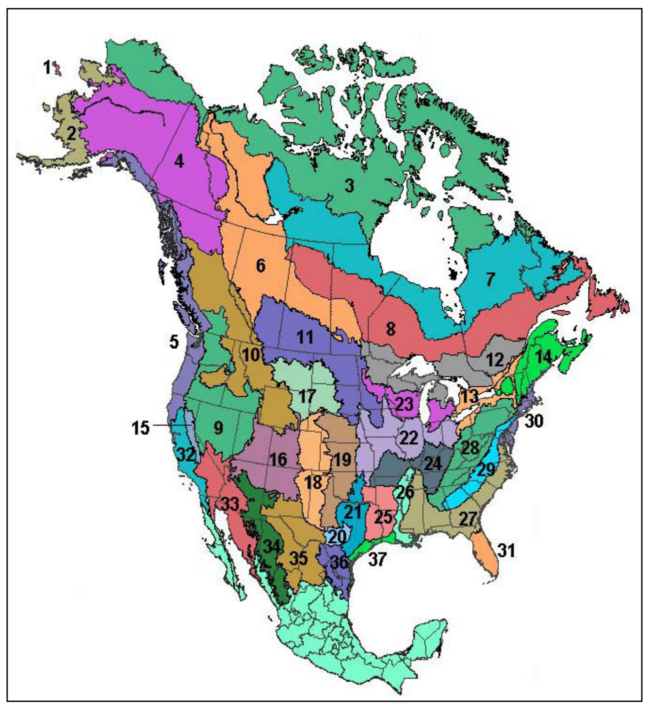


Figure 4.9.2-1. Bird Conservation Regions in North America. Figure Credit: USFWS (2008).

Madre Occidental BCR (BCR-34), although the latter park is close to the edge of the Southern Rockies-Colorado Plateau BCR (Figure 4.9.2-2). Wupatki NM is primarily within the Southern Rockies-Colorado Plateau BCR, but the extreme western portion of the park is within the Sierra Madre Occidental BCR.

Conservation Organizations Listing Species of Conservation Concern

Below we identify some of the organizations/efforts that list species of conservation concern; these are the listings we used for this condition assessment. Appendix E presents additional details on each of the organizations/efforts. Note that in addition to the U.S. Fish and Wildlife Service (USFWS) maintaining a list of endangered and threatened species (first bullet below), they maintain a list of species protected under the Migratory Bird Treaty Act (MBTA; USFWS 2016b). This Act, which protects 1,026 birds, regulates "the taking, possession, transportation, sale, purchase, barter, exportation, and importation of migratory birds" (USFWS 2013). Although we did not compare the list of birds that have been recorded at Walnut Canyon NM to this extensive list, the MBTA is discussed in Appendix E, and some of the lists that we reviewed include birds protected under the MBTA (see bullets below). An updated list of species protected under the MBTA can be found in USFWS (2013).

- U.S. Fish & Wildlife Service: Under the Endangered Species Act (ESA), the USFWS lists species as threatened, endangered, or candidates for listing (USFWS 2016c).
- USFWS: This agency also developed lists of birds of conservation concern according to: the Nation, USFWS Region, and BCR (USFWS 2008a). These listings include both migratory and non-migratory bird species (beyond those already designated as federally threatened or endangered). Bird species considered for

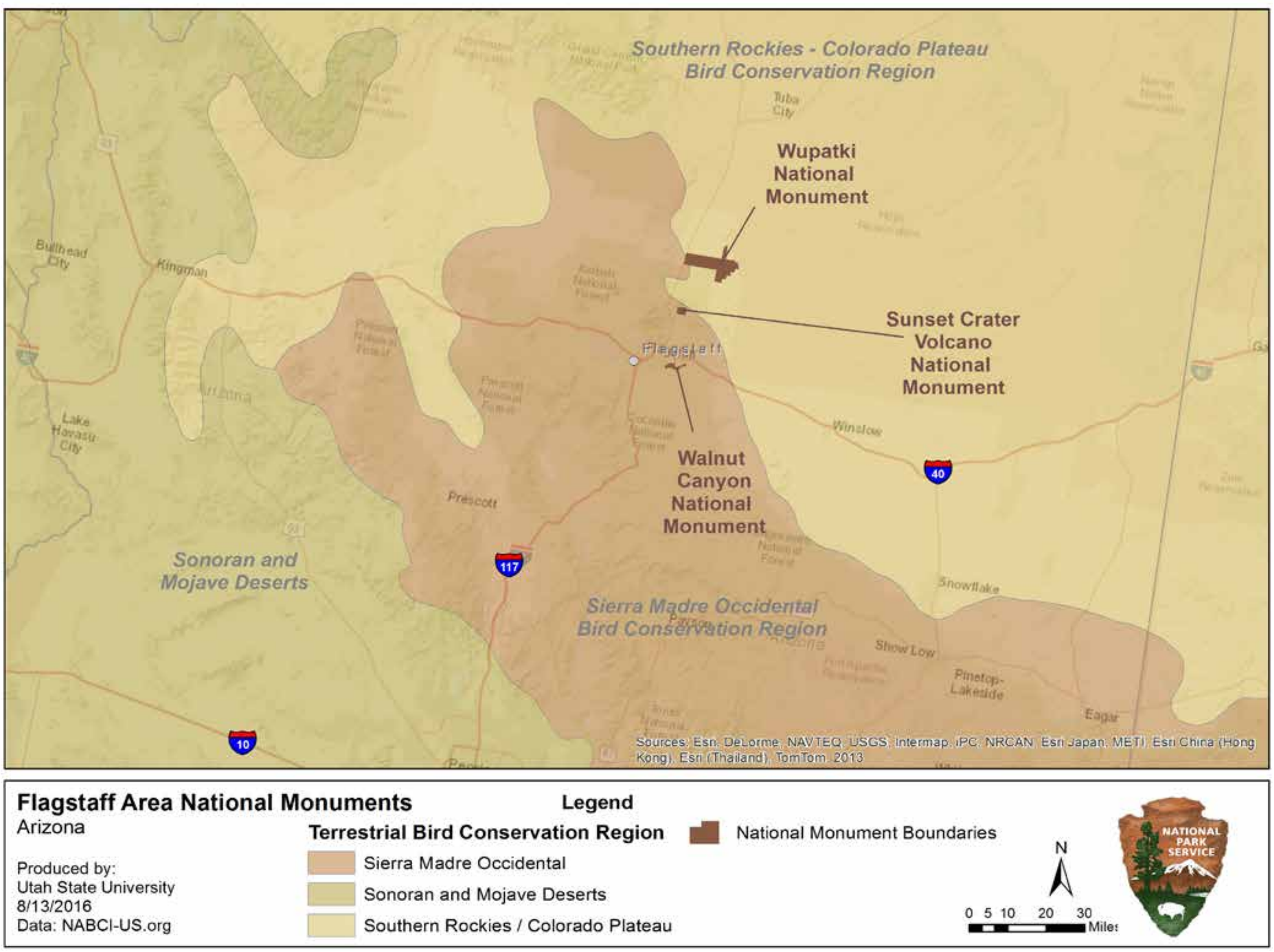


Figure 4.9.2-2. Walnut Canyon NM is located in the Sierra Madre Occidental Bird Conservation Region.

inclusion on the lists include: nongame birds; gamebirds without hunting seasons; and ESA candidate, proposed endangered or threatened, and recently delisted species.

- North American Bird Conservation Initiative (NABCI): A team of scientists from this group identified U.S. bird species most in need of conservation action (Rosenberg et al. 2014). A Watch List is published every few years, and the 2014 Watch List contains 233 species. Most of the species are protected by the MBTA, and some are protected by the ESA. The Watch List has two primary levels of concern: a "Red Watch List," which contains species with extremely high vulnerability due to small population, small range, high threats, and rangewide declines; and a "Yellow Watch List," which contains species that are either range restricted (small range and population) or are more widespread but with concerning declines and high threats (Rosenberg et al. 2014).
- Partners in Flight (PIF): This is a cooperative effort among federal, state, and local government agencies, as well as private organizations. PIF has adopted BCRs as the geographic scale for updated regional bird conservation assessments. At the scale of the individual BCRs, there are species of Continental Importance (Continental Concern [CC] and Continental Stewardship [CS]) and Regional Importance (Regional Concern [RC] and Regional Stewardship [RS]). We included only the CC and RC species in our assessment. The BCR lists used for this assessment were obtained online (Partners in Flight Science Committee 2012).
- AZ Species of Greatest Conservation Need (SPGN): Under Arizona's State Wildlife Action Plan (2012-2022), SGCN have been designated in the state (Arizona Game and Fish Department [AGFD] 2012). Of the 347 vertebrate SGCN statewide, 145 are birds. The plan includes three tiers, Tier 1A, 1B, and 1C. Of the 145 birds considered SGCN, 12 are Tier 1A, 56 are Tier 1B, and 77 are Tier 1C. Tier 1A contains "those species for which the Department has entered into an agreement or has legal or other contractual obligations, or warrants the protection of a closed season. Tier 1B represents the remainder of the vulnerable species. Tier 1C contains those species for which insufficient information is available to fully assess the vulnerabilities and therefore need to be watched for signs of stress. This tier replaces the species of unknown status from the Comprehensive Wildlife Conservation Strategy" (AGFD 2012). Species listed as federally endangered, threatened, or candidate species, and those considered "endangered wildlife" by the State are Tier 1A species. We compared the list of species for Walnut Canyon NM to the list of birds of SGCN in the State plan; we report only birds in the two highest tiers (except we note 1C species when they also appeared on at least one other of the lists we reviewed).

<u>Data Sources</u>

The following paragraphs provide brief summaries of the primary sources of data and information used for this assessment: surveys by Short (2002) and Holmes et al. (2011), and species lists by Haldeman and Clark (1969) and NPS (2016).

Haldeman and Clark (1969)

As mentioned previously, Haldeman and Clark (1969) was the oldest publication/report we reviewed for the assessment. The publication generally discussed bird species presence in the national monument in relation to the plant communities present. The list of species observed was compiled based on the observations of 15 different individuals over 34 years. Few details on the observers were provided. The list includes observations made throughout the year, so species that nest in the area, as well as spring and fall migrants, are included. The authors also provided dates of occurrence of individual species, as well as a list of species known to nest within the park.

Short (2002)

Short (2002) sampled birds in ponderosa pine habitat in Walnut Canyon NM during the breeding season in 1999-2001. Her work was part of a larger study on the effects of low-severity prescribed fires in ponderosa pine forests on vegetation, breeding birds, and arthropods (Short 2002). Her overall study sites were in the national monument, as well as Saguaro NP and Grand Canyon NP. Within Walnut Canyon NM, her study locations (two, one burned and one unburned site) were on the south rim of the canyon (Figure 4.9.2-3 [red points]) at elevations of 2,010-2,080 m (6,594-6,824 ft). Vegetation in her study sites consisted of ponderosa pine and Douglas-fir in the overstory, and Gamble oak, pinyon pine, and multiple juniper species in the midstory; also, a sizable

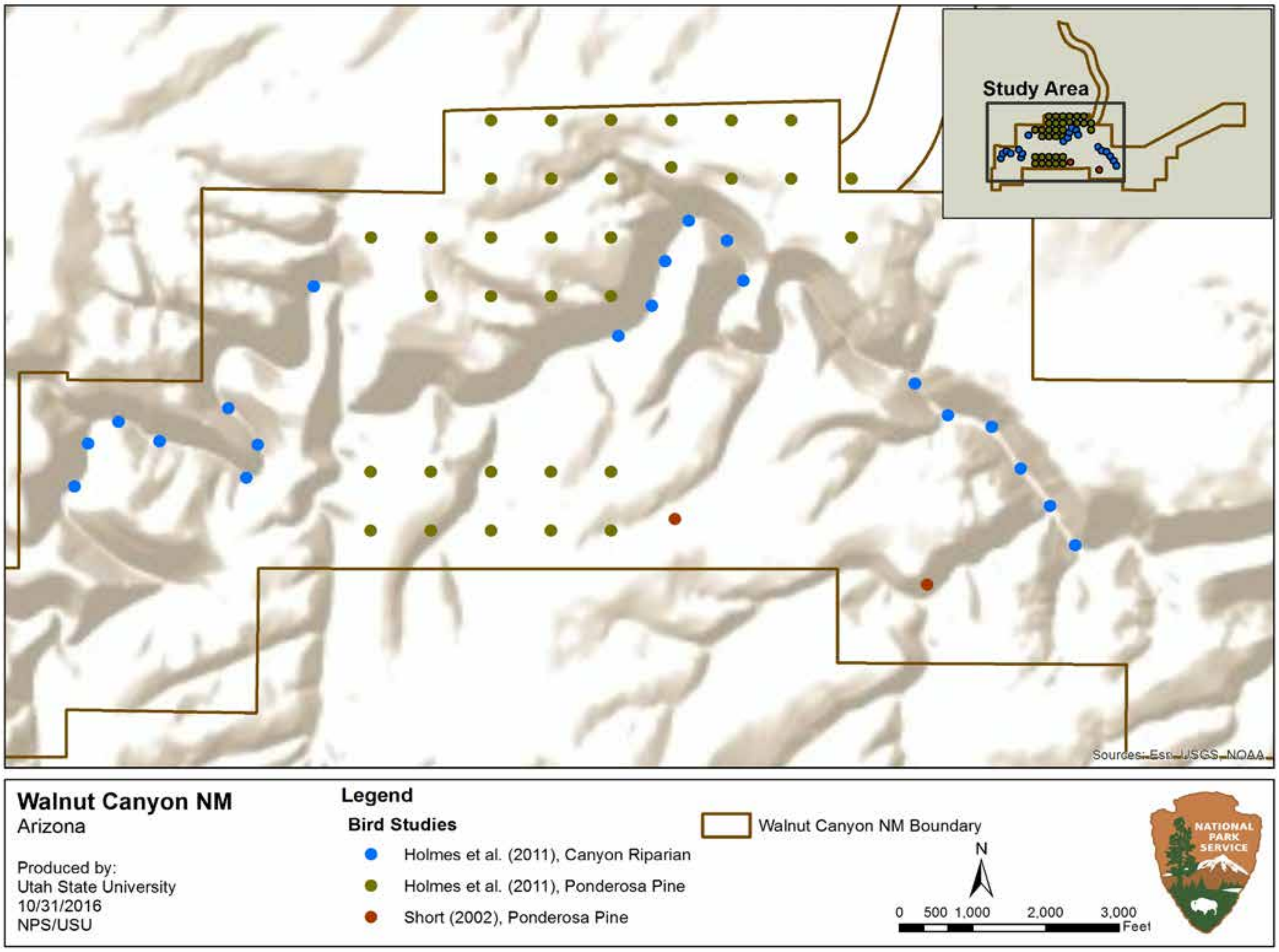


Figure 4.9.2-3. Locations of sampling plots to survey birds in ponderosa pine and riparian habitats at Walnut Canyon NM. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction.

number of species occurred in the understory and herbaceous layer. Within her 40-ha (99-acre) study plots, she established six interior gridpoints at which she conducted point counts. The point count stations were at least 200 m (656 ft) apart. During 10-minute point counts, she recorded the number of individuals of species that were heard or seen within a 50-m (164-ft) radius. Counts were conducted in the morning on three separate occasions per year from May-August.

Holmes et al. (2011)

Holmes et al. (2011) conducted an inventory of birds in Walnut Canyon NM in 2009-2010. The only two habitats inventoried were ponderosa pine and deciduous riparian habitat, and the inventory was conducted between mid-May and mid-July of each year. Birds were sampled using eight-minute Variable Circular Plot (VCP) counts with distance estimation. Thirty-three sampling plots were established in ponderosa pine habitat, and 20 sampling plots were established in canyon riparian habitat (Figure 4.9.2-3 [green points and blue points, respectively). At each VCP, all birds seen or heard were recorded during the 8-minute sampling period. Birds were recorded regardless of the distance from the observer to the bird (and regardless of the location, meaning that birds in adjacent habitats may have been recorded). Researchers recorded the species, gender (if known), detection method, and distance from the VCP center to the bird. Overall, a total of 118 VCP counts were conducted in ponderosa pine habitat, and 40 VCP counts (in 2009 only) were conducted in riparian habitat. The vegetation in the areas surveyed is described in detail in Holmes et al. (2011), and information on the park's vegetation in general was provided in the Background and Importance section.

Holmes et al. (2011) also reported the abundance (average abundance per VCP count) and distribution (proportion of plots in which a species was detected) for each species observed during sampling. We present some of this information in the condition assessment.

NPSpecies List (NPS 2016b)
The list of birds for the national monument from NPSpecies was also reviewed (NPS 2016b; obtained from IRMA in March 2016). We used the list as supporting information and for the inclusion of additional species not recorded in the primary bird survey efforts or 1969 list.

The status of selected species indicator focuses on t three raptor species that occur within the park and for which park personnel or contractors conduct annual (roughly) nest monitoring surveys. For each of the three species, northern goshawk, peregrine falcon, and golden eagle, the corresponding measure focuses on the occupancy/use of nesting territories within Walnut Canyon NM. Two additional species are monitored within the national monument, but one, Mexican spotted owl, is the subject of a separate assessment, and the other, great horned owl, has only been monitored for a small number of years at the park (and so few data are available). However, we present the monitoring results for the great horned owl in the condition section.

Nesting surveys are conducted by park personnel for the three raptor species (and great horned owl) approximately every year. Park personnel provided a summary for the condition assessment of nesting surveys for the species for the years 2006-2016. Some additional details on the surveys are provided below. All three of the species appear in the species of conservation concern table presented in the condition section of the assessment.

Figure 4.9.2-4. A northern goshawk in flight. Photo Credit: © Robert Shantz.

Northern Goshawk
The northern goshawk (Figure 4.9.2-4) inhabits forests of various types, ages, and successional stages (Reynolds et al. 1992). In the Southwest, it inhabits mainly forests of ponderosa pine, mixed species, and spruce-fir. Small and medium-sized birds and mammals (e.g., robins and chipmunks) are the main prey of the species, and it captures them in the air or on the ground. At least as of the early 1990s, concerns were expressed for northern goshawk populations due to potential forest changes from timber harvesting, as well as other human activities, and drought. In general, goshawks nest in areas with large trees and dense canopies. Within a goshawk's nesting home range are the nest area, the post fledging-family area (PFA), and the foraging area, and the general sizes of these areas (12.1 hectares [30 acres], ~170 ha [420 acres], and ~2,185 ha [5,400 acres], respectively) have been determined from goshawk studies. The nest area is surrounded by the PFA, and the PFA is surrounded by the foraging area. This species lays two to four eggs per nest (Cornell Lab of Ornithology 2015).

For the northern goshawk, two PFAs are monitored within Walnut Canyon NM (Hall 2008); an additional PFA is near but outside of the park. Monitoring of the two PFAs within Walnut Canyon NM dates back at least to the 1990s. Monitoring for northern goshawk within the park consists of visually inspecting all known nest trees and the area in between them for evidence of occupancy and/or activity and a new nest. Such evidence includes molted feathers, concentrations of excrement, fresh plant material in a nest, remains of prey, and the presence of an adult bird (Hall 2008). A PFA is considered active when a nest with an incubating female is observed. If activity at known nests is not observed, those monitoring broadcast goshawk calls in accordance with a set protocol (U.S. Forest Service, Region 3 monitoring protocol) to see if adults are at previously unidentified active nests (Hall 2007, Hall 2008).

Peregrine Falcon
The peregrine falcon (Figure 4.9.2-5) preys mostly on other birds, but may also take prey such as bats. It can reach speeds of up to 112 km/h (69 mph) while flying after its prey, and much higher speeds can be

attained as it drops from high in the sky (with wings closed) to obtain prey. In the middle 1900s, the species was extremely low in numbers due to poisoning by the pesticide DDT. It was listed under the Endangered Species Conservation Act of 1969 (the precursor to the Endangered Species Act) in 1970. Through extensive recovery efforts and the banning of DDT, the species recovered enough to be removed from the Endangered Species List in 1999. The peregrine falcon may be found in Arizona year-round. It prefers open landscapes with cliffs (or skyscrapers in cities) for nesting, where it lays 2-5 eggs (Cornell Lab of Ornithology 2015).

Golden Eagle

One of the largest and fastest raptors in North America, the golden eagle (Figure 4.9.2-6) preys mostly on small and medium-sized mammals, such as the jackrabbit. Golden eagles locate their prey while soaring, flying close to the ground, or perch hunting. They use habitat that is partly or completely open, particularly in proximity to hills, mountains, and cliffs. They nest on steep escarpments and cliffs in areas such as grasslands, shrublands, and forests. Golden eagles may use the same nest for multiple years, and the large nests average 1.5 to 1.8 m (5-6 ft) wide and 0.6 m (2 ft) high. They lay one to three eggs (Cornell Lab of Ornithology 2015).

4.9.3. Reference Conditions

No reference conditions were developed for the first measure under the first indicator in this assessment (i.e., species presence/absence). This is because there are not two survey/monitoring efforts that have been conducted using similar methods in the same habitats (other than for ponderosa pine) at different points in time. Therefore, for the first measure, we presented the information available on the types and number of species that have been recorded in the park under the different survey or observation efforts, as well as some information on the most commonly observed species during the surveys.

Reference conditions were developed for the remaining measures used in the assessment, occurrence of species of conservation concern, and status of selected species (Table 4.9.3-1). Reference conditions are described for resources (i.e., species) in good, moderate concern, and significant concern conditions.

4.9.4. Condition and Trend

Species Presence/Absence

A total of 121 bird species have been recorded at Walnut Canyon NM or otherwise appear on the NPSpecies list for the park (NPS 2016b; Appendix F). As shown in the appendix, a total of 96 species were reported by Haldeman and Clark (1969; minus a few entries that have changed taxonomically over time [e.g., being combined with other species]). Short (2002) recorded a total of 42 species in ponderosa pine habitat during her surveys. Holmes et al. (2011) recorded a total of 62 species in ponderosa pine habitat and 53 species in riparian habitat, for a total of 75 species during their two years of surveys. A total of 108 species appear on the NPSpecies list, including 10 that did not appear on any of the other survey/report lists. Thirteen of the 121 species are not listed by NPS (2016); eight of these were observed by Holmes et al. (2011), and five were reported by Haldeman and Clark (1969).

Figure 4.9.2-5. Peregrine falcon. Photo Credit: © Robert Shantz.

Figure 4.9.2-6. Golden eagle adult and young. Photo Credit: © Harry Engels.

Table 4.9.3-1. Reference conditions used to assess birds at Walnut Canyon NM.

Indicator	Measure	Good	Moderate Concern	Significant Concern
Species Occurrence	Presence/Absence	No reference conditions were developed for this measure.	No reference conditions were developed for this measure.	No reference conditions were developed for this measure.
	Presence of Species of Conservation Concern	A moderate to substantial number of species of conservation concern occur at the national monument, meaning that the park provides important habitat for these species and contributes to their conservation.	A small number of species of conservation concern occur at the national monument.	No species identified as species of conservation concern have been recorded in the national monument.
Status of Selected Species	Occupancy / Use of Nesting Territories [3 measures, one for each species: Northern goshawk, Peregrine falcon, Golden eagle]	Use of nesting territories within the national monument has increased or remained stable over the years monitored.	Use of nesting territories within the national monument has fluctuated (more than would be expected) or decreased somewhat over the years monitored.	Use of nesting territories within the national monument has fluctuated considerably (more than would be expected) or decreased substantially over the years monitored.

Two of the survey efforts occurred in the same habitat type. Both Short (2002) and Holmes et al. (2011) sampled in ponderosa pine habitat. Short (2002) reported six species that were not reported by Holmes et al. (2011) in ponderosa pine. However, Holmes et al. (2011) reported 26 species in their more recent surveys in ponderosa pine that were not reported by Short (2002). Holmes et al. (2011) noted that many of the differences may have been due to the areas sampled in one versus the other study. Short sampled only in ponderosa pine south of the canyon, while Holmes et al. (2011) sampled in ponderosa pine both south and north of the canyon. The northern areas sampled were closer to development and NPS buildings, while those south of the canyon were more remote. For example, three species associated with human development were observed by Holmes et al. (2011) north of the canyon but not south of the canyon by either of the two sets of surveys; these species were house finch (*Carpodacus mexicanus*), northern mockingbird (*Mimus polyglottos*), and Eurasian collared-dove (*Streptopelia decaocto*; Holmes et al. 2011).

We present the following information because it is from the most recent inventory of birds within the national monument. In ponderosa pine habitat, Holmes et al. (2011) recorded 1,283 individual birds of 62 species during their surveys. The species recorded in the greatest number was violet green swallow (*Tachycineta thalassina*), which accounted for over 9% of the total number of birds recorded (Table 4.9.4-1). For the species shown in the table, the percentage of plots with detections of the species is also shown, which gives an indication of species distribution across the area sampled. In ponderosa pine habitat, the average bird species richness (unadjusted for detectability) per VCP count was 8.20 (n=118, SD=2.82).

Cavity nesting species comprised a substantial proportion of the ponderosa pine bird community at the park (i.e., 28.6% of all species in the habitat type; Holmes et al. 2011). The authors also reported that 10 of the 20 species most commonly detected are either primary cavity excavators or secondary cavity nesters.

In canyon riparian habitat, Holmes et al. (2011) recorded 486 individual birds of 53 species during their surveys. The species recorded in the greatest number was spotted towhee (*Pipilo maculatus*), which accounted for over 13% of the total number of birds recorded (Table 4.9.4-2). For the species shown in the table, the percentage of plots with detections of the species is also shown. In canyon riparian habitat, the average bird species richness (unadjusted for detectability) per VCP count was 12.15 (n=40, SD=4.06).

As described elsewhere, the habitat sampled as canyon riparian habitat included the riparian vegetation along the canyon bottom, as well as the north-facing canyon slopes and the south-facing canyon slopes. A diverse bird community was found within this variety of

Table 4.9.4-1. The ten most commonly detected species during surveys in ponderosa pine habitat at Walnut Canyon.

Species	% of all Detections	% of Plots with Detections
Violet-green swallow	9.12	75.76
Ash-throated flycatcher	6.86	84.85
Purple martin	6.31	72.73
Pygmy nuthatch	5.30	72.73
Steller's jay	4.99	69.70
White-breasted nuthatch	4.60	81.82
Acorn woodpecker	4.36	57.58
Plumbeous vireo	3.90	69.70
Mountain chickadee	3.66	75.75
Western bluebird	3.27	66.67

Source: Holmes et al. (2011).

Table 4.9.4-2. The ten most commonly detected species during surveys in canyon riparian habitat at Walnut Canyon.

Species	% of all Detections	% of Plots with Detections
Spotted towhee	13.58	82.50
Canyon wren	11.73	82.50
Black-headed grosbeak	10.08	77.50
Common raven	7.61	57.50
Broad-tailed hummingbird	5.56	50.00
Yellow-warbler	4.32	37.50
Black-chinned hummingbird	3.91	40.00
Steller's jay	3.09	32.50
Turkey vulture	2.88	27.50
Lesser goldfinch	2.26	25.00

Source: Holmes et al. (2011).

habitats (Holmes et al. 2011). These species included the yellow warbler (*Setophaga petechia*), a riparian obligate species, as well as painted redstart (*Myioborus pictus*), spotted towhee, and peregrine falcon (*Falco peregrinus*).

As discussed previously in the assessment, we did not develop reference conditions for this measure. However, because it is clear that a substantial number of bird species have been documented (or more casually observed) in Walnut Canyon NM within the variety of plant communities occurring in the monument, we consider condition under this measure to be good. Our confidence in the measure, however, is low. The Holmes et al. data are now about seven years old, and the Short data are older..

<u>Presence of Species of Conservation Concern</u>

There are 37 species that have been recorded during one or more of the surveys/studies at Walnut Canyon NM (or that otherwise appear on the NPSpecies List for the park or the Haldeman and Clark [1969] list) that are listed as species of conservation concern on one or more of the lists described in Section 4.9.2 (Table 4.9.4-3). Eighteen of the 37 species were recorded in at least one of the two survey efforts (Short 2002 or Holmes et al. 2011), including seven species that were recorded in both of the surveys.

- USFWS / Listed Species: One threatened or endangered species is known to occur at Walnut Canyon NM- the Mexican spotted owl (*Strix occidentalis lucida*), a threatened subspecies of the spotted owl. This species is discussed in detail in a separate assessment. Table 4.9.4-3 includes the willow flycatcher (*Empidonax traillii*), but only the southwestern willow flycatcher (*Empidonax traillii extimus*) is listed under the ESA. The willow flycatcher has not been recorded during any of the surveys at the park, but it is included on the NPSpecies List for the park and was noted as recorded in 1933 by Haldeman and Clark (1969). Those records do not indicate that it is for the endangered subspecies. We included it in the table to present all information related to the species, and because the overall species and subspecies appear on other species of conservation concern lists. The endangered subspecies is known to occur in Coconino County (USFWS 2016d).
- USFWS / Birds of Conservation Concern: There are 21 species that have been recorded at the national monument that have been identified by USFWS as having the greatest conservation need at a National, USFWS Regional, or BCR geographic scale (USFWS 2008a). Note that while the park is entirely within BCR 34, we also

Table 4.9.4-3. Bird species detected at Walnut Canyon NM that are of conservation concern.

Species	Federal[1]	US Fish & Wildlife Service				NABCI[2]	Partners in Flight National Conservation Strategy[3]				State (AGFD)[4]
							BCR 34		BCR 16		
	USFWS	National	Region 2	BCR 34	BCR 16	2014 Watch List	CC	RC	CC	RC	Species of Greatest Conservation Need
American Kestrel	–	–	–	–	–	–	–	X	–	–	–
Bald Eagle	–	X	X	X	X	–	–	–	–	–	1A
Band-tailed Pigeon	–	–	–	–	–	Yellow	–	–	–	–	1C
Black-chinned Sparrow	–	X	X	X	–	Yellow	X	X	X	–	1C
Black-throated Gray Warbler	–	–	–	X	–	–	–	X	–	X	1C
Brewer's Sparrow	–	X	–	–	X	–	–	–	–	X	1C
Broad-tailed Hummingbird	–	–	–	–	–	–	–	X	–	–	–
Cassin's Finch	–	–	–	–	X	Yellow	–	–	X	X	–
Clark's Nutcracker	–	–	–	–	–	–	–	–	–	X	–
Common Nighthawk	–	–	–	–	–	–	–	X	–	X	1B
Common Poorwill	–	–	–	–	–	–	–	–	–	X	1C
Evening Grosbeak	–	–	–	–	–	Yellow	–	X	–	–	1B
Ferruginous Hawk	–	–	–	–	X	–	–	–	–	X	1B
Flammulated Owl	–	X	X	X	X	Yellow	X	–	X	–	1C
Golden Eagle	–	–	X	–	X	–	–	X	–	X	1B
Grace's Warbler	–	X	X	X	X	–	–	X	–	–	1C
Juniper Titmouse	–	–	–	–	X	–	–	X	–	–	1C
Lazuli Bunting	–	–	–	–	–	–	–	–	–	X	1C
Lewis's Woodpecker	–	X	X	X	X	Yellow	–	X	–	X	1C
Loggerhead Shrike	–	X	X	–	–	–	–	–	–	X	–
MacGillivray's Warbler	–	–	–	–	–	–	–	–	–	–	1B
Mountain Bluebird	–	–	–	–	–	–	–	–	–	X	1C
Northern Goshawk	–	–	–	–	–	–	–	X	–	–	1B
Olive warbler	–	–	X	X	–	–	–	–	–	–	1C
Olive-sided Flycatcher	–	X	–	–	–	Yellow	X	–	X	X	1C
Painted redstart	–	–	–	–	–	–	–	X	–	–	1C
Peregrine Falcon	–	X	X	X	X	–	–	–	–	–	1A
Pinyon Jay	–	X	X	X	X	Yellow	X	X	X	X	1B
Plumbeous Vireo	–	–	–	–	–	–	–	X	–	–	–
Prairie Falcon	–	–	–	–	X	–	–	X	–	X	1C
Red-faced Warbler	–	X	X	X	–	–	–	X	–	–	1C

[1] Federally Listed Species Codes
T = Threatened E = Endangered

[2] NABCI- 2014 Watch List
Red List or Yellow List

[3] PIF NCS Categories
CC = Continental Concern RC = Regional Concern

[4] Species of Greatest Conservation Need
1A, 1B, or 1C (lowest category)

[5] Listing is for the Mexican spotted owl only (*Strix occidentalis lucida*), which occurs and is monitored within the monument.

[6] Listing is for a non-ESA-listed subspecies or population of spotted owl.

[7] Listing is for the extimus subspecies only (*Empidonax traillii extimus*, the southwestern willow flycatcher).

[8] Listing is for a non-ESA-listed subspecies or population of willow flycatcher.

Table 4.9.4-3 continued. ***Bird species detected at Walnut Canyon NM that are of conservation concern.***

Species	Federal[1]	US Fish & Wildlife Service				NABCI[2]	Partners in Flight National Conservation Strategy[3]				State (AGFD)[4]
	USFWS	National	Region 2	BCR 34	BCR 16	2014 Watch List	BCR 34		BCR 16		Species of Greatest Conservation Need
							CC	RC	CC	RC	
Rufous Hummingbird	–	X	–	–	–	Yellow	–	–	–	–	–
Sharp-shinned Hawk	–	–	–	–	–	–	–	X	–	–	–
Spotted Owl	T [5]	–	–	–	–	Yellow[5]	X [6]	X [6]	X [6]	X [6]	1A [5]
Virginia's Warbler	–	X	–	–	–	Yellow	X	–	X	–	1C
Willow Flycatcher	E [7]	X [8]	–	–	X [8]	Red [7]	–	–	–	–	1A [7]
Yellow Warbler	–	–	–	–	–	–	–	–	–	–	1B

[1] Federally Listed Species Codes
T = Threatened E = Endangered

[2] NABCI- 2014 Watch List
Red List or Yellow List

[3] PIF NCS Categories
CC = Continental Concern RC = Regional Concern

[4] Species of Greatest Conservation Need

1A, 1B, or 1C (lowest category)

[5] Listing is for the Mexican spotted owl only (*Strix occidentalis lucida*), which occurs and is monitored within the monument.

[6] Listing is for a non-ESA-listed subspecies or population of spotted owl.

[7] Listing is for the extimus subspecies only (*Empidonax traillii extimus*, the southwestern willow flycatcher).

[8] Listing is for a non-ESA-listed subspecies or population of willow flycatcher.

reviewed the list of birds for BCR 16 since it is nearby.

- NABCI: There are 11 species (not including the southwestern willow flycatcher, discussed under the first bullet) that have been recorded in the national monument (or otherwise occur on the NPSpecies or Haldeman and Clark lists) that are included on the NABCI 2014 Watch List. All 11 of the species are on the Yellow List.
- PIF: Twenty-eight of the bird species in Table 4.9.4-3 are listed by PIF as either CC or RC (recall we did not include the stewardship categories). Twenty-one species are listed for BCR-34 (in which the park is located) and 19 species are listed for BCR-16. Eleven of the species are listed for both BCRs.
- Arizona SGCN: Eleven of the species listed in Table 4.9.4-3 are considered Tier 1A or 1B SGCN in Arizona (excluding southwestern willow flycatcher, which has not specifically been recorded in the park). Two of the species appear only on this list (Yellow warbler and MacGillivray's warbler [*Geothlypis tolmiei*]). Additional species are considered Tier 1C, but we only show those species if they were also included on at least one of the other species of conservation concern lists.

The focus of this measure is on the bird species for which the national monument can play a role in their conservation. Eighteen of the species recorded during one or both of the surveys conducted in 1999-2001 and 2009-2010 are considered species of conservation concern on one or more lists. Nineteen additional species of conservation concern appear on the NPSpecies list and/or the Haldeman and Clark (1969) list. In accordance with our reference conditions, we consider condition for this measure to be good. It seems clear that the relatively small Walnut Canyon NM, with its diversity of plant communities and microhabitats, provides important habitat to the region's avifauna, including those most in need of conservation. The trend in condition is unknown. We have medium confidence in this measure because the most recent species-wide surveys were conducted in 2009-2010. However, as discussed for the next indicator, four of the raptor species (including the Mexican spotted owl) are monitored annually or in most years during the breeding season.

<u>Occupancy/Use of Nesting Territories- Northern Goshawk</u>

A summary of the nesting survey results for the northern goshawk from 2006-2016 is presented in Table 4.9.4-4). As seen from the table, only one nest (with one fledged juvenile) has been recorded over the

Table 4.9.4-4. Summary of raptor nesting surveys at Walnut Canyon NM.

Year	Northern Goshawk	Peregrine Falcon	Golden Eagle	Great Horned Owl
2006	1 nest, 1 fledge	not surveyed	not surveyed	not surveyed
2007	0	not surveyed	0	not surveyed
2008	0	1 nest, 2 fledges	1 nest, 1 fledge	not surveyed
2009	0	1 nest, 0 fledges	1 nest, 1 fledge	not surveyed
2010	not surveyed	not surveyed	0	not surveyed
2011	not surveyed	1 nest, 3 fledges	1 nest, 2 fledges	not surveyed
2012	0	1 nest, 3 fledges	1 nest, 0 fledges	not surveyed
2013	0	1 nest, 2 fledges	1 nest, 1 fledge	2 nests, 4 fledges
2014	not surveyed 3 wildlife camera detections	1 nest, 2 fledges	1 nest, 1 fledge	not surveyed
2015	0 2 wildlife camera detections	1 nest, 3 fledges	1 nest, 1 fledge	1 nest, 2 fledges
2016	0	1 nest, 2 eggs	1 nest, 2 fledge	not surveyed

Source: Mark Szydlo, Biologist, Flagstaff Area NMs.

past 11 years. Furthermore, this one nest was present in 2006; no nesting has been confirmed in the park for over 10 years.

Hall (2008) reported that goshawks nested and successfully fledged young in one of the PFAs in 1999, 2000, and 2004-2006. In her 2008 report, Hall suggested some possible reasons for the observed lack of breeding activity in 2008; these potential reasons were that one of the pair had died and not yet been replaced; the pair had moved to a new location outside of the area surveyed; or the pair was inactive in the year surveyed. Hall (2008) also suggested disturbance may have played a role in the lack of nesting. In 2006, there was a wildland fire in the adjacent drainage caused by lightning, and actions to suppress the fire may have disturbed the pair to an extent, which caused them to leave (Hall 2008). In 2007, Hall (2007) reported that northern goshawks were present, although not breeding, in the PFA. Flagstaff Area National Monuments personnel have also suggested the possibility of the quality of their habitat being affected due to the mortality of large trees used for nesting (Paul Whitefield, Natural Resources Specialist, Flagstaff Area NMs, pers. comm.; Figure 4.9.4-1).

In the other PFA, breeding has not been documented since the early 1990s (Hall 2008). The author noted that it was unclear whether goshawks had abandoned the PFA or were affected by drought.

Based on the information presented here and our reference conditions, we consider condition under this measure to be of moderate concern. Although northern goshawks have been observed within the park on occasion (such as by stationary park wildlife cameras in 2014 and 2015 (see Table 4.9.4-4), the PFAs within the park have not been known to be occupied for nesting since 2006. We consider the trend to be unknown and our confidence is medium, because in some of the recent years (2010, 2011, and 2014) no monitoring was conducted. It should also be noted that some periods of inactivity at other PFAs (in the Coconino National Forest) have been noted, with the periods of inactivity followed by a return of nesting (Hall 2008a).

<u>Occupancy/Use of Nesting Territories- Peregrine Falcon</u>

A summary of the results of nesting surveys for the peregrine falcon from 2006-2016 is presented in Table 4.9.4-4. As seen from the table, surveys were not conducted for the species in three of the years. However, for the other eight years, surveys were conducted and a nest was recorded in every year, including the last six years. In at least six of the eight years, two or three young fledged. For the other two

Figure 4.9.4-1. Large, dead ponderosa pine trees in habitat used by northern goshawk. Photo Credit: NPS.

of the eight years, no young were fledged in one of the years, and the nest was last observed during the egg stage in 2016.

Based on our reference conditions and the nesting information from 2006-2016, we consider current condition to be good for the peregrine falcon. The trend is unchanging, and our confidence in the measure is high. However, also see the Threats section at the end of the assessment.

Occupancy/Use of Nesting Territories- Golden Eagle

As for the other species, a summary of the results of nesting surveys for the golden eagle from 2006-2016 is presented in Table 4.9.4-4. This species was surveyed during the breeding season for at least 10 of the last 11 years. Golden eagles nested in eight of the 10 years, including in the last six years. Nests were successful, fledging one or two young, in all but one of the years. In 2016, two young fledged.

Based on our reference conditions and the nesting information from 2006-2016, we consider current condition to be good for the golden eagle. The trend is unchanging, and our confidence in the measure is high. However, also see the Threats section at the end of the assessment.

Great horned owl

We did not include a measure for the great horned owl because nesting surveys were conducted for the species in only a few of the last 11 years (Table 4.9.4-4). Some successful nesting has been documented in the park, with up to two nests located in 2013; four young fledged from these two known nests.

Status of Selected Species Indicator Summary

In this measure we assessed the condition of three raptor species in Walnut Canyon NM by focusing on their occupancy/use of nesting territories within the national monument. We consider current condition and trend of two of the species (peregrine falcon and golden eagle) to be good (condition) and unchanging (trend). We consider the condition of the third species, northern goshawk, to be of significant concern with an unknown trend. Although northern goshawks have been observed in the park, including as recently as 2014 and 2015, the PFAs have not been occupied for nesting in approximately 10 years.

Overall Condition, Trend, Confidence Level, /and Key Uncertainties

To assess the condition of birds at Walnut Canyon NM, we used two indicators with a total of five measures, which are summarized in Table 4.9.4-5. A total of approximately 80 species have been recorded during the two survey efforts reviewed in this assessment, and an additional ~41 species occur on the NPSpecies list and/or Haldeman and Clark (1969) list for the park. The most recent inventory surveys within the park were conducted in ponderosa pine and canyon riparian habitats in 2009-2010. Condition for species presence/absence was considered good because of the substantial number of bird species that have been documented/reported in the park, but our confidence in the measure is low due to the age of the survey. Among these species are 37 that are considered species of conservation concern on one or more of the organizational/governmental lists we reviewed for the assessment. This includes 18 species that were documented during surveys by Short (2002) and/or Holmes et al. (2011). We considered condition good

Table 4.9.4-5. Summary of birds indicators, measures, and condition rationale.

Indicators of Condition	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Species Occurrence	Species Presence/ Absence		A total of 121 birds have been documented at Walnut Canyon NM or appear on the NPSpecies list and/or Haldeman and Clark (1969) list. Short (2002) recorded 42 species in ponderosa pine habitat during surveys in 1999-2001, and Holmes et al. (2011) recorded 62 species in ponderosa pine and 53 species in riparian habitat during their 2009-2010 surveys, the most recent for the park. We consider condition under this measure to be good due to the substantial variety of species that have been recorded, but our confidence in the assessment is low due to the age of the surveys.
	Presence of Species of Conservation Concern		Of the 121 bird species that have been reported for the park, 37 are species of conservation concern on one or more government/organization lists. Eighteen of these species were observed by at least one of the two surveys in the park- Short (2002) and Holmes et al. (2011). Condition for this measure is good, as the national monument provides habitat for a number of species in particular need of conservation. Trends are unknown, and confidence in the assessment is medium.
Status of Selected Species	Northern Goshawk		We consider condition under this measure to be of moderate concern. Northern goshawks have been observed in the park on occasion in recent years, but the PFAs monitored within the park have not been occupied for nesting since 2006. The trend is unknown and our confidence is medium; no monitoring was conducted in some recent years (2010, 2011, 2014). Also, Hall (2008) notes that periods of inactivity at PFAs of several years have been observed in Coconino National Forest. It is possible that goshawks may return to nest in the national monument.
	Peregrine Falcon		Based on our reference conditions and the nesting information from 2006-2016, we consider current condition to be good for the peregrine falcon. Surveys were conducted for the species in eight of the 11 years, and a nest was recorded in every year (including the last six years). In most years, two or three young fledged. Based on the data, the trend appears unchanging, and our confidence in the measure is high.
	Golden Eagle		Condition for the golden eagle is good. Golden eagles nested in eight of the last 10 years surveyed, including in every year of the the last six years. Nests were successful, fledging one or two young, in all but one of the years. In 2016, two young fledged. Based on these data, the trend appears unchanging, and our confidence in the measure is high.
Overall Condition			We used two indicators to assess the condition of birds. Condition under the first indicator was good for both measures, although confidence was low for the first measure. Condition for the second indicator was of moderate concern for one measure (with medium confidence) and good for the other two measures (with high confidence). We consider overall condition to be good, and overall, our confidence is medium. In general, trends are unknown. As described, some concern exists for the northern goshawk.

under this measure, acknowledging that the national monument provides habitat for a number of species in particular need of conservation. Providing habitat for these species, whether it is during the breeding or non-breeding season, contributes to their conservation.

For the second indicator, status of selected species, we examined the use/occupation of nesting territories for three raptor species. The current condition of two of the species is good, and the trend appears unchanging; our confidence in these measures is high. For the third species, northern goshawk, we consider current condition to be of moderate concern based on the information available. However, the trend is unclear, and our confidence is only medium. Individual northern goshawks have been documented in the park in the last few years. Park personnel have suggested that the loss of large ponderosa pine trees within their nesting area may be the reason for their lack of breeding (Paul Whitefield, Natural Resources Specialist, Flagstaff Area NMs, pers. comm.).

Overall, we considered current condition to be good. However, some concern exists for the northern goshawk, which has not has not occupied the mainly-used PFA in the national monument since 2006. Continued nesting season surveys will help determine whether this species will again nest in the park. Also, see the discussion below about the uncertainties associated with the Northern Arizona Shooting Range. The overall trend is unknown, and overall confidence is medium. For more of a discussion on the condition and status of ponderosa pine habitat in Walnut Canyon NM, which relates to the discussion of northern goshawk.

One of the main uncertainties in this assessment is with the current condition of bird species presence/absence. The most recent inventory of birds within the park was conducted in 2009-2010, approximately seven years ago. Also, some areas of the park were not surveyed (see Figure 4.9.2-3).

Threats, Issues, and Data Gaps

There are threats that are common to many bird species, including birds that occur within Walnut Canyon NM. Migratory and other bird species face threats throughout their range, 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 2016e). The federal Migratory Bird Treaty Act protects more than 1,000 species of birds, and many of these species are experiencing population declines because of increased threats within their range (USFWS 2016e). Also, across the U.S., free-ranging domestic cats may be responsible for as many as one billion bird deaths each year (Wildlife Society 2011, Loss et al. 2013).

In Walnut Canyon NM, specifically, two issues that are important at the present time are negative effects on habitat from the loss of large ponderosa pine trees, and potential noise and disturbance effects from the development and use of a shooting range adjacent to the park.

The loss of large ponderosa pine trees in northern goshawk nesting habitat was mentioned under the assessment's second indicator. As discussed, park personnel believe that the loss of such trees may have contributed to the cessation of nesting within the park where goshawks had previously nested. The separate assessment on Ponderosa Pine Vegetation presents much more information on the current condition and trend of ponderosa pine habitat within the national monument.

The Northern Arizona Shooting Range is being developed by the AGFD (http://www.azgfd.gov/outdoor_recreation/nazsr.shtml). The shooting range is south of the park (and closest to the eastern half of the park), and, depending on the location within the park, is anywhere from approximately 1.6 km to 8.0 km (1-5 mi) away. The shooting range includes a new road, facilities for the range, and operation of various, specific ranges (e.g., trap and skeet, sporting clays, and a rifle/pistol range; http://www.northernarizonashootingrange.org/). Concerns exist that aspects of the shooting range (e.g., vehicle traffic and noise disturbance, and the noise and disturbance of gunshots) could affect breeding raptors, potentially their prey, and other bird species. According to information provided by Flagstaff Area NMs personnel, either active (as of 2016) or historic nest sites of Mexican spotted owl, golden eagle, peregrine falcon, and northern goshawk are within 4.0 km (2.5 mi) of the shooting range. Hearing is a critical sense for birds and other wildlife. The ability to hear is vital in activities such as courtship, predation, predator avoidance, and effective use of habitat, and studies have found that wildlife can be adversely affected by intrusive sounds. Although the extent to which impacts occur varies depending on the species and other factors, documented responses of wildlife to noise include increased heart rate, startle responses, flight, disruption of behavior, separation of mothers and young, and interference with communication (Selye 1956, Clough 1982, USFS 1992, Anderssen et al. 1993, NPS 1994, Dooling and Popper 2007, Kaseloo 2006).

Park personnel are presently conducting a study on noise from the shooting range. They are collecting data on sounds heard at different distances away from the range (data collected in 2014-2016), but a report from the study will not be available until 2017 (Mark Szydlo, Biologist, Flagstaff Area NMs, pers. comm.). It's important to note that they have attempted to lessen the gun noise by building up a 3 m (10 ft) earthen berm (Lisa Leap, Chief of Resources, pers. comm.). The shooting range is also addressed in the soundscape assessment of this report.

4.9.5. Sources of Expertise

No outside experts were consulted for this condition assessment. This section was written by biologist and writer Patty Valentine-Darby, Utah State University.

4.10. Mexican Spotted Owl (*Strix occidentalis lucida*) and Inner Canyon Environment

4.10.1. Background and Importance

The Mexican spotted owl (*Strix occidentalis lucida;* MSO) is a medium-sized owl that is brown in color, with irregular white and brown spots on its otherwise brown abdomen, back, and head (U.S. Fish and Wildlife Service [USFWS]; Figure 4.10.1-1). Males and females are very similar in appearance, but age classes can be distinguished by plumage (Forsman 1981, Moen et al. 1991). The MSO is one of three subspecies, with the other two subspecies being the Northern spotted owl (*S. o. caurina*) and the California spotted owl (*S. o. occidentalis*). The MSO was listed as threatened under the Endangered Species Act (ESA) in 1993 (USFWS 1993). The USFWS implemented a recovery plan for the owl in 1995, and the plan was updated and revised in 2012 (USFWS 2012). Critical habitat for the MSO was designated in 2004 and includes about 3.5 million hectares (ha; 8.6 million acres) on federal lands in Arizona, New Mexico, Colorado, and Utah (USFWS 2004, USFWS 2012). The primary reasons for listing the owl in 1993 were historical alteration of its habitat due to timber management practices, and the threat of the practices continuing (USFWS 2012). In 2012, USFWS stated that the primary threats to the U.S. population are an increased risk of landscape level stand-replacing wildland fire and forest management practices.

The MSO has an expansive range, occurring in forested mountains and rocky canyonlands throughout the southwestern U.S. (Utah, Colorado, Arizona, New Mexico, and western Texas) and Mexico (USFWS 2012). The owl, however, is patchily distributed within its range, and within Arizona is known to occur in at least 13 counties (including Coconino). Within the central/east-central part of the state, the MSO inhabits forested mountains and canyons with mixed-conifer, ponderosa pine (*Pinus ponderosa*)-Gambel oak (*Quercus gambelii*), and/or riparian forests (Ganey et al. 2011).

Based on the available information, Mexican spotted owls are more selective when choosing habitat for roosting and nesting, as compared to habitat for foraging (Ganey et al. 2011). Owls use mixed-conifer forest the most for roosting and nesting, followed by ponderosa pine-Gambel oak forest; ponderosa pine and riparian forest are used to a lesser extent. Douglas-fir (*Pseudotsuga menziesii*)-Gambel oak forest is a type of mixed-conifer forest. Areas used for roosting and nesting usually have a high canopy cover (≥50%), high basal area (≥19.5 m^2 per ha [≥85 ft^2 per ac]), and large trees (Ganey et al. 2011).

Mexican spotted owls are known to occur in Walnut Canyon NM, and most of the park occurs within

Figure 4.10.1-1. Adult and juvenile Mexican spotted owls at Walnut Canyon NM. Photo Credit: NPS.

federally-designated critical habitat for the subspecies. This area falls within the Upper Gila Mountains Ecological Management Unit (UGM EMU), which is one of five EMUs for the MSO throughout its U.S. range (USFWS 2012). More than one-half of the known population of the subspecies occurs within the UGM EMU (Ganey et al. 2011). It should be noted that in the 1995 Recovery Plan, the owl's range was divided into six recovery units (RUs), which were later renamed EMUs (and two of the original RUs were combined to result in five EMUs; USFWS 2012). The configuration of the UGM EMU was not changed in 2012. Walnut Canyon NM falls within the UGM EMU #12 (Figure 4.10.1-2), which also includes areas of the Coconino National Forest (NF).

Approximately 730 ha (1,800 ac) of land within Walnut Canyon NM is considered MSO habitat (USFWS 2012; Figure 4.10.1-3). This habitat consists of Douglas-fir-Gambel oak and ponderosa pine-Gambel oak vegetation on steep slopes, the riparian corridor that runs along the bottom of the canyon, and patches of ponderosa pine-Gambel oak vegetation occurring on slopes less than 15%. In Walnut Canyon, the MSOs roost and nest most often in Douglas-fir-Gambel oak vegetation within the narrow canyon terrain, and they may also use crevices in the bedrock along the lower canyon walls (Szydlo et al. 2015). These forest types are also used for foraging, as are adjacent pinyon-juniper woodlands (Hart 2005). The owl's main prey species at the national monument are woodrats (*Neotoma* spp.), white-footed mice (*Peromyscus* spp.), voles (*Microtus* spp.), and cottontail rabbits (*Sylvilagus* spp.) (Ganey 1992). Detailed descriptions of the forest and habitat types used by the MSO are provided in Ganey et al. (2011) and USFWS (2012).

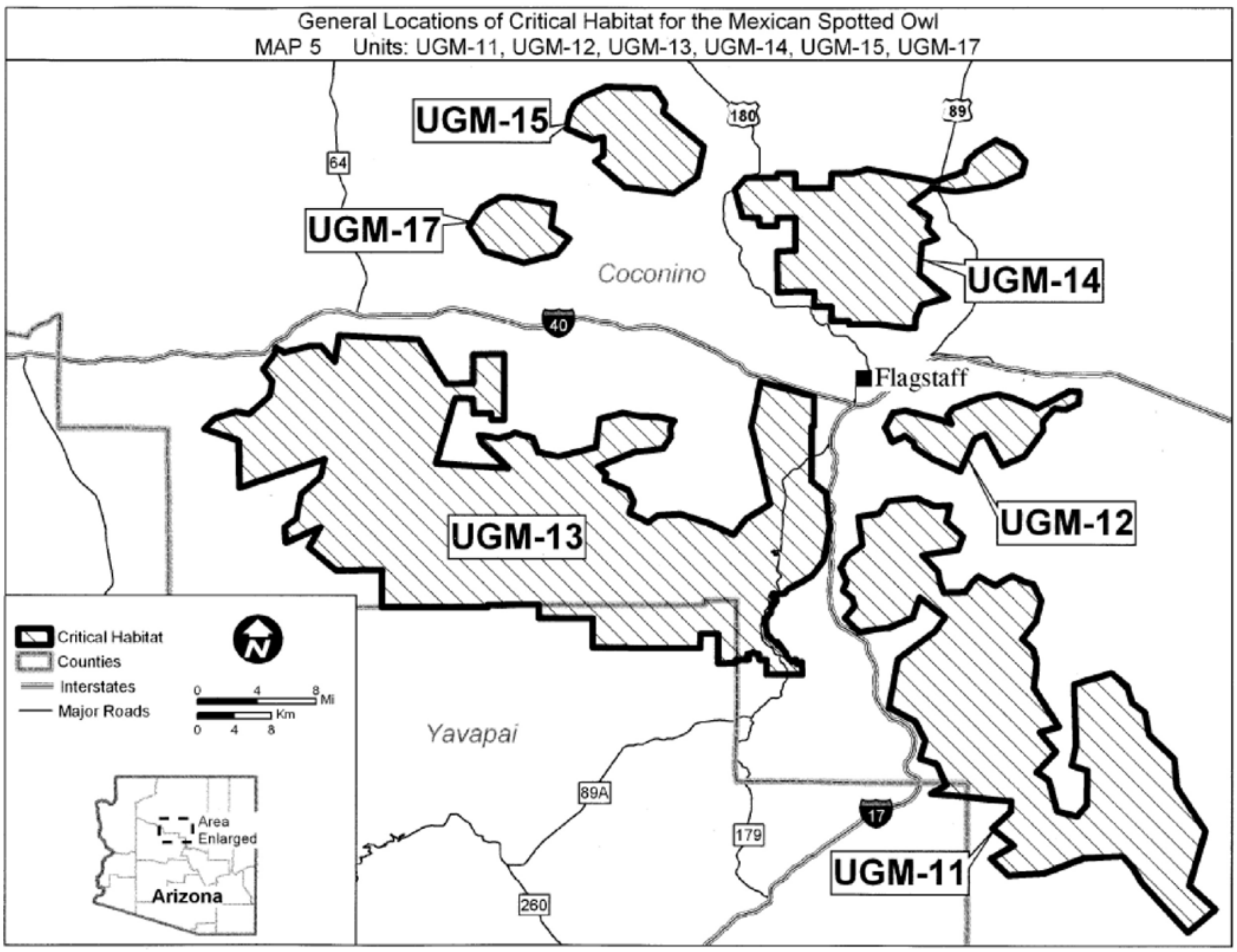


Figure 4.10.1-2. General locations of critical habitat for the Mexican spotted owl within the Upper Gila Mountains EMU, including UGM-12, which includes Walnut Canyon NM. Figure Credit: USFWS (2004).

Figure 4.10.1-3. MSO habitat within Walnut Canyon NM. Photo credit: NPS.

The MSO habitat at Walnut Canyon NM does not cleanly fit the description of the "mixed conifer" forest type or the "rocky canyon" habitat type, but rather, the habitat in the national monument is somewhat of a blend of both habitats (Paul Whitefield, Natural Resource Specialist, Flagstaff Area NMs, pers. comm.). The habitat includes two midstory trees, Gambel oak and Rocky Mountain juniper (*Juniperus scopulorum*), which provide crucial hunting and shade day-roost perches (as observed by Flagstaff Area NMs staff). Box elder (*Acer negundo*) and Gambel oak along the canyon bottom corridor are also used for perches.

Based on MSO monitoring results in the 1990s, four MSO Protected Activity Centers, or PACs, were designated within and extending outside of the national monument (Hart 2005, Szydlo et al. 2015; Figure 4.10.1-4), and several PACs have been designated on adjacent Coconino NF lands. [Note that Hart (2005) provides a history of designating the PACs within the park]. The four PACs within the park are named Cherry, Lucida, Breezy, and Walnut-33, and they include most of the steeply sloping canyon terrain within the national monument. The boundaries of the PACs were drawn to intentionally exclude the visitor center, Island Trail, and Ranger Ledge Cliff Dwellings (NPS 2004bb). According to USFWS (2012), PACs consist of at least 243 ha (600 ac) of land around known owl nest/roost sites. MSO Recovery Plan management recommendations are conservative within PACs, because nest/roost habitat is limiting for the owl throughout its range. However, there is recognition that habitat management is needed in some cases (e.g., to reduce fire risk) to maintain or enhance habitat conditions for the owl (USFWS 2012).

Mexican spotted owl activity within the national monument was first recorded in 1980 with the report of a roost site (Hart 2005, USFWS 2012 [p. 356]). Although no nest was located, a pair of owls was observed in the vicinity again in 1986. A brief history of MSO monitoring within the national monument is provided below. As described by Szydlo et al. (2015), the NPS monitors the MSO within the park as a conservation measure under the General Management Plan for the park (NPS 2007b) and under the Wildland Fire and Fuels Management Plan for the Flagstaff Area National Monuments (NMs; NPS 2007b, USFWS 2008b). NPS also monitors for the owl to have information available for assessing potential effects from management actions and projects, in accordance with Section 7 of the ESA. NPS engages in informal and/or formal consultation with the USFWS as appropriate for particular actions, projects, or programs (e.g., a consultation history from 1998-2012 is provided in Appendix C of Whitefield 2012).

This brief history of MSO monitoring within the national monument was taken from Szydlo et al. (2015), but it is in a condensed form.

> Some of the earliest ecological studies of MSO were conducted in Walnut Canyon during the 1980s (e.g., Ganey 1988). Systematic surveys for nesting MSO within the park and adjacent habitat on the Coconino National Forest were conducted from 1987 through 1999 by wildlife biologists with the AGFD, Coconino NF, and NPS (Hart 2005)… There were no surveys for MSO within the park from 2000 through 2003. Between 2004 and 2010, biologists with the Flagstaff Area National Monuments (NMs), U.S. Geological Survey Colorado Plateau Field Station, USFWS, and Northern Arizona University surveyed for MSO under various ESA Section 10 permits... Full surveys according to the recommended protocol (USFWS 2003) were completed… in 2004, 2008, 2009, and 2010. Partial surveys were conducted in 2005, 2006, and 2007, which focused on nest areas that were active during the 1990s, and on areas having MSO detections in mid-2000s surveys. Both full and partial surveys included nighttime

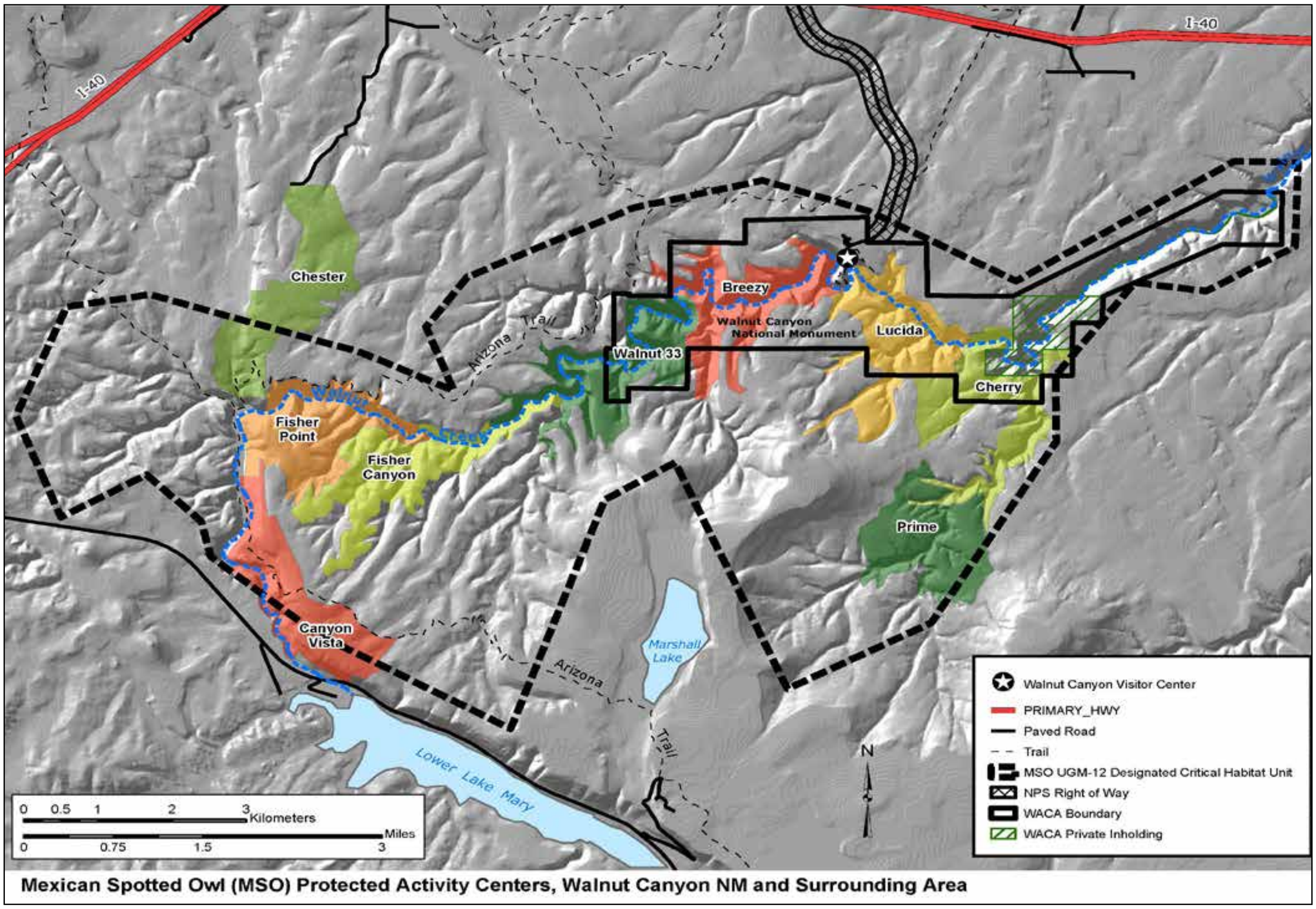


Figure 4.10.1-4. Map showing the four MSO PACs within Walnut Canyon NM and five PACS outside of the park, as well as the boundaries of the UGM-12 crtitical habitat unit. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction. Figure Credit: Flagstaff Area NMs.

broadcast-calling, listening sessions, and daytime follow-up searches in habitat where MSO calls had been detected.

Starting in 2010, personnel with the Flagstaff Area NMs have monitored MSOs using passive audio methods in which audio recorders are deployed in the field to record owl vocalizations during the breeding season (Whitefield and Hetzler 2012a, Whitefield et al. 2015, Hetzler et al. 2015, Szydlo et al. 2015). A network of 58 recorder stations has been used in the park since 2010 (Szydlo et al. 2015).

4.10.2. Data and Methods

This assessment of the MSO and inner canyon environment is based on the use of three indicators with a total of five measures. The first indicator, with one measure, focuses on the occurrence of the MSO at the national monument (based on annual breeding season surveys for the species). The second indicator focuses on the status/condition of the habitat used the most for nesting and roosting within the national monument-- Douglas-fir-Gambel oak forest. MSOs are most selective when choosing roosting and nesting habitat (Ganey et al. 2011). We include some discussion of other habitat types used for foraging and dispersal that also occur within the four designated PACs (Ponderosa pine-Gambel oak, and riparian habitat). We used three measures under this indicator, but two were used primarily for informational purposes. The last indicator/measure focuses on the level of human disturbance (e.g., from recreation, park operations) in MSO habitat within the park.

<u>Number of Adult MSO Pairs Exhibiting Territorial Occupancy</u>

Flagstaff Area NMs conducts monitoring for the MSO during the breeding season within the monument's four Protected Activity Centers (PACs). Under this indicator/measure, we present information on the number of MSOs that have been documented over the years, but we focus on results from monitoring within the park over the last seven years (2010-2016). Specifically, we present data on the number of adult MSO pairs exhibiting territorial occupancy. The 2010-2016 monitoring results were summarized for the report by Mark Szydlo, Biologist, with Flagstaff Area NMs. For supporting and additional details to the summary, we also relied on the annual reports of MSO monitoring using passive audio survey methods (Whitefield and Hetzler 2012a, Whitefield et al. 2015, Hetzler et al. 2015, Szydlo et al. 2015). Szydlo et al. (2015) was the most recent report available at the time of writing the assessment. The older reports of monitoring within the park were also used for this purpose (e.g., Hart 2005, Johnson et al. 2010). We refer the reader to those specific reports for details of monitoring methods. A primary assumption of the MSO monitoring using passive audio surveys is that the owls communicate at night using vocalizations (Szydlo et al. 2015). Adults on territories or MSO pairs will call frequently to one another as they become active at dusk or as they become less active at dawn. Within the national monument, the audio recorders are deployed within bedrock crevices, ledges, alcoves, or tree cavities within the inner canyon environment. The recorder stations are spaced apart so as to provide overlapping coverage of most suitable habitat within the park. It should be noted that detectability of all individual animals (in any wildlife survey) is never 100%, so a lack of detection does not necessarily mean that animals were not present.

<u>Total Area of Douglas-fir-Gambel Oak Cover</u>
Within Walnut Canyon NM, Mexican spotted owls have nested primarily in the Douglas-fir-Gambel oak community. For this reason, we focused our assessment of habitat within the national monument on this habitat/vegetation type. We used three measures under this indicator, but only one (total area of Douglas-fir-Gambel oak cover) was used to assess condition. The other two measures are provided primarily for informational purposes.

<u>Total Area of Douglas-fir-Gambel Oak Cover</u>
One of the 24 map classes (including 13 vegetation classes) used during the vegetation mapping project at the national monument was Douglas-fir-Gambel oak forest (Hansen et al. 2004). This map class/vegetation association occurs on the steep, north-facing walls of the canyon and its major tributaries. Within the park, the only species that consistently occurs in the understory of Douglas-fir is Gambel oak. The association occurs mainly at higher elevations within the park (from 1,980-2,130 m [6,496-6,988 ft]). All of the plots from the mapping project occurred on 15-65% slopes (average 50%). Within the national monument, associated species were Rocky Mountain juniper and ponderosa pine. It should also be noted that the Douglas-fir-Gambel oak association is also found in the Canyon Floor Complex map class (Hansen et al. 2004). The total area of Douglas-fir-Gambel oak forest within the national monument is discussed in the Condition section, as is the total vegetation cover and cover in the tree, shrub, and herbaceous layers according to that measured by Hansen et al. (2004).
This measure assesses condition by examining changes in area of the forest type over time. It should be noted that our main source of information for examining changes in area are communications with park natural resource personnel, photographs, data from the U.S. Forest Service (USFS) Forest Health Monitoring (FHM) Program, and other reports in the region and national monument on the mortality of trees (e.g., Ganey and Vojta 2011, Parker et al. 2003). This measure as assessed at the present time is qualitative due to the existence of only baseline information on the area of this vegetation association in the park (i.e., from Hansen et al. 2004). In the future, however, results of a currently ongoing project by NPS and Northern Arizona University (Measure Recent Change in Mexican Spotted Owl Habitat, Walnut Canyon NM) will be available to assess changes quantitatively.

<u>Minimum Tree Basal Area, and Minimum Density of Large Trees</u>
In the Recovery Plan for the MSO, the USFWS presents minimum desired conditions for mixed-conifer and pine-oak forests that are managed as nest/roost and nest/roost replacement habitat (USFWS 2012). Minimum desired conditions are provided for minimum (total) tree basal area (BA), minimum density of large trees, and percent BA by size class. We focus more on the first two, because they fit better with the data from the park available to us at this time. However, as discussed here and in the Condition section, the data available to use do not match closely with the metrics used by USFWS (2012). We used the numbers for mixed-conifer only, because our assessment focuses on Douglas-fir-Gambel oak forests. The values in the Recovery Plan are based on averages among plots sampled in forest stands (e.g., 27 stands for mixed-conifer forest applicable to the UGM

EMU). The Recovery Plan (USFWS 2012) stresses that the values provided are minimums, not targets.

For the UGM EMU, USFWS (2012) recommends a minimum tree BA of 27.5 m^2 per ha (120 ft^2 per acre) for mixed-conifer forest. These values are also applicable across three other EMUs. This minimum BA includes all trees of any species that are greater than 2.54 cm (1 inch) diameter-breast-height (DBH).

For the minimum density of large trees, USFWS (2012) considers "large trees" those > 46 cm (18 inches) DBH. The recommended minimum value is 30 trees per ha (12 per acre).

For the % BA by size class, two size classes are provided. USFWS (2012) recommends that >30% of the stand BA is composed of trees 30-46 cm DBH (12-18 in), and that >30% of the stand BA is composed of trees >46 cm (>18 in) DBH.

The data from the national monument on Douglas-fir stands that we used to compare to these minimum desired conditions are from Knox (2004). Knox's thesis presented forest structure data from two Douglas-fir stands (slope stands; 1-2 ha [2.47-4.94 acres] in size) within the national monument. Specifically, data were provided on the number of stems per hectare and basal area per hectare for five tree species of different size classes. Knox (2004) presented the data for the two stands individually and for the mean of the stands (the latter being what we used). The size classes used in the study were 5-10 cm (2-3.9 in), 11-22 cm (4.3-8.7 in), >22-30 cm (>8.9-11.8 in), and >30 cm (>11.8 in).

As can be seen from the description of the USFWS (2012) minimum desired condition size classes and those used by Knox (2004), the metrics are not the same. For example, USFWS (2012) considers large trees as those > 46 cm (18 in), but the largest size class used by Knox (2004) was >30 cm (12 in). The reason for the difference is that the categories used by Knox (2004) followed tree size classes discussed in the original, 1995, MSO Recovery Plan (USFWS 1995; Paul Whitefield, Natural Resource Specialist, Flagstaff Area NMs, pers. comm.). This inconsistency in the size classes used prohibits a clean comparison for both the minimum density of large trees and the % BA by size class. A direct comparison can be made only for the minimum tree BA. We present the information from Knox (2004), and compare it to the extent possible to the minimum desired conditions from USFWS (2012), in the Condition section of the assessment. In addition to the minimum desired conditions discussed here for mixed-conifer and pine-oak forest areas, USFWS (2012) provides a table of seven desired conditions with associated relevance to the MSO (see Table C2 of USFWS 2012).

Occurrence/Level of Potentially-Disturbing Activities and Noise in MSO Habitat

The purpose of this measure is to assess the extent of visitor activity and NPS operations within the national monument that might disturb MSOs and/or their habitat. By "disturbance" we mean primarily noise and associated effects related to the presence of people. We also address actions that have been and are taken by the park to avoid or minimize such disturbance. Our analysis is rough and qualitative because data and information are not available to support a more rigorous analysis.

Our main sources of information for this measure are: 1) the Recovery Plan (USFWS 2012), Delaney et al. (1999a, b), Swarthout and Steidl (2003), and Hockenbary (2011) for a summary of activities and noise levels that might disturb MSOs; and 2) several NPS/park documents that discuss potentially-disturbing activities within the national monument (NPS 2004b [and USFWS 2005], NPS 2009a, Whitefield 2012, Whitefield and Hetzler 2012b), as well as the Soundscape assessment in the NRCA, which addresses sound levels at two locations in the eastern part of the park.

Information Available on Disturbance to MSOs

USFWS (2012) includes discussions of recreational activities and noise as factors that have the potential to disturb MSOs. The Recovery Plan, which addresses the owl throughout its range, mentions recreational activities such as hiking, camping, hunting, and off-road vehicle (ORV) use as having the potential to affect owls directly through disturbance, and/or indirectly (e.g., by damage to vegetation, soil compaction). Within Walnut Canyon NM, the only one of these recreational activities that occurs is hiking. However, noise from the Northern Arizona shooting range, which is 1.6 km (1 mi) from the park at its closest point, is discussed in the assessment. It should also be noted that some of the owl PACs designated within the park extend onto adjacent land, where recreation may occur at higher levels. Our assessment here focuses on activities occurring within the park.

At high enough levels, hikers near nests can disturb MSOs. An experimental study looked at the effects of a controlled level of hiking on nesting MSOs in canyons in Utah (Swarthout and Steidl 2003). During the hiking treatments of the experiment, one of the research team hiked past the nest one time every 15 minutes. Observations were made for 4 hours during each of three time periods (morning, mid-day, and evening). The "hiker" passed no closer than an average of 34 m (111 ft) from each nest. The researchers stated that while activity budgets did not change "markedly" when hikers were near nests, there were decreases in the amount of time females handled prey and spent on daytime maintenance behaviors (e.g., preening, maintaining the nest). Also, both male and female owls increased contact vocalizations when hikers were present. The researchers concluded that high levels of short-duration hiking near nests may be detrimental to MSOs on a cumulative basis. They considered high levels of hiking in canyons in Utah to be more than about 50 hikers per day.

Another study of MSOs in Utah examined whether recreation level affected roost behavior, territorial occupancy rates, or reproduction in canyon habitats (Hockenbary 2011). The researcher found that occupancy and reproduction were not affected by recreation, but that daytime roost behavior of fledglings may have been affected by different levels (high or low) of recreation. Fledglings in areas with high levels of recreation spent less time in vigilant behaviors and more time in maintenance behaviors compared to fledglings in low-recreation areas.

Infrequent noises are in general believed to have relatively little long-term impact on spotted owls (USFWS 2012). However, owls may respond to noise disturbance by altering their behavior (e.g., Swarthout and Steidl 2003) or flushing from perches, which may affect nesting and roosting and make them more susceptible to predators and other threats (e.g., heat-related stress; USFWS 2012). USFWS (2012) suggests that it is likely that persistent noises are more disruptive to MSOs than are infrequent disturbances, and that the degree of disturbance is proportional to the volume of the noise. In addition to the frequency of a noise disturbance, other factors that may affect spotted owl responses to noise include distance to the disturbance, source of the sound, habitat type, and topography (Delaney and Grubb 2004, as cited by USFWS 2012). Delaney et al. (1999a, as cited in USFWS 2012), for example, found that MSOs flushed from perches in higher proportions when closer to sounds and when sounds were louder. Furthermore, other researchers (Pater et al. 2009, as cited by USFWS 2012) identified specific noise levels that led to a greater than 60% chance of causing an owl to flush (i.e., ≥ 80 dBO [where dBO is "decibels weighted for middle sound frequencies where owl hearing is the most sensitive"], which is about 69 dBA, or about twice as loud as typical conversation). Regarding the type of noise, one study found that MSOs responded more to sounds from chainsaws than to helicopters at the same distance in forested habitat (Delaney et al. 1999b). Delaney et al. (1999b) also reported that spotted owls did not flush if the SEL noise level (sound exposure level for total sound energy) for helicopters was ≤ 120 dBO (92 dBA), and the LEQ level (10-second equivalent average energy level) for chainsaws was ≤ 59 dBO (46 dBA). USFWS (2012) also suggests that owls may be more easily disturbed in canyon habitats than in forested habitats due to differences in the behavior of sound in canyons and caves, and differences in visual barriers.

Visitors and NPS Operations/Management

In accordance with the park's General Management Plan (GMP; 2007), most of the national monument is zoned to restrict general visitor access in order to protect the unique cultural resources, the riparian corridor along the canyon bottom, and habitat for rare and sensitive wildlife species (such as the MSO). The monument is also closed to the public every night by 6 pm, which also minimizes human interference with the activity of nocturnal wildlife. The park receives a substantial level of visitation, with more than 153,000 visitors to the monument recorded at the Visitor Center during 2015 (NPS Integrated Resource Management Application website: https://irma.nps.gov/App/), but park visitation occurs primarily in/on the Rim Trail, the Island Trail, and the visitor center area.

NPS management activities that occur within or near the MSO PACs include ranger-guided hikes, fire suppression and fuels reduction, archeological site monitoring and preservation, natural resource inventory and monitoring, scientific studies, boundary fence maintenance, and resource protection patrols (Szydlo et al. 2015). In addition to the inaccessibility of most of the canyon to the public, Flagstaff Area NMs also takes actions to minimize disturbance to MSOs and their habitat and protect/maintain the habitat. In preparing the Fire Management Plan (FMP), NPS consulted with the USFWS in accordance with Section 7 of the ESA. Measures were incorporated into the FMP to protect and eliminate/reduce adverse effects on the MSO, other federally-protected species, and other sensitive natural resources (NPS 2009a). Many of the measures are summarized in Appendix K of the FMP. Such efforts include those identified in Appendix K-6 (Ponderosa Stand and Wildlife Habitat Management Objectives: WACA-FMU-2) of the FMP (NPS 2009a). The first item in Appendix K-6 addresses MSO PAC areas within FMU-2 (Fire Management Unit 2). Fire Management Units were described in more detail in the Ponderosa Pine assessment.

Nearly all of the Douglas-fir-Gambel oak forest within the national monument is contained within FMU-4 (NPS 2009a). This FMU also contains the canyon bottom with its deciduous riparian vegetation and conifers. One of the management objectives for this FMU is to protect the inner canyon environment and its resources by restoring the surrounding fire-dependent vegetation and reducing the fire risk in FMU-2 (composed largely of ponderosa pine vegetation). Within FMU-4, NPS manages with more passive strategies than in the other FMUs.

4.10.3. Reference Conditions

Reference conditions for this assessment are shown in Table 4.10.3-1. Reference conditions are described for resources in good, moderate concern, and significant concern for each of the indicator's measures.

Although the additional information presented below is not used to assess condition of the Douglas-fir-Gambel oak habitat for the MSO at Walnut Canyon NM, it is of interest in the context of changes in this forest type within the national monument over time. Also, we present information below on the primary constituent elements of MSO critical habitat to assist in describing the habitat needs of the subspecies.

Historic Conditions in Douglas-fir-Gambel Oak Forests in Walnut Canyon NM

Knox (2004) presented estimates of forest density in 1880, prior to widespread Euro-American settlement. He made rough estimates for both ponderosa pine forests and Douglas-fir forests. Within Douglas-fir forests on the canyon's north and east-facing slopes, he estimated that, from 1880 to 2003: the density of Douglas-fir doubled (from 204.5 stems/ha to 410.4 stems/ha); ponderosa pine density increased (115.3 stems/ha to 174.2 stems/ha); and Rocky Mountain juniper density more than doubled (68.7 stems/ha to 177.8 stems/ha). He also found that the density of Gambel oak increased dramatically (from 6.4 stems/

Table 4.10.3-1. Reference conditions used to assess the MSO and Inner Canyon Environment at Walnut Canyon NM.

Indicator	Measure	Good	Moderate Concern	Significant Concern
Species Occurrence	Number of Adult MSO Pairs Exhibiting Territorial Occupancy	Three or more MSO pairs identified through surveys in three distinct/separate core areas.	Two MSO pairs identified through surveys in two distinct/separate core areas.	One or no MSO pairs identified through surveys.
Status/ Condition of MSO Habitat: Douglas fir-Gambel oak	Total Area/Cover of Douglas fir-Gambel Oak Forest	Total area of Douglas fir-Gambel Oak vegetation type (based on Hansen et al. 2004) is stable over time.	Total area of Douglas fir-Gambel Oak vegetation type (based on Hansen et al. 2004) has decreased by a small to moderate proportion over time.	Total area of Douglas fir-Gambel Oak vegetation type (based on Hansen et al. 2004) has decreased substantially over time.
	Minimum Tree Basal Area	No reference conditions were developed for these measures.	No reference conditions were developed for these measures.	No reference conditions were developed for these measures.
	Minimum Density of Large Trees	No reference conditions were developed for these measures.	No reference conditions were developed for these measures.	No reference conditions were developed for these measures.
Level of Human Disturbance	Occurrence/level of Potentially-disturbing Activities and Noise in MSO Habitat	MSO & MSO habitat is exposed to a minimal level of human disturbance.	MSO & MSO habitat is exposed to a relatively greater level (or moderate level) of human disturbance.	Human disturbance of MSO & MSO habitat appears great enough to affect use of the park by MSO.

ha in 1880 to 152.4 stems/ha in 2003), and that pinyon pine (*Pinus edulis*) did not appear to be present in the forest stands in 1880.

Knox (2004) found that Douglas-fir-Gambel oak stands within the national monument had a frequent, low-severity fire regime, with some mixed-severity events occurring on an infrequent basis (NPS 2009a). The relatively frequent, asynchronous fires were also small in extent, and they occurred in localized areas of the monument within both Douglas-fir and ponderosa pine forests (Knox 2004). Historical fire frequency in the pinyon-juniper woodlands on the xeric canyon slopes appeared to be relatively less frequent.

For the Fire Management Plan for the Flagstaff Area NMs, NPS conducted a Fire Regime Condition Class (FRCC) analysis (NPS 2009a). The analysis characterized the degree of historic change in vegetation as a result of the disruption from its natural fire regime. "The results can help identify appropriate management strategies and can help prioritize areas for restoring vegetation and natural ecological process" (NPS 2009a). NPS conducted the initial assessment in 2003 using the vegetation maps from Hansen et al. (2004) and studies in the park that provided information on the natural historical fire regime, reference vegetation, and present day vegetation. The results of the FRCC analysis indicated the Douglas-fir-Gambel oak forest was in a condition class of 2. NPS (2009a) defines the FRCC 2 as "Fire regimes have been moderately altered from their historical range. The risk of losing key ecosystem components is moderate. Fire frequencies have departed from historical frequencies by one or more return intervals (either increased or decreased). This results in moderate changes to one or more of the following: fire size, intensity and severity, and landscape patterns. Vegetation attributes have been moderately altered from their historical range."

<u>Primary Constituent Elements of MSO Critical Habitat</u>

Primary constituent elements of critical habitat were listed by USFWS (2004), based on the habitat features associated with MSO occupancy described in the 1995 Recovery Plan (USFWS 2012). We provide these primary constituent elements here as shown in USFWS (2004).

Primary Constituent Elements Related to Forest Structure:

> A range of tree species, including mixed-conifer, pine-oak, and riparian forest types, composed of different tree sizes reflecting different ages of trees, 30-45% of which are large trees with a trunk diameter of ≥0.3 m (12 in) when measured at 1.4 m (4.5 ft) from the ground; a shaded canopy created by the tree branches and foliage covering ≥40% of the ground; and, large, dead trees (i.e., snags) with a trunk diameter of at least 0.3 m (12 in) when measured at 1.4 m (4.5 ft) from the ground.

Primary Constituent Elements Related to Maintenance of Adequate Prey Species:

> High volumes of fallen trees and other woody debris; a wide range of tree and plant species, including hardwoods; and, adequate levels of residual plant cover to maintain fruits, seeds, and allow plant regeneration.

Primary Constituent Elements Related to Canyon Habitat (one or more of the following):

> Presence of water (often providing cooler air temperature and often higher humidity than the surrounding areas); clumps or stringers of mixed-conifer, pine-oak, pinyon-juniper, and/or riparian vegetation; canyon walls containing crevices, ledges, or caves; and, high percentage of ground litter and woody debris.

4.10.4. Condition and Trend

<u>Number of Adult MSO Pairs Exhibiting Territorial Occupancy</u>

Four MSO PACs have been designated in the national monument, and several PACs have been designated on adjacent Coconino NF lands. A survey and observation history was presented by Hart (2005) and is summarized below. This information is interesting and of obvious importance to the park in their efforts to monitor the MSO over time and conduct management activities within the national monument. However, to assess current condition we focus on information from the most recent seven years, 2010-2016.

<u>Summary of PAC Survey Results, 1980-2004</u>

Information in this section was taken directly from Hart (2005), but we condensed it down to the most relevant information for our purposes. Note that in Hart's summary, he assigned records to a given PAC, even if the PAC was designated after the date of the record.

> The earliest NPS record of MSO activity at Walnut Canyon dates to 1980, when a use/perch site was reported... NPS staff observed a pair of MSO near this location again in 1986, but no nest was found. Ganey and Balda (1989) documented three breeding pairs of MSO during dietary and habitat-use studies at WACA from 1984 to 1987. The first documented systematic MSO surveys at WACA were conducted in 1987.
>
> During the period from 1987 through 1999, MSO nested at least four times in the Lucida PAC and three times in the Walnut 33 PAC... Nest sites associated with the Cherry PAC have not been discovered during formal surveys (or may not have been documented on the private in-holding surrounding Santa Fe Dam). A roost site was discovered within the Breezy PAC in 1999, but nesting was not documented. Nest buffers have been established in all four PAC's, even though nest sites are not known in two of them. Since 2000, NPS, USFS, USGS, and USFWS personnel have sporadically surveyed for MSO in and around the monument; no MSO were observed during these efforts. However, in 2003 NPS cultural resources staff encountered and photographed a MSO in a tributary canyon on the south side of Walnut Canyon.... Of the 36 total MSO vocalizations, roost sites, nests, and other sightings between 1980 and 2003, 33 (92%) are within 0.8 km (½ mile) of four locations... in the Walnut 33 PAC, the Lucida PAC, the Cherry PAC, and the Breezy PAC.

Hart (2005) conducted surveys in 2004 in all four PACs (two times), as well as a partial survey in areas where MSO were documented in the past. The surveys used fixed call points and 15 minute sessions per point; calls were made and surveyors listened for a response at each point. No MSOs were detected during the PAC surveys, but they did detect one MSO during a walk-through survey of the 1996 eastern boundary expansion area. Johnson et al. (2010) summarized survey results through 2010 by PAC, but recall that surveys were not complete in all years from 2005-2009.

<u>Walnut 33 PAC/Walnut 33 East- 2010-2016</u>
Over the last seven years of monitoring (using audio recording methods), a male-female pair was confirmed in the PAC core every year (Table 4.10.4-1), indicating that they were exhibiting territorial occupancy. In 2010, a full protocol survey was also conducted, and three MSO call detections were reported. In 2011, 2012, 2013, and 2016, an adult pair and fledglings were confirmed visually. In 2014 and 2015, no observations/sightings in addition to the audio data were recorded. However, as noted, it was confirmed that MSOs nested and fledged young in 2016.

<u>Walnut 33 PAC/Walnut 33 West- 2010-2016</u>
A full protocol survey was conducted in 2010 in Walnut 33 West, and one call detection was reported. For the remaining years, audio data confirmed a male-female pair in the core during each year. Adults (and young in some years) were visually confirmed in most of the years from 2011-2016. This includes 2016, in which an adult pair and fledging young were observed.

<u>Lucida PAC/Site 1- 2010-2016</u>
A full protocol survey was conducted in this site in 2010, but no detections were recorded. Although some owl activity has been recorded in this area since 2010 (e.g., habitat use in 2014 and 2015; see Table 4.10.4-1), there has been no evidence of owl pairs nesting. The audio survey in this site was discontinued after 2015. However, Shaula Hedwall, USFWS Mexican spotted owl lead and Mexican spotted owl Recovery Team member, states that it would be desirable to continue to monitor the site; data show that owl sites have appeared abandoned for many years (up to 10 years or more), only to have owls return (Shaula Hedwall, USFWS, pers. comm.).

<u>Lucida PAC/Site 2- 2010-2016</u>
Although some owl activity was confirmed in the PAC area in 2011-2012, pairs were confirmed by audio data in 2013-2016 only. In 2013, a roosting pair was visually confirmed. In 2015 and 2016, a pair was visually confirmed, and in 2016, young were observed.

<u>Cherry PAC- 2010-2016</u>
There were no detections of owls in this PAC in 2010, even with a full protocol survey. In 2011-2012, no detections were recorded, but audio surveys were incomplete in coverage. However, in 2013-2016, a male-female pair was confirmed in the PAC core. A MSO pair was also visually confirmed in each of the

Table 4.10.4-1. Mexican spotted owl monitoring results for Walnut Canyon NM.

PAC/Site	2010	2011	2012	2013	2014	2015	2016
Walnut 33/ Walnut 33 East	Full protocol survey (within WACA) – 3 call detections. Male-female confirmed in core on audio data.	Male-female confirmed in core on audio data. Adult pair and fledging young visually confirmed.	Male-female confirmed in core on audio data. Adult pair and fledging young visually confirmed.	Male-female confirmed in core on audio data. Adult pair and fledging young visually confirmed.	Male-female confirmed in core on audio data.	Male-female confirmed in core on audio data.	Male-female confirmed in core on audio data. Adult pair and fledging young visually confirmed.
Walnut 33/ Walnut 33 West	Full protocol survey (within WACA) – 1 call detection.	Male-female confirmed in core on audio data. Adult pair and fledging young visually confirmed.	Male-female confirmed in core on audio data. Adult pair and fledging young visually confirmed.	Male-female confirmed in core on audio data. One adult visually confirmed. No young observed.	Male-female confirmed in core on audio data.	Male-female confirmed in core on audio data. Single adult and one fledgling visually confirmed.	Male-female confirmed in core on audio data. Adult pair and fledging young visually confirmed.
Lucida/ Site 1	Full protocol survey - no detections.	Audio detections confirm habitat occupancy in western PAC area. No audio evidence of pairs in Lucida PAC.	Audio detections confirm pair roosting across canyon from Site 1. Visual confirmation of pair roosting – no evidence of nesting.	Pair presumably moved to Lucida- Site 2.	Audio detections confirm habitat use.	Audio detections confirm habitat use.	Audio survey discontinued.
Lucida/ Site 2	Full protocol survey - no detections.	Audio detections confirm habitat occupancy in western PAC area. No audio evidence of pairs in Lucida PAC.	Audio detections confirm habitat occupancy in western PAC area.	Male-female confirmed in Site 2 core on audio data. Adult pair at roost site visually confirmed.	Male-female confirmed in core on audio data.	Male-female confirmed in core on audio data. Adult pair visually confirmed. No young observed.	Male-female confirmed in core on audio data. Adult pair and fledging young visually confirmed.
Cherry	Full protocol survey - no detections.	No audio detections. Coverage not complete.	No audio detections. Coverage not complete.	Male-female confirmed in core on audio data. Sub-adult pair at roost site visually confirmed. No young observed.	Male-female confirmed in core on audio data. Incidental observation of adult pair.	Male-female confirmed in core on audio data. Adult pair visually confirmed. No young observed.	Male-female confirmed in core on audio data. One adult pair and one fledging young visually confirmed.
Breezy	–	–	–	–	Audio detections confirm habitat use.	Male-female confirmed in core on audio data. Adult pair visually confirmed. No young observed.	Male-female confirmed in core on audio data. Adult pair visually confirmed. No young observed.

Data Source: Mark Szydlo, Biologist, Flagstaff Area NMs.

years, either during a survey or incidental to surveys (Table 4.10.4-1). One fledgling was visually confirmed in 2016.

Breezy PAC- 2010-2016
Table 4.10.4-1 includes no information on MSOs in the Breezy PAC for 2010-2013. Johnson et al. (2010) reported MSO detections in the PAC in some years prior to this period (e.g., 2005, 2007, 2008, 2009). However, in 2014, habitat use was confirmed through audio detections (Table 4.10.4-1). In both 2015 and 2016, a pair was confirmed in the PAC core via audio data and visual observations, although no young were observed.

Summary and Condition
As reported by Szydlo et al. (2015), MSO activity was widespread within the national monument during the 2015 nesting/sampling season based on both passive audio surveys and searches of selected areas of habitat. Based on the monitoring surveys, PACs were occupied by five pairs, and nesting was confirmed in at least one case. In 2016, the same number of pairs was confirmed through both audio data and visual observations; fledglings were observed in association with four of the pairs. The number of adult and young MSO documented for the 2015 and 2016 monitoring seasons is the highest recorded over the period of record for Walnut Canyon NM. Also, the number of territorial pairs exceeds the number that might be expected based on prior telemetry studies to establish territory size in Walnut Canyon (Ganey and Balda 1989; Paul Whitefield, Natural Resource Specialist, Flagstaff Area NMs, pers. comm.).

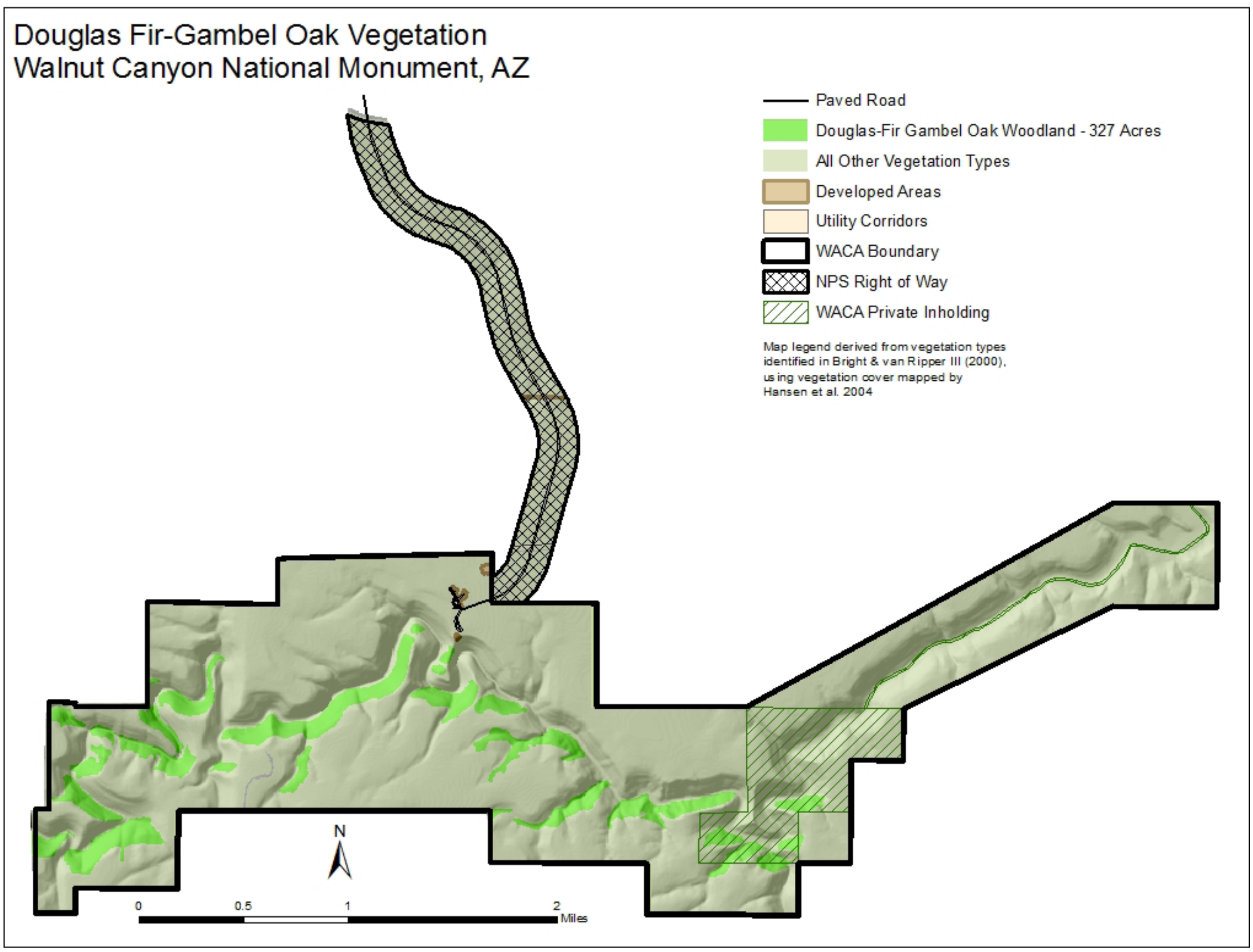


Figure 4.10.4-1. The occurrence of Douglas-fir-Gambel oak vegetation in Walnut Canyon NM. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction. Figure Credit: Flagstaff Area NMs.

Although not related to our assessment of condition, the USFS reported that in 2016, at least three MSO pairs and one male owl were detected in the five MSO PACs on national forest lands near the national monument (information provided by Cary Thompson of USFS to Paul Whitefield, Natural Resource Specialist, Flagstaff Area NMs).

Based on these data for the national monument, and our reference conditions, we consider current condition of MSO occurrence (i.e., number of pairs exhibiting territorial occupancy) in the national monument to be good. Our confidence in the assessment is high. Trends in the number of adult pairs exhibiting territorial occupancy over the last several years appear largely unchanging (or even increasing) at this time; however, because we focused the assessment on the 2010-2016 time period-- a relatively short period of time, and surveys were not conducted in all years until around 2010, we took a conservative approach and judged trends unknown. Some changes over time have been observed in the use of individual PACs from 2010-2016 (e.g., in the Lucida PAC/Site 1 and in the Breezy PAC).

Total Area of Douglas-fir-Gambel Oak Forest Cover

Approximately 133 ha (330 ac) of Douglas-fir-Gambel oak forest occur within Walnut Canyon NM (Figure 4.10.4-1). This vegetation type comprises about 9.2% of the national monument's area (133.5 ha/1,449 ha). Figure 4.10.4-1 is based on the vegetation mapping project of Hansen et al. (2004), which spanned the years of 1999-2004; the map was created using 1996 aerial photographs. Also note that the figure includes Douglas-fir-Gambel oak vegetation within the private inholding.

Hansen et al. (2004, Appendix E-6) provided a description of vegetation cover within the Douglas-fir-Gambel oak forest based on the seven plots sampled during the mapping project. Total vegetation cover within the forest ranged from 41-75% (average 59%), with the tree layer having 28-62% absolute cover (average 45%), the shrub layer having 6-20% absolute cover (average 10%), and the herbaceous layer having 4-15% absolute cover (average 9%). Douglas-fir dominated the tree layer with 16-62% absolute cover (average 29%) and DBH ranging from 11-67 cm (4-26 inches) (average 21 cm [8 in]). Rocky Mountain juniper and ponderosa pine may also have high cover, but they never dominate the tree canopy. Gambel oak consistently dominated the shrub layer, with 4-22% absolute cover (average 16%); it also occurred within the ground and tree layer. In the tree layer, Gambel oak DBH ranged from 11-31 cm (4-12 in) (average 16 cm [6 in]). A variety of herbs and grasses grew in the herbaceous layer.

Over the past 20 years, changes have occurred to vegetation within the park, as well as in the region. The park and region were subjected to a prolonged and severe drought from 1996 to 2006 (and beyond), with extremely dry conditions occurring between 2000 and 2002 (NPS 2007c). A large proportion of coniferous trees in the surrounding Coconino National Forest died after the driest period and subsequent bark beetle infestations (Ganey and Vojta 2011, NPS 2015a). In their 10-year study of mortality in mixed-conifer and ponderosa pine forests in Kaibab and Coconino NFs, Ganey and Vojta (2011) found that mortality occurred on most of their 1-ha (2.5-ac) mixed-conifer and ponderosa pine plots; in most cases, the mortality was due to forest insects attacking drought-stressed trees. In the mixed-conifer forest, the number of trees that died during 2002-2007 was more than 200% greater than the number that died during 1997-2001. Also, trees in the largest size class died in greater numbers.

Mortality of trees in the Douglas-fir-Gambel oak forest within the national monument also occurred during this period. As also described in the Ponderosa Pine assessment, substantial numbers of ponderosa pine, pinyon pine, and juniper trees died along the rim terraces starting in 2003. Pockets of mature Douglas-fir began dying along the north-facing and east-facing canyon slopes starting around 2004 (NPS 2007c; Figure 4.10.4-2). Changes in canopy cover in Douglas-fir-Gambel oak forest are of concern because high canopy cover (≥50%) is one of the most important aspects of areas used by MSOs for roosting and nesting (Ganey et al. 2011). In addition to park staff observations and photographs, data/information from Parker et al. (2003) and USFS (Forest Health data) document or report on the loss of Douglas-fir, ponderosa pine, and other tree species within the park during this time period.

Parker et al. (2003) conducted a study within the park entitled *The Effects of Prescribed Burns on Drought Related Tree Mortality in Walnut Canyon National Monument*. The study included two prescribed burn plots and one control plot, with one burn plot on the

Figure 4.10.4-2. Dead Douglas-fir trees in Douglas-fir-Gambel oak forest within Walnut Canyon NM. Photo Credit: NPS.

north rim and one on the south rim, and a control plot on the south rim. All three plots were transitional between ponderosa pine and pinyon-juniper communities; none were within Douglas-fir-Gambel oak forest. However, the information from the Parker et al. (2003) work provides evidence of tree mortality within the park during the 2000s.

Parker et al. (2003) found that one of the burned plots on the south rim had the highest mortality (39% of all tree species), but that even within the control stand, mortality was 25% (greater than the mortality in the north rim stand, which was 20%). It was not clear to Parker et al. (2003) why the trees died, and why so many more trees died in the one stand. However, they noted that bark beetles were invading stands of ponderosa pine in this part of Arizona, and that they had noticed "a large number of beetle holes on the bark of large dead trees at the Pictograph site..." Data on Gambel oak were also provided in the study. In the two burn plots, 25% of Gambel oak trees were dead, and 18% of the Gambel oak trees within the control stand were dead.

Some quantitative information on the area of the park affected by bark beetles and/or drought is available from the USFS Forest Health Monitoring Program. Data from the USFS program indicates that several hundred hectares of the park were affected by bark beetles in 2002-2003 (Table 4.10.4-2). In 2004, 128 ha (317 ac) were reported as affected by drought, and 6.5 ha (16 ac) of Douglas-fir trees were affected by bark beetles.

As stated at the beginning of this section, there are approximately 133 ha (330 ac) of Douglas-fir-Gambel oak forest within Walnut Canyon NM. Although there are no current data on the acreage or cover of this forest type within the park, Douglas-fir trees within the park are known to have died during the extended drought and dry conditions from 1996-2006. Flagstaff Area NM staff suggest that a rough estimate of the mortality could be as high as 20-25% in some areas (Paul Whitefield, Natural Resource Specialist, Flagstaff Area NMs), but this number is an area of uncertainty. Because Douglas-fir-Gambel oak forest is so important to the MSO, including the cover of this forest type and the presence of large, mature trees, widespread mortality of Douglas-fir trees is of substantial concern to park management. For these reasons, a study has been designed and is currently being implemented to address the issue (see below). Because the loss of Douglas-fir trees does not appear to be occurring at the current time, and park monitoring indicates that MSO continue to occupy territories within Walnut Canyon NM, we consider current condition under this measure to be of moderate concern. Trends are unknown. We have medium confidence in the assessment. Once data are available from the study described below, a more thorough assessment under this measure will be possible.

The project entitled *Measure Recent Change in Mexican Spotted Owl Habitat, Walnut Canyon NM* began in 2013 and is scheduled for completion in 2018 (NPS and Northern Arizona University [NAU] 2013). The project's objectives are to: measure changes in canopy cover and/or condition of Douglas-fir-Gambel oak vegetation over the period from 2000-2009; establish a baseline for future monitoring; and assess the effects of recent forest cover change on MSO habitat occupancy within the national monument (NPS and NAU 2013). Project cooperators are using remotely sensed imagery provided by Landsat Thematic Mapper (TM) and/or Enhanced Thematic Mapper Plus (ETM+) for their analysis of vegetation canopy cover change. In addition to the aerial imagery, the cooperators are also considering making repeat measurements at the sites studied by Knox (2004) in 2003.

<u>Minimum Tree Basal Area and Minimum Density of Large Trees</u>

These two measures are included for informational purposes. However, the two (plus a third) measure are included in the MSO Recovery Plan as "minimum

Table 4.10.4-2. Area of forest affected by bark beetles and drought in 2001-2004 and 2013-2015 at Walnut Canyon NM.

Year	Ponderosa pine *Ips* ha (ac)	Pinyon pine *Ips* ha (ac)	Western pine beetle ha (ac)	Douglas-fir beetle ha (ac)	Drought ha (ac)	Total ha (ac)
2001	0	0	2 (5 ac)	0	0	2 (5)
2002	560 (1,383)	0	0	0	0	560 (1,383)
2003	731 (1,805)	18 (45)	0	0	0	749 (1,850)
2004	5 (13)	0	0	6.5 (16)	128 (317)	140 (346)
2013	6 (14)	0	0	0	0	6 (14)
2014	0	0	0	0	0	<0.4 (<1) *
2015	0	0	0	0	0	0

Data Sources: USFS 2004, 2014a, 2014b, and 2016b.

Note: Some of the numbers shown may include some areas affected in nearby Sunset Crater Volcano NM.

* No specific bark beetle was named for 2014.

desired conditions" for mixed-conifer forest areas managed for nesting/roosting habitat; therefore, we believe they are important to consider in the assessment. Data (from Knox 2004) used in this discussion are presented in Tables 4.10.4-3 and 4.10.4-4).

From the first table, it can be seen that Douglas-fir had the greatest average total BA within the stands, followed by ponderosa pine, Rocky Mountain juniper, Gambel oak, and pinyon pine, respectively. Douglas-fir accounted for 46.6% of the total average BA, and Gambel oak accounted for 6.1%. Based on the stem density data, Douglas-fir had the greatest number of total stems, followed by Rocky Mountain juniper, ponderosa pine, Gambel oak, and pinyon pine. Douglas-fir accounted for 43.8% of the total number of stems, and Gambel oak accounted for 16.2%.

Minimum Tree Basal Area

The overall tree basal area (total for all species, average of the two stands) was 34.4 m^2/ha (or 150.0 ft^2/ac; Table 4.10.4-3). This figure is for all trees 5 cm (2.0 in) and greater DBH. Comparing this value to the minimum desired condition value for mixed-conifer forest areas from USFWS (2012; i.e., 27.5 m^2/ha (120 ft^2/ac), the BA from the national monument stands exceeds that from the Recovery Plan. Again, we did not attempt to assign specific thresholds corresponding to a good, moderate concern, or significant concern condition, but it is noted that the data from the two Douglas-fir stands within the park exceed the minimum recommended in the Recovery Plan.

Minimum Density of Large Trees

As noted in the Data and Methods section, it is more difficult to make a comparison between the Knox (2004) data for the park and the minimum desired condition from the Recovery Plan for this measure. The recommended minimum number of trees is 30 per ha (12 per ac), but they consider "large" trees to be those > 46 cm (18 in) DBH. The largest size class of trees for which we have data is the >30 cm (>12 in) class. The total average density for all tree species in this size class (made up mostly of Douglas-fir and ponderosa pine) is 97.8 stems per ha (39.6 stems per ac; Table 4.10.4-4). Because we do not know how many of the trees at Walnut Canyon NM were greater than 46 cm (18 in) DBH, we cannot determine whether the minimum density of large trees recommendation was met.

Other Information of Interest: % BA by Size Class

The other information (potential measure) we discussed in the Data and Methods section was the percent BA by size class. As noted, USFWS (2012) recommends that >30% of the stand BA is composed of trees 30-46 cm DBH (12-18 in), and that >30% of the stand BA is composed of trees >46 cm (>18 in) DBH. Again, the size classes used by Knox (2004) are not consistent for a direct comparison. Knox's data indicate that 41.3% (14.2/34.4) of the average total BA of the stands was composed of trees in the largest size class he measured, those trees >30 cm (12 in) DBH (Table 4.10.4-3).

These data were presented to point out a potential data gap in information on Douglas-fir-Gambel oak stands

Table 4.10.4-3. Basal area for two Douglas-fir slope stands at Walnut Canyon NM.

DBH in cm (and inches)	Ponderosa pine	Gambel oak	Douglas-fir	Rocky Mountain juniper	Pinyon pine	Total
5-10 (2.0-3.9)	0.05 (0.22)	0.35 (1.52)	0.42 (1.83)	0.23 (1.00)	0.03 (0.13)	1.08 (4.70)
11-22 (4.3-8.7)	1.67 (7.27)	1.39 (6.05)	3.05 (13.28)	1.51 (6.58)	0.33 (1.44)	7.95 (34.63)
>22-30 (>8.7-11.8)	2.20 (9.58)	0.36 (1.57)	6.77 (29.49)	1.84 (8.01)	0	11.18 (48.70)
>30 (>11.8)	5.9 (25.70)	0	5.81 (25.31)	2.50 (10.89)	0	14.22 (61.94)
TOTAL	9.82 (42.77)	2.10 (9.15)	16.06 (69.96)	6.09 (26.53)	0.36 (1.57)	34.44 (150.0)

Data Source: Knox (2004).

Notes: Data in m^2 per ha taken from Table 4 of Knox (2004). Knox also provided values for each stand individually. Numbers are averages of two stands in m^2/per hectare (and ft^2/acre).

Table 4.10.4-4. The number of stems of tree species in Douglas-fir forests, Walnut Canyon NM.

DBH in cm (and inches)	Ponderosa pine	Gambel oak	Douglas-fir	Rocky Mountain juniper	Pinyon pine	Total
5-10 (2.0-3.9)	10.93 (4.42)	76.65 (31.03)	94.33 (38.19)	50.77 (20.55)	7.21 (2.92)	239.90 (97.12)
11-22 (4.3-8.7)	82.95 (33.58)	69.36 (28.08)	146.64 (59.37)	75.93 (30.74)	15.45 (6.26)	390.34 (158.03)
>22-30 (>8.7-11.8)	40.235 (16.29)	6.4 (2.59)	128.98 (52.22)	33.835 (13.70)	0	209.45 (84.80)
>30 (>11.8)	40.05 (16.21)	0	40.445 (16.37)	17.275 (6.99)	0	97.77 (39.58)
TOTAL	174.165 (70.51)	152.42 (61.71)	410.39 (166.15)	177.815 (71.99)	22.67 (9.18)	937.46 (379.54)

Data Source: Knox (2004).

Note: Data (in stems per ha) taken from Table 4 of Knox (2004). Knox also provided values for each stand individually. Numbers are averages of two stands per hectare (and per acre) measured in 2003

in the national monument, and to better characterize this forest type that is so important to the MSO within the park.

Occurrence/Level of Potentially-Disturbing Activities and Noise in MSO Habitat

The extent and effect of noise from visitor activities and NPS operations within the inner canyon environment is an important data gap (Paul Whitefield, Natural Resource Specialist, Flagstaff Area NMs, pers. comm.), but we attempt to address it because of its importance.

Management of Walnut Canyon NM by the NPS has "generally favored the long-term protection of natural systems and processes" (NPS 2004b). In addition to most of the park being closed to public access, only a small proportion of the park (i.e., <5%) is directly affected by roads, buildings, fences, utilities, and visitor activities (NPS 2004b). About 93% of the monument lies within the Resource Preservation Zone. This zone provides for maximum preservation of fragile and/or unique resources, listed species, and sacred sites; resource protection is emphasized. The majority of MSO PAC and recovery habitat is located within this zone (USFWS 2005).

The following paragraph presents condensed information from NPS (2004), which is a good summary (and history) of activities and disturbances in the developed/administrative area of the park. This excerpt begins by describing the few sightings of MSOs and the few night-time vocal responses heard over the 25 years prior to about 2004 within 0.8 km (1/2 mi) of the Island Trail. Note, however, that since 2012, night-time MSO activity has steadily increased in the Island Trail area based on the number of recorded MSO calls during audio surveys (Paul Whitefield, Natural Resource Specialist, Flagstaff Area NMs, pers. comm).

> The NPS presumes that recurring, day-time roosting or nesting in close view of the visitor center-Island Trail area would have at least

> occasionally been documented during the last 25 years, as many employees and visitors to the national parks are avid birdwatchers with excellent skills. The available records are not sufficient to scientifically analyze the effects of NPS operations and visitor activities on MSO habitat utilization in the visitor center-Island Trail area. Baseline information is also lacking on ambient noise patterns around the visitor center and sound propagation within the inner canyon environment. However, the monitoring records suggest that MSO do not nest or roost in the Island Trail reach of the canyon. The most likely explanation is MSO avoid daytime use of the area because of prevalent human activity and elevated daytime noise from NPS operations and public use. Major construction projects started as early as the 1930's, when the Civilian Conservation Corps built the first visitor center and the Island Trail. Since then, NPS housing, maintenance shops, water supply, and wastewater treatment facilities have been built and continuously utilized within ⅛ to ¼ mile of the canyon rim. Public visitation steadily increased during the last century... The NPS estimates 65% of all visitors hike either the Island or Rim Trails. Between Memorial Day weekend and Labor Day weekend, the NPS also offers three guided day-hikes per week to either Ranger Cabin or the Ranger Ledge Cliff Dwellings. Most habitat in this area has long been protected from traditional land uses, and should retain all favorable vegetation structure and prey base attributes. If NPS operations and visitor activities are affecting MSO nesting and roosting within the Island Trail area, these effects have likely persisted for many decades.... If undiscovered nesting and roosting is occurring within the Island Trail area, individual MSO have likely become habituated to current levels of daytime human activity and ambient noise.

Whitefield and Hetzler (2012b) add that peak noise during the daytime may travel as far as 0.4 - 0.8 km (1/4 to 1/2 mi) up and down Walnut Canyon. They also note that sound levels from park operations are typically very low during the evening and night.

Another source of information to consider for this discussion is the Soundscape assessment, which was based on acoustical monitoring conducted in the park in 2010. Baseline acoustical monitoring data were collected by park natural resource staff at two locations, both on the eastern side of the monument (see Soundscape assessment for a map of site locations). The "Northeast Rim" site was located approximately 24 m (80 ft) from the canyon rim and was monitored for 30 days. Data were analyzed by the National Transportation Systems Center (Volpe Center). This site within the park was near the northeast corner, relatively distant from any PACs. The second site, "Southeast Rim" was chosen because of its close proximity to the Northern Arizona Shooting Range. This site was also outside of all MSO PACs, but it was near the eastern portion of the Cherry PAC. The shooting range is located about 1.6 km (1 mi) from the park boundary. NPS staff have concerns about the range due to potential effects of gunshot noise on wildlife and visitor enjoyment of the park, as well as effects from increased traffic along the access road through Coconino NF (NPS 2011c), which comes to within 0.8 km (0.5 mi) of the park's southeast rim. Monitoring data from this site, collected over 22 days, was analyzed by the Natural Sounds and Night Skies Division of NPS.

Monitoring data from the Southeast Rim site has somewhat greater relevance to our assessment of the MSO because it is nearer to designated PACs. However, we also mention the results from the Northeast Rim site. The overall conclusions from the Soundscape assessment are that the park's soundscape condition warrants moderate concern (based on the two monitoring locations). Noise levels were greater at night than during the day, and most noise was attributed to vehicles and trains, although noise from aircraft was audible. However, the proportion of time sound levels were above reference conditions was relatively low, especially for sounds greater than 45 dBA. At the Southeast Rim monitoring site, the median existing ambient sound level during monitoring was 25 dbA, which was slightly higher than natural ambient sound levels (and lower than existing ambient sound levels at Northeast Rim site). During test shooting from the range (on one day in August 2010; Acoustical Consulting Services 2010), sound levels ranged from 30 dBA to 60 dBA, with most shots centered around either 38 dBA or 55 dBA. These latter values, when they occur, indicate a substantial loss of existing ambient sounds (see the Soundscape assessment for further explanation). Gunshot noise could also be heard from several other locations in the monument (including the visitor center and remote areas). These sound levels, 38 dBA and 55 dBA, are lower than levels mentioned in the literature in which MSOs flushed or had a higher probability of flushing (see earlier discussion of Pater et al. [2009 as cited by USFWS 2012] and Delaney et al. [1999b]). The exception was that Delaney et al. (1999b) reported that sound levels greater than about 46 dBA from chainsaws caused MSO to flush. These researchers also found that ground-based disturbances elicited a greater flush response than aerial disturbances (eg., helicopter noise).

Although we have no site specific data to assess effects of gunshot noise on MSOs at Walnut Canyon NM, it appears that some concern for disturbance to owls in the eastern portion of the park may exist due to the levels of sound measured. It should also be noted, however, that a pair has been confirmed in the Cherry PAC core area every year from 2013-2016. Therefore, at least so far, spotted owls have continued to use this area.

Based on the information presented under this measure and our reference conditions, we consider condition to be good to of moderate concern. Our discussion focused mainly on potential noise disturbance and related disturbance from the presence of humans. Other than noise disturbance from outside of the park (e.g., due to vehicles, trains, and aircraft, such as measured at the Northeast Rim monitoring location, and gunshots from the shooting range), we addressed visitor and NPS operations noise/disturbance, which occurs primarily in a small portion of the national monument. Further, when the park does conduct visitor and management activities, they take measures to avoid or minimize disturbance. Because we have no quantitative data, except for that from the Soundscape assessment based on acoustical monitoring in 2010, we have low to medium confidence in this measure. The trend is unknown.

<u>Overall Condition, Trend, Confidence Level, and Key Uncertainties</u>

To assess the condition of the MSO and inner canyon environment, we used three indicators with a total of five measures (although two of the measures were for informational purposes only). The indicators and measures and their associated conditions are summarized in Table 4.10.4-5. Overall, we consider the condition to be good to of moderate concern, with a medium confidence level. Trends in overall condition are unknown.

As shown in the table, the first measure (number of adult MSO pairs exhibiting territorial occupancy) was assessed to be in good condition. We have high confidence in this measure as it is based on current field survey data (passive audio recording and supplemental visual searches). In the most recent two years (2015 and 2016), five MSO pairs exhibited territorial occupancy within the park. Also, fledglings were observed in association with four of the pairs in 2016.

The second measure used to assess condition (total area/cover of Douglas-fir-Gambel oak forest), was assessed to be of moderate concern. Our confidence in the measure is medium, because updated information on the coverage of the forest type is needed (NPS 2007c, NPS and NAU 2013). The 133.5 ha (330 acres) of Douglas-fir-Gambel oak forest within Walnut Canyon NM reported by Hansen et al. (2004) may have decreased in coverage due to the mortality of Douglas-fir trees during extended drought and dry conditions in the early 2000s. Although the loss of trees does not appear to be occurring at the current time, the measure is of moderate concern due to the importance of forest canopy cover and mature trees for the MSO.

The final measure was considered to be in good condition to of moderate concern. This qualitative measure focused on the general level and location of human disturbance (e.g., from activities generating noise and human disturbance) in MSO habitat within the park. We focused on visitor and NPS operations noise/disturbance, but included discussion of sources of noise/disturbance from outside the park. Most of the national monument is closed to public access, and only a small portion of the park is directly affected by roads, buildings, visitor activities, etc. (NPS 2004b). Additionally, measures are taken to avoid and minimize disturbance to MSOs/habitat within the park during management activities and operations (such as measures associated with the FMP and other specific projects). In accordance with the ESA, NPS also informally and formally consults with USFWS on actions that have the potential to affect MSOs, their

Table 4.10.4-5. Summary of MSO and inner canyon environment indicators, measures, and condition rationale.

Indicators of Condition	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Species Occurrence	Number of Adult MSO Pairs Exhibiting Territorial Occupancy		Current condition of the MSO under this measure is good. Based on breeding season monitoring surveys, five MSO pairs exhibited territorial occupancy in both 2015 and 2016. Additionally, nesting was confirmed in at least one case in 2015, and fledgling young were observed in association with four of the pairs in 2016. Two to four pairs were recorded in PAC cores from 2011-2014. Trends over the last several years appear largely unchanging (or improving), but because surveys were not conducted in all years until around 2010, and the period over which we have consistent data is relatively short, we consider the trend unknown. We have high confidence in the assessment.
Status/ Condition of MSO Habitat: Douglas-fir-Gambel oak	Total Area/ Cover of Douglas fir-Gambel Oak Forest		There are 133.5 ha (330 ac) of Douglas-fir-Gambel oak forest within the park based on Hansen et al. (2004). No current data are available on the acreage of this forest type, but Douglas-fir trees are known to have died during extended drought and dry conditions from 1996-2006. Because this forest type is so important to the MSO, widespread mortality of Douglas-fir trees is of substantial concern. Because the loss of Douglas-fir trees does not appear to be occurring at the current time, and park monitoring indicates that MSO continue to occupy territories within the park, we consider current condition to be of moderate concern. Trends are unknown, although no recent mortality has been reported. We have medium confidence in the assessment. A more thorough analysis will be possible once the ongoing study to assess Douglas-fir-Gambel oak cover is complete (in 2018).
	Minimum Tree Basal Area	NA	This measure was included for informational purposes and was not used to assess condition. USFWS (2012) recommends a minimum tree BA of 25.5 m^2/ha (120 ft^2/acre) for mixed-conifer forest. The average for the two stands within the park (from Knox 2004) was 34.4 m^2/ha (or 150.0 ft^2/ac). This figure is for all trees 5 cm (2.0 in) and greater DBH. The average total BA from the national monument stands (from 2003) exceeded the minimum recommended in the Recovery Plan.
	Minimum Density of Large Trees	NA	This measure was included for informational purposes and was not used to assess condition. USFWS (2012) recommends a minimum density of large trees (>46 cm [18 in]) of 30 trees/ha (12 trees/ac). Data on this size class was not available for the park from Knox (2004). Knox's (2004) largest size class was >30 cm (>12 in), and the average total density for all trees in this class was 97.8 stems per ha (39.6 stems per acre). Therefore, we do not know whether the USFWS recommended minimum for large trees (>46 cm) was met.
Level of Human Disturbance	Occurrence/ level of Potentially-disturbing Activities and Noise in MSO Habitat		We consider condition under this measure to be good to of moderate concern. The measure addressed potential noise disturbance and related disturbance from the presence of humans. Although some noise disturbance may occur from outside of the park, we focused on visitor and NPS operations noise/disturbance, which occurs primarily in a small portion of the national monument. We have low to medium confidence in this measure. Trend is unknown, but if disturbances inside or outside of the park increase (e.g., use of the shooting range, development/use pressure on adjacent lands), disturbance to owls using the national monument would be expected to grow.
Overall Condition			Overall, we consider condition of the MSO and inner canyon environment to be good to of moderate concern, with medium confidence. We consider trends unknown. There are data gaps for this resource (described in the assessment), with efforts currently underway to collect recent information on the cover of Douglas-fir-Gambel oak forest in the park.

habitat, and designated critical habitat. Confidence in this measure is low to medium, and trends are unknown.

Data Gaps

In this section we address data gaps that led to uncertainties in our assessment (and that affected our confidence level in the assessment), as well as other data gaps that did not directly affect our assessment of condition. The main data gaps and uncertainties in our assessment were 1) current information on the area/cover of Douglas-fir-Gambel oak forest in the national monument, and the area of forest affected by the mortality of Douglas-fir trees; and 2) the extent and effect of noise/disturbance from visitor activities and NPS operations within the inner canyon environment. A lack of better information/data in these two areas led to a somewhat less informative assessment and lower confidence in it. As described in the assessment, Flagstaff Area NMs is currently working with a cooperator to study the first data gap. Furthermore, they are planning to examine whether any changes in MSO occupancy within the national monument may relate to changes in habitat that occurred from 2000-2009 (NPS and NAU 2013). The project is scheduled for completion in 2018. The second data gap is not being addressed by any studies at this time, except that park staff are collecting data on sound levels from the shooting range.

If another data gap did not exist, we would have been able to make more use of the two informational measures. This data gap is a baseline inventory of habitat attributes and desired conditions that are specified in the MSO Recovery Plan, such as for vegetation composition/canopy cover/stand structure (Paul Whitefield, Flagstaff Area NMs, Natural Resource Specialist, pers. comm.). The two measures we included for informational purposes under the second indicator were minimum tree basal area and minimum density of large trees (as well as the percent basal area by size class); these are three components of desired conditions recommended for mixed-conifer and pine-oak forest areas managed for nesting/roosting habitat (we only discussed those for mixed-conifer). We were able to address these somewhat in our assessment using data collected in two Douglas-fir stands in the park from Knox (2004), but an actual assessment was not possible due to data limitations.

Other data gaps that exist did not directly affect this condition assessment, but may have led to other potential measures. These include: an accurate map of the ponderosa pine-Gambel oak habitat above the canyon rim; information on whether MSOs are using this habitat above the rim (no MSOs have been observed and no calls have been recorded during monitoring); monitoring data on selected Principal Constituent Elements identified in the Critical Habitat Designation Rule (USFWS 2004); and information on prey populations and their dynamics (Paul Whitefield, Natural Resource Specialist, Flagstaff Area NMs, pers. comm.). Regarding the first gap mentioned, there are errors in the vegetation map from Hansen et al. (2004; Paul Whitefield, Natural Resource Specialist, Flagstaff Area NMs, pers. comm.).

Threats and Issues

Although a list of potential threats to MSOs that use Walnut NM may include a number of factors (e.g., risk of crown fire in MSO habitat, the expansion of visitor activity into new areas of MSO habitat, and growth/development of nearby communities, the two greatest threats at the present time are probably impacts of noise from the Northern Arizona shooting range, and the potential for continued die-off of Douglas-fir due to climate change/drought conditions. The first of these two threats was discussed under the third indicator of the assessment. In addition to being discussed in this assessment and in the Soundscape assessment, the shooting range was also addressed in the Birds assessment. It should be noted that park personnel are presently conducting a study on noise from the shooting range. They are collecting data on sounds heard at different distances away from the range (data collected in 2014-2016), but a report from the study will not be available until 2017 (Mark Szydlo, Biologist, Flagstaff Area NMs, pers. comm.).

Regarding the second threat, there are concerns that additional Douglas-fir trees within the park could be lost due to the return of conditions like those in the early 2000s. Also, as noted previously, larger, more mature trees may be at particular risk (e.g., Parker et al. 2003, Ganey and Vojta 2011). Temperatures in the Southwest have been predicted to increase by more than 3 degrees Fahrenheit (up to 9 degrees Fahrenheit) by 2100 (Kent 2015). It is harder to predict precipitation in the Southwest, and predictions to date vary (Kent 2015). However, droughts are projected to be more intense and last longer in the coming century (Kent 2015). Warmer and drier conditions can lead to drought-stressed trees, bark beetle infestations, tree mortality, and increased fire severity. Although not specific to Douglas-fir forest, the park's foundation document noted that conifer mortality within the park has resulted in "an unprecedented accumulation of dead and downed wood/wildland fuel over the last 10 years" (NPS 2015a).

It should also be acknowledged that this threat is also of concern for the ponderosa pine-Gambel oak forest/woodland within the park; this habitat is within PACs and may be used for various purposes by MSOs at Walnut Canyon NM.

4.10.5. Sources of Expertise

Information for this assessment was provided by Mark Szydlo, Biologist, and Paul Whitefield, Natural Resource Specialist, both with Flagstaff Area NMs. One outside expert was consulted for the assessment; Shaula Hedwall, USFWS Supervisory Fish and Wildlife Biologist, Mexican spotted owl Recovery Team member, and USFWS Mexican spotted owl lead, reviewed and provided comments on a preliminary table showing the indicators and measures to be used, as well as a complete draft assessment. Patty Valentine-Darby, biologist and science writer with Utah State University, authored the assessment.

The Walnut Creek riparian corridor is a biological hotspot supporting several types of wildlife species. Photo Credit: NPS.

Chapter 5. Discussion

5.1. Overall Condition Summary

The Colorado Plateau Ecoregion has the highest density of national parks, monuments (including the Flagstaff Area National Monuments (NMs)), and recreational areas than any other location in the United States (AZGFD 2006). However, despite the high number, land managers are increasingly recognizing resource impacts from activities occurring outside their jurisdictions, underscoring the fact that no single agency (or group of agencies) can conserve species survival needs alone. Instead, these protected lands need to be linked with their surrounding landscapes, working together as a whole, especially given the very real threats of climate change and increasing habitat fragmentation.

This landscape-scale influence on Walnut Canyon NM's natural resources is apparent for some of its condition ratings that are summarized in Table 5.1-1. For example, even though most of the monument's evaluated resources were in good or moderate condition, the Walnut Creek riparian area has been negatively impacted, primarily due to activities occurring outside the monument's boundary.

Near the downstream end of Walnut Canyon, the Santa Fe Dam was built in 1885/1886, and in 1904, another dam was constructed upstream of the monument, which created Lower Lake Mary. In 1941, a third dam was constructed upstream of Lower Lake Mary creating Upper Lake Mary, which currently serves as an important water supply for the city of Flagstaff, Arizona (Soles and Monroe 2012). Following construction of the two upper dams, flows through Walnut Canyon NM have been rare (Monroe and Soles 2015), and the absence of seasonal stream flows during the last 113 years has altered the structure and function of Walnut Creek, including sedimentation, spring and seep recharge and maintenance of stream channel pools, and vegetation composition and structure (Brian 1992, Rowlands et al. 1995, Soles and Monroe 2012, Wagner et al. 2017). This in turn impacts the viability of the wildlife and vegetation that depend upon this the water resource.

The altered hydrologic regime, coupled with impacts from climate change and the ever-increasing population in the greater-Flagstaff, AZ area, make it imperative for land managers to understand resource needs from a landscape-scale perspective if resource sustainability

Table 5-1. Overall condition summary of Walnut Canyon NM's natural resources.

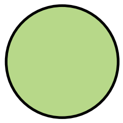
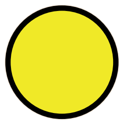
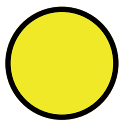
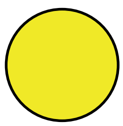
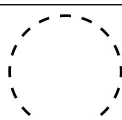
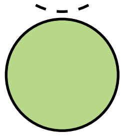
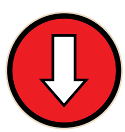
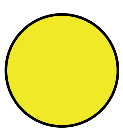
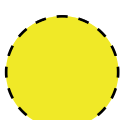
Priority Resource or Value	Condition Status/Trend	Summary of Overall Condition Rating
Viewshed		Viewsheds are an important part of the visitor experience at national parks, and features on the landscape influence the enjoyment, appreciation, and understanding of a particular region. At Walnut Canyon NM, few human-made features are visible within the monument's assessed viewshed. Both housing and road densities are low, resulting in a good condition rating. There are no data available to determine overall trend. Instead, these data may serve as a baseline to make future comparisons. Confidence in this condition rating is medium since the majority of data used were based on models.
Night Sky		Walnut Canyon NM preserves a night sky that corresponds to a rural to suburban transition. Of the five measures used to assess condition, one is good, two are of moderate concern, and two are unknown due to lack of reference conditions. Field data were collected over a 11-year period (2002-2012), and there were only four data points from which to assess condition. Trend is unknown; however, confidence in the data is high, with an overall rating of moderate concern.
Soundscape		Natural sounds and the absence of human-caused noise are important resources to national park visitors and wildlife. In Walnut Canyon NM, while sound levels rarely exceeded 45 dBA, which is the maximum recommended noise level for bedrooms, the amount of time noises were heard and the corresponding reduction in listening area warrants an overall condition of moderate concern. Confidence in the data is high but trend is unknown at this time.
Air Quality		The air we breathe is important for good human health, as well as maintaining viable conditions for wildlife, vegetation, soil, and water quality. It also affects our ability to see scenery. Of the various measures used to assess the air quality at Walnut Canyon, visibility, ozone for human health, and wet deposition for nitrogen and mercury are of moderate concern. Sulfur wet deposition is good, and ozone level for vegetation health is of significant concern. The only trend is for visibility, which is stable. The overall confidence in the data is medium due to interpolated values.
Cherry Pools in Cherry Canyon	 	The condition for the majority of measures used to assess Cherry Pools is unknown since most of the data is more than 10 years old and are sparse, or reference conditions have not been established. Based on the lack of historical reference conditions and availability of current data it was difficult to assign an overall condition for Cherry Canyon pools. The most important measures for assessing the condition of Cherry Canyon pools is stream flow and persistence of pooled water, and these two measures indicate good condition. Overall condition is good to unknown, with no trend.
Walnut Creek Riparian Area		The majority of vegetation, hydrology, and erosion/deposition measures along the Walnut Creek riparian area warrant significant concern, and both stream reaches assessed by the NPS Water Resources Division were considered non-functional. Upstream dams have largely contributed to the overall significant concern condition rating of the Walnut Creek riparian corridor, with high confidence and deteriorating trend.
Ponderosa Pine Forest		The assessment was based on three indicators with four measures, two of which were of moderate concern, one of which was good to of moderate concern, and one of which was of significant concern. Under the FMP the monument is restoring the fire-adapted ponderosa pine stands to the extent possible and protecting ponderosa pines in the larger size classes. Overall condition is moderate, with medium confidence and an unknown trend.
Non-native Invasive Plants		Overall, we consider the condition for non-native and invasive plants in Walnut Canyon NM to warrant moderate concern. Frequency data indicate that non-native plants are widespread, but cover data indicate low abundance for those species. However, the number of non-native plants with high NatureServe and AZ-WIPWG rankings indicate the potential for a number of species to significantly alter native plant communities in the monument. Overall, condition is of moderate concern, with low confidence and an unknown trend.

Table 5.1-1 continued. ***Overall condition summary of Walnut Canyon NM's natural resources.***

Priority Resource or Value	Condition Status/Trend	Summary of Overall Condition Rating
Birds		Birds are good indicators of ecosystem health because they can respond quickly to changes in resource and environmental conditions. One hundred twenty-one birds occur on Walnut Canyon's species list, with 37 considered to be of conservation concern. The overall condition of birds is good and of a medium confidence level. Trends are stable for peregrine falcon and golden eagle but unknown overall.
Mexican spotted owl and Environment		Much of Walnut Canyon NM provides critical habitat for the Mexican spotted owl (MSO). Overall, we consider condition of the MSO and inner canyon environment to be good to of moderate concern, with medium confidence. We consider trends unknown. There are data gaps for this resource (described in the assessment), with efforts currently underway to collect recent information on the cover of Douglas-fir- Gambel oak forest in the park.

is to be achieved. This is an already familiar concept and management strategy for the Flagstaff Area NM resource management staff. The monument staff have worked in partnership with several agencies and stakeholders to proactively manage Walnut Canyon, Wupatki, and Sunset Crater Volcano NMs' resources in such a way that maintains and/or improves resource conditions. According to Walnut Canyon NM's foundation document (NPS 2015a) "its location and orientation make it an important wildlife corridor, and even though the monument is relatively small, it provides habitat for numerous charismatic or rare wildlife species, such as mule deer *(Odocoileus hemionus*), elk (*Cervus canadensis*), black bear (*Ursus americanus*), mountain lion (*Puma concolor*), peregrine falcon (*Falco peregrinus*), and Mexican spotted owl (*Strix occidentalis lucida*)."

5.2. Habitat Connectivity Importance

Some of the greatest threats to wildlife species and biodiversity around the globe are from habitat loss and fragmentation associated with land use changes (Turner 1989, US General Accounting Office 1994, Trzcinski et al. 1999, Fahrig 2003 as cited in Monhan et al. 2012). This loss increases the risk of species extirpation or extinction; thus, maintaining connectivity of habitat is an integral part of protecting species (Crooks and Sanjayan 2006). In general, a connected landscape increases population viability for numerous species (Beier and Noss 1998) but also maintains or improves conditions of abiotic resources such as scenic views, natural quiet, and dark night skies— resources that most park visitors value and appreciate and that certain wildlife species require for their survival.

In 1980, the National Park Service (NPS) reported that over 50% of threats to park resources were from activities occurring outside park boundaries. Surrounding development, such as roads and railroads, housing/business developments, and air pollution were the most frequently cited concerns (NPS 1980). To further exacerbate these threats, specifically to national park resources, Davis and Hansen's (2011) study of land use change trajectories noted that lands surrounding national parks were altered at a more rapid rate than national averages.

Unfortunately, after almost 40 years, the concerns cited in NPS (1980) and Davis and Hansen (2011) are even more relevant and threatening to park resources today. The reality is that very few national parks are large enough to encompass a self-contained ecosystem to adequately conserve species' life cycle needs (Monahan et al. 2012). Thus, partnerships that focus on landscape-scale conservation goals are critical for achieving resource sustainability.

5.2.1. Arizona and Coconino County Population

Throughout the state of Arizona, the population is expected to increase from almost 6.5 million in 2010 to more than 14 million by 2050 (Arizona Department of Transportation [ADOT] 2010, U.S. Census Bureau 2011, both as cited by AGFD 2011). This same source notes that the population of Coconino County, where the Flagstaff Area National NMs are located, may increase by more than 50% by the year 2050. Based on 2010-2015 data, the populations of both Coconino County and Flagstaff, AZ have increased over the five-year period since April 2010, increasing 3.5% and 6.4%, respectively (U.S. Census Bureau 2016a).

5.2.2. Preserving State-wide and Coconino County Habitat Connectivity

In 2004, a group of concerned land managers and biologists from federal, state, and regional agencies, along with researchers from Northern Arizona University (NAU) formed the Arizona Wildlife Linkages Workgroup (AWLW). The workgroup identified critical areas that would help preserve Arizona's diverse natural resources in the midst of the state's rapid population growth. They identified and mapped large areas of protected habitat (i.e., habitat blocks) and the potential linkages (i.e., matrix) between these blocks. This effort became known as the *Arizona Missing Linkage*s project, identifying 152 statewide coarse-level linkage zones (AWLW 2006). The Deadman Mesa – Gray Mountain linkage was the only one associated with any of the Flagstaff Area NMs, with Wupatki NM's western boundary accounting for 3% of the linkage area along Highway 89 (AWLW 2006).

Following AWLW's statewide effort, in 2009 and 2010 the Arizona Game and Fish Department (AGFD), in partnership with Coconino County and the AWLW, developed a *Wildlife Connectivity Assessment Report* for Coconino County (AGFD 2011). The goal of this was to facilitate the maintenance and enhancement of wildlife connectivity throughout the county. The linkages identified were intended to be used as a starting point to assist future finer-scale evaluations of habitat connectivity throughout the county. Several of the linkages identified in Coconino County are associated with the three Flagstaff Area NMs.

Coconino County encompasses an area of 48,332 km^2 (18,661 mi^2), with Wupatki, Walnut Canyon, and Sunset Crater Volcano NMs protecting a little over 170 km^2 (~65.6 mi^2) of public land combined. And while the national monuments are managed as one administrative unit, they are separated by approximately 17.7 km (11 mi) between Walnut Canyon NM and Sunset Crater Volcano NM and about 17.1 km (10.6 mi) between Sunset Crater Volcano NM and Wupatki NM (as a straight line distance from the northern boundary of the first stated monument to the southern boundary of the second monument). The physical separation of the monuments, some of which support the same wildlife species, presents unique management challenges and opportunities, which is why monument staff were interested in evaluating the habitat connectivity between the three national monuments as part of their NRCA effort.

According to Monahan et al. (2012), "the importance of habitat area and pattern is readily apparent for parks, but it is nonetheless difficult to identify a small suite of metrics that adequately describe area and pattern characteristics in ways that generally inform decisions on how to manage park resources. Many people want to know, for example, whether large intact patches of habitat still exist, without reference to any particular species or other resource. [However,] the most important habitat features vary according to question, species, or issue. For example, structural connectivity measures physical attributes without any consideration to species or ecological function. [Conversely], functional connectivity measures landscape attributes, such as land cover type, elevation, distance from roads, etc., that are relevant to an identified species or process." As a result, habitat connectivity "is shaped by both pattern and the attributes of what is moving" (Monahan et al. 2012). It is within this functional connectivity context that NAU scientists developed tools to assist others in evaluating habitat connectivity on a landscape-scale. While NRCAs are not designed to report on conditions outside a park's boundary, an evaluation such as this can serve as an initial step to identify areas that may be of high conservation value, thereby, working "for connectivity than against fragmentation" (Beier et al. 2008).

5.3. Habitat Connectivity Methods

5.3.1. Arizona CorridorDesigner and Area of Analysis Characteristics

Identifying functional habitat connectivity between the three national monuments required several steps throughout the analysis process. These steps or descision points are listed in Appendix G, Table G-1, using a framework from lessons learned during NAU's *Arizona's Missing Linkages* (AWLW 2006) and *South Coast Wildlands 2003-2006* (Penrod et al. 2006) wildlife linkages projects. NAU conservation biologists and GIS analysts developed this decision framework along with two GIS toolboxes, CorridorDesigner and Arizona CorridorDesigner (2007-2013) (Beier et al. 2008, Majka et al. 2007), to guide end-users in creating "a transparent, rigorous rationale for a linkage design."

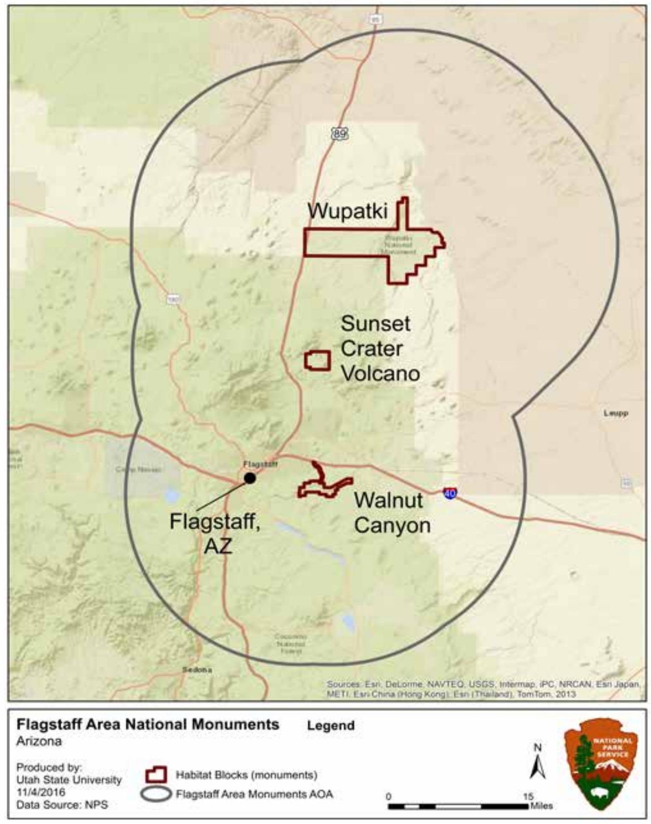


Figure 5.3.1-1. The entire area of analysis for Flagstaff Area NMs' habitat connectivity evaluation is 7,489 km². **The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction.**

To begin the Flagstaff Area NMs' connectivity evaluation process, an area of analysis (AOA) needed to be determined. Through an extensive literature review of ecologically-relevant AOAs, Monahan et al. (2012) identified a 30 km (18.6 mi) radius from a park's boundary as sufficient for meeting most park's natural resource survival needs (NPS 2011d). Following this guidance, a dissolved 30 km buffer surrounding each of the three Flagstaff Area NMs' boundaries served as the entire AOA, totaling 7,489 km² (2,891.5 mi²) (Figure 5.3.1-1, Table 5.3.1-1). The land within each monument's legislated boundary served as the habitat blocks from which the matrix or connectivity between the monuments was evaluated. Each individual monument and its surrounding 30 km (AOA) is discussed in more detail within its respective NRCA report, although a certain degree of overlap exists between the three monuments' habitat connectivity discussions given the nature of the topic.

Walnut Canyon NM encompassed the second largest 30 km AOA (shown in thicker black polygon in subsequent figures), totaling 3,607 km² (1,393 mi²) or 48.1% of the entire Flagstaff Area AOA. Walnut Canyon NM's 30 km AOA extends approximately 28.2 km (17.5 mi) north of the intersection of Highways 89 and Interstate 40 and is located halfway between Sunset Crater NM and Wupatki NM boundaries. Walnut Canyon's western AOA boundary encompasses two-thirds of Camp Navajo then extends approximately 46.7 km (29 mi) east, with Interstate 40 bisecting the AOA. The south boundary ends just north of Sedona, AZ, approximately 32.2 km (20 mi) south of Flagstaff AZ. Information specific to Wupatki and Sunset Crater Volcano NMs is also presented in Table 5.3.1-1 but is further discussed within each of their respective NRCA reports.

The U.S. Geological Survey (USGS) (2016c) Gap Analysis Program (GAP) Protected Areas Database (PAD)-US version 1.4 conservation status metric was used to calculate the percentage of Flagstaff Area NMs' 30 km AOA that is classified as GAP status 1-4 categories (1 = highest protection, 4 = lowest protection) (refer to Appendix G for category definitions) and the percentage of broad ownership categories (e.g., federal, state, tribal, etc.). According to Monahan et al. (2012), "the percentage of land area protected provides an indication of conservation status and offers insight into potential threats (e.g., how much land is available for conversion and where it is located in relation to a park's boundary), as well as offers insights into potential opportunities (e.g., connectivity and networking of protected areas)."

Within the entire Flagstaff Area AOA, 42,606 hectares (ha) (105,282 ac) (5.7%) of land is designated as permanently protected and managed for biodiversity (dark and light green areas shown in Figure 5.3.1-2). Disturbance events on 39.5% of the permanently protected lands are allowed, whereas events are suppressed on the remaining 60.5% of those

Table 5.3.1-1. Area of analysis summary.

Area	Sq. km	Sq. Miles	% Total
Entire AOA	7,489	2,891.5	100
Wupatki NM	4,917	1,898	65.7
Sunset Crater Volcano NM	3,254	1,256	43.4
Walnut Canyon NM	3,607	1,393	48.1
Area of Overlap	1,096	423	14.6

permanently protected lands. Another 331,835 ha (819,983 ac) (44.3%) of land within the entire AOA is managed for multiple uses, such as logging, mining, etc. (yellow areas shown in Figure 5.3.1-2). The U.S. Forest Service (USFS) and Bureau of Indian Affairs are the primary agencies managing 363,302 ha (897,739 ac) (48.5%) and 242,425 ha (599,046 ac) (32.4%) of the land throughout Flagstaff Area NMs 30 km AOA.

The conservation status of lands specifically within Walnut Canyon's 30 km AOA is largely comprised of lands that are managed for multiple uses (yellow areas on Figure 5.3.1-2) such as extraction or off road vehicle use, accounting for 74.7% of land within its AOA. An additional 7.2% of the land within Walnut Canyon's AOA is permanently protected, including the areas within Walnut Canyon and Sunset Crater Volcano NMs. The white areas shown in Figure 5.3.1-2 represent potentially unprotected or privately held land and include the city of Flagstaff, AZ. Walnut Canyon NM's western boundary is nearly adjacent to the City of Flagstaff, Arizona.

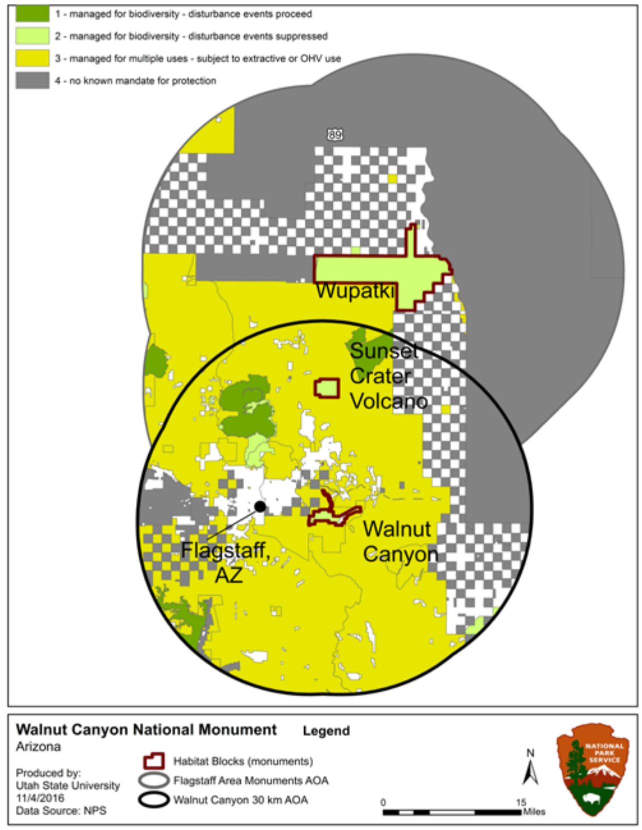


Figure 5.3.1-2. Conservation status of lands within the entire area of analysis surrounding Flagstaff Area NMs. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction.

5.3.2. Arizona CorridorDesigner Models

The Arizona CorridorDesigner toolbox was developed to assess habitat suitability and size of breeding areas for 16 mammal and 12 herpetofauna Arizona wildlife species. In turn, these models are used to develop wildlife corridor models. For Walnut Canyon NM, seven native wildlife species (American badger (*Taxidea taxus*), American black bear, American pronghorn (*Antilocapra americana*), lyre snake (*Trimorphodon biscutatus*), mountain lion, mule deer, and white-nosed coati (*Nasua narica)* which are listed on its species list (NPS 2016b) were selected to evaluate habitat connectivity between its boundary and Sunset Crater Volcano and Wupatki NMs. These species and their associated selection criteria are presented in Table 5.3.2-1.

The Arizona CorridorDesigner toolbox outputs for each species included three models that were mapped at a 30 m x 30 m (98 ft x 98 ft) resolution: 1) habitat suitability models (HSM), 2) patch models (PM), and 3) corridor models (CM). Four datasets were used to create a HSM for each species: 1) Southwest Regional Gap Analysis Project (SWReGAP) land cover (USGS 2004), (2) U.S. Geological Survey's (USGS 2016a) National Elevation Dataset (NED) digital elevation model (DEM), (3) topography, and (4) distance from roads.

Subject matter experts assisted with identifying attributes within each dataset that served as proxies for each of the species survival needs, including cover, food, hazard avoidance, reproductive habitat needs, etc. If an expert was unavailable, three biologists independently reviewed the scientific literature and assigned scores then compared their results to calculate an average score.

The SWReGAP land cover dataset was categorized into 46 vegetation classes creating 10 broad categories, such as evergreen forest or grassland-herbaceous vegetation. By grouping the closely related vegetation types, the accuracy of the models improved (Beier et al. 2008). Using the entire Flagstaff Area NM 30 km AOA, the SWReGAP's land cover dataset was clipped, and resulted in all 10 land cover types occurring within the AOA (Figure 5.3.2-1). Shrub-scrub (tan), grassland-herbaceous (light green), and evergreen forest (dark green) are the dominant land cover types throughout the AOA and are situated along a northwest to southeast gradient from north to south. The primary

Table 5.3.2-1. Arizona CorridorDesigner wildlife species selected for Walnut Canyon NM's habitat connectivity assessment and their associated habitat factors.

Common Name	Scientific Name	Species Selection Criteria	Land Cover	Elevation	Topography	Distance From Roads
			Percent (%)			
American badger	*Taxidea taxus*	Large home range; many protected lands are not large enough to ensure species' life cycle.	65	7	15	13
American black bear	*Ursus americanus*	Requires habitat variety; low population densities makes them vulnerable to habitat fragmentation.	75	10	10	5
American pronghorn	*Antilocapra americana*	Susceptible to habitat fragmentation and human development; sensitive to barriers.	45	0	37	18
Lyre snake	*Trimorphodon biscutatus*	Susceptible to habitat fragmentation.	–	10	80	10
Mountain lion	*Puma concolor*	Requires a large area of connected landscapes to support even minimum self sustaining populations.	70	0	10	20
Mule deer	*Odocoileus hemionus*	Important prey species; road systems may affect the distribution and welfare of species.	80	0	15	5
White-nosed coati	*Nasua narica*	Appears to be dispersal limited.	95	–	–	5

land cover types within Walnut Canyon NM's 30 km AOA were evergreen forest and grassland-herbaceous, followed by barren land, (representing the volcanic-derived landscape between Sunset Crater Volcano and Wupatki), and developed land, which includes the city of Flagstaff, AZ and developments, such as subdivisions, north of Walnut Canyon NM.

Using the USGS (2016a) NED DEM, topographic features such as aspect and slope were analyzed to create topographic position categories (i.e., canyon bottom, flat-gentle slopes, steep slopes, and ridgetop; Figure 5.3.2-2). These features were ranked for each species based on their survival needs. For example, Ockenfels et al. (1996) noted that pronghorn avoid canyon walls due to the increased likelihood of mountain lion predation and instead prefer flat to gently rolling terrain where they are able to easily detect predators. This topographic preference is shown in Table 5.3.2-1, with the highest topography rank of 37% assigned to pronghorn, reflecting its sensitivity to this feature.

Elevations were identified for each species also using the USGS (2016a) NED DEM. And finally, distance to nearest roads was used as a proxy for disturbance avoidance. Beier et al. (2008) suggested not including crossing structures in the habitat connectivity evaluation process since it "forces the position of a

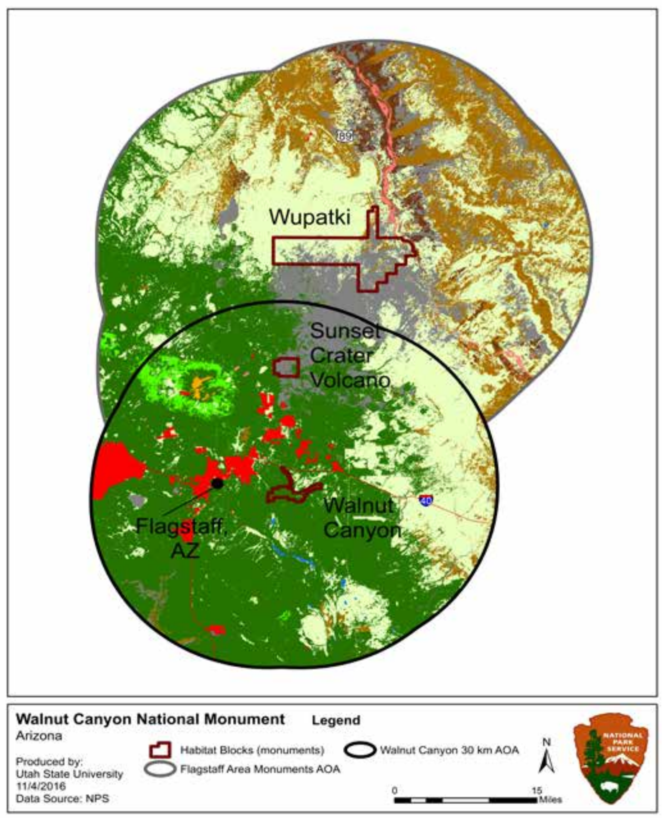


Figure 5.3.2-1. Land cover classes within the Flagstaff Area NM 30 km area of analysis. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction.

modeled corridor, which may in fact be a suboptimal location."

Four scores, based on a scale of 1 (best habitat) to ten (worst habitat), were assigned to each grouping or class of attributes within each of the four datasets for a given species. Each 30 m x 30 m pixel was assigned a score between 1 and 10 then each factor was weighted by a factor between 0 - 100%, summing to 100%. The four weighted scores were combined using a weighted geometric mean to "better reflect situations in which one factor limits wildlife movement in a way that cannot be compensated for by a lower resistance for another factor" (UWFWS 1981 as cited in Beier et al. 2008). This scoring process created the HSMs for each species, which were then used to create the PMs and CMs (refer to Beier et al. 2008 for a detailed account of the methodology involved in developing these models).

The HSMs identified five classes of habitat suitability for each species based on the weighted habitat factors. The five classes, shown in Figure 5.3.2-3, ranged from absolute non-habitat to optimal. Areas of habitat large enough to support breeding populations were identified using neighborhood analysis, creating PMs. The PMs were grouped by size into three classes: less than (<) breeding patch, breeding patch, and population patch as shown in Figure 5.3.2-4. The population patch was the largest area of the three classes and represented the ability to support the breeding requirements of a given species for 10 or more years, even if isolated from interaction with other populations of the species (Majka et al. 2007). The breeding patch represented a "core" area for each species. A breeding patch was smaller than a population patch, but large enough to occasionally support a single breeding event and serve as a potential "stepping stone" within a corridor linkage (Beier et al. 2008).

Finally, the third model type, CM, was created by identifying well-connected pixels in the HSMs and PMs that represented the easiest area for a particular species to move through. This is based on the assumption that the habitat requirements for each species survival are the same ones needed for their movement patterns (Beier et al. 2008). The habitat patches within the wildland blocks (i.e., monuments) were used as the corridor terminuses, and the travel cost

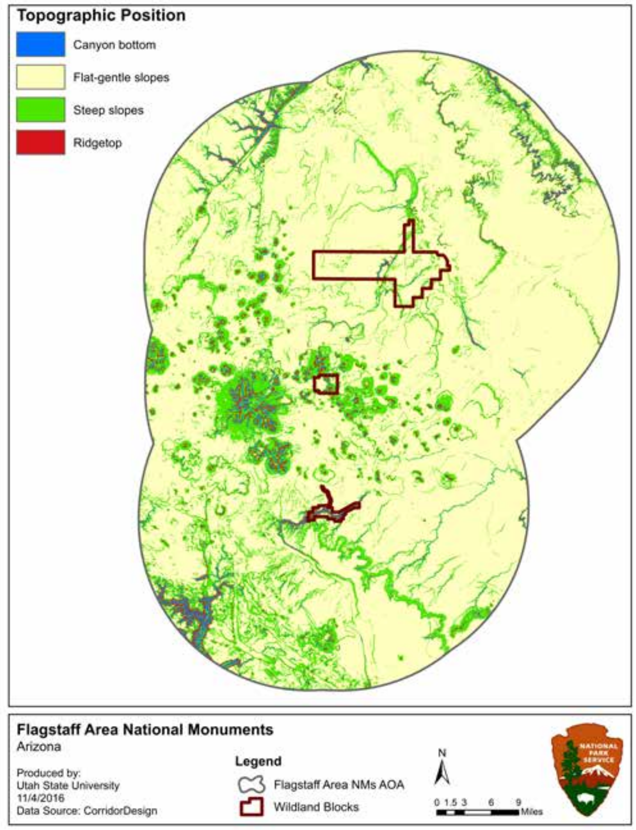


Figure 5.3.2-2. Topographic position within the Flagstaff Area NM 30 km area of analysis. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction.

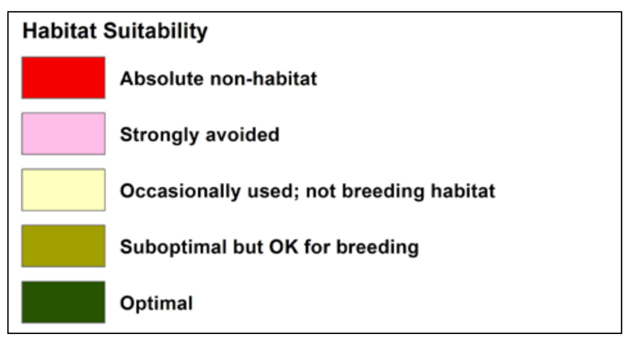


Figure 5.3.2-3. Five classes were used in each species' habitat suitability model.

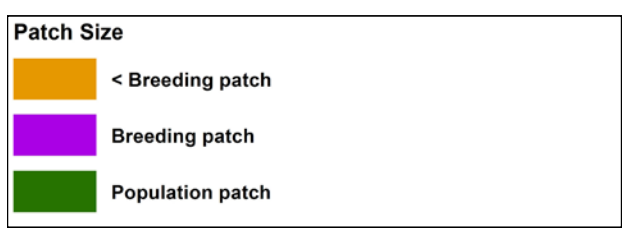


Figure 5.3.2-4. Three classes were used in each species' patch model.

was mapped as increasingly wide polygons sliced into 11 different widths (i.e., 0.1%, 1-10%). The smallest slice (i.e., 0.1%) represented the least amount of effort or resistance for a species to move through. As the corridor widths increased so did practical constraints that would affect realistic conservation efforts by land managers. As a result, each species largest corridor width was selected based on its home range size, using information provided in Majka et al. (2007). Finally, all selected CM slices were unioned (and minimally trimmed only when an area represented one species but suitable habitat was available nearby within the remaining corridor), showing potential areas of connectivity to facilitate movements of the selected species. The output for this phase of the evaluation process is referred to as the preliminary linkage design (PLD).

5.4. Preliminary Linkage Design Results

The PLD for Walnut Canyon NM, shown in Figure 5.4.1-1, resulted in two primary areas linking Walnut Canyon NM to Sunset Crater Volcano and Wupatki NMs. Majka et al. (2007) suggested not modeling corridors for species where no habitat patches exist within the wildland blocks (i.e., monuments). As a result, Walnut Canyon's PLD is based on the unioned CMs for badger, pronghorn, mountain lion, bear, and mule deer. Corridors were not created for white-nosed coati and lyre snake since they are listed as present only in Walnut Canyon NM. However, suitable habitats for both species were included in the preliminary linkage design results. The dominant land cover classes within Walnut Canyon NM's 30 km AOA were evergreen forest and grassland-herbaceous vegetation, in addition to a high concentration of development located west and north of Walnut Canyon NM.

Two primary linkage routes were modeled, with one located north of Walnut Canyon NM and one located east of the monument. The northern PLD is comprised primarily of evergreen forest, which is the predominant land cover type that exists between Walnut Canyon and Sunset Crater Volcano, and development. Whereas, the eastern PLD is predominantly comprised of the grassland/herbaceous cover type, with a minimal amount of evergreen forest and development compared to the northern linkage.

The northern PLD connects Walnut Canyon NM's northeastern boundary to two locations along Sunset Crater Volcano's southern boundary, with the primary linkage located at Sunset Crater Volcano's southwestern corner. Pronghorn, badger, mountain lion, mule deer, bear, and some habitat for white-nosed coati and lyre snake are included in the wider area of the northern PLD linkage, shown in Figure 5.4.1-1. Extending from Walnut Canyon NM, the northern PLD crosses I-40/U.S. 180 then extends north to its widest area north of Turkey Hills. The largest (and southernmost) hole in the linkage is located around Doney Park. Townsend-Winona Road bisects the widest area of the PLD into northern and southern portions and Highway 89 bisects the PLD into eastern and western sections.

Walnut Canyon's northern PLD is becoming increasingly developed as the city of Flagstaff expands north and east and numerous subdivisions, either built or planned, are located north of Townsend-Winona Road in the widest portion of the northern PLD. In addition, Slayton Ranch Estates development is located in the middle strand that was modeled for bear only as shown on Figure 5.4.1-1. The easternmost strand of the northern PLD was modeled for mountain lion only and extends north crossing I-40/U.S. 80 east of O'Neil Crater and west of Little Cinder Basin where it joins the middle strand for bear. These two narrow strands finally join and connect to Sunset Crater Volcano NM's southeastern boundary at a very narrow point. The majority of the 21.7 km (13.5 mi) northern PLD is privately owned, with the exception of the easternmost strand for mountain lion, which is located in the Coconino National Forest.

The easternmost PLD, located between Walnut Canyon and Wupatki NMs, begins at the northern boundary of Walnut Canyon's northeastern corner and extends approximately 14.5 km (9 mi) through Coconino National Forest until it reaches mixed ownership of private and state lands. It continues another 0.64 km (0.4 mi) until it splits into two strands just south of Leupp Road. The western (left) strand of the eastern PLD is for mule deer only and follows the western edge of tribal land eventually paralleling the Little Colorado River. The easternmost split strand, extending approximately 40.2 km (25 mi) all within tribal land, represents habitat connectivity for pronghorn and badger. This strand also includes some patchy habitat for bear, mountain lion, white-nosed coati, and lyre snake, but is more suited to the grassland-dependent species that comprised Wupatki's species assemblage. While the westernmost

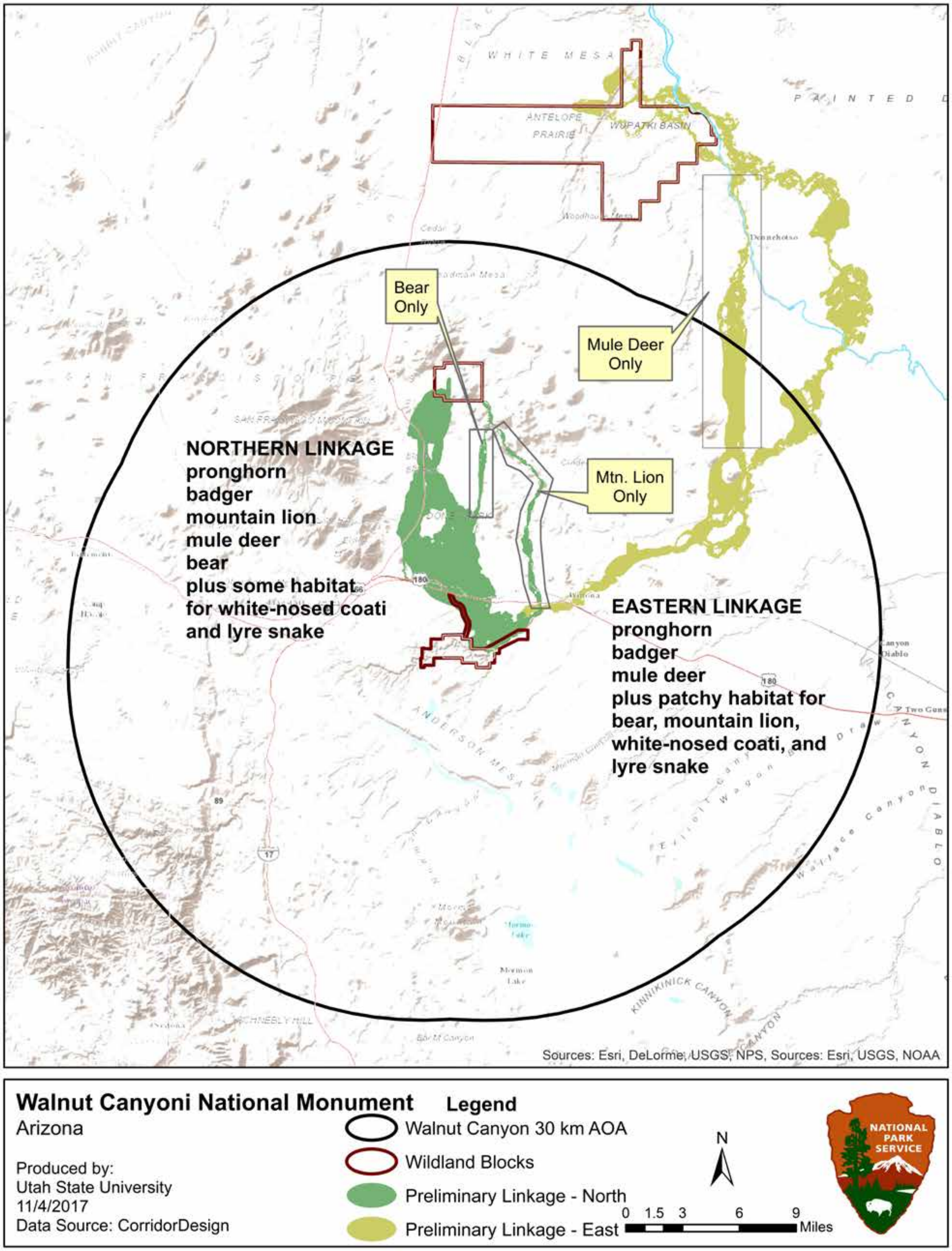


Figure 5.4.1-1. Preliminary linkage design for Walnut Canyon NM only. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction.

strand was modeled for mule deer only, it was retained since it shared the same corridor area that originated at Walnut Canyon NM's northern boundary as the other species included until splitting off just south of Leupp Road.

Both the Walnut Canyon to Wupatki and Walnut Canyon to Sunset Crater Volcano PLDs include habitat for pronghorn, although the easternmost strand from Walnut Canyon to Wupatki contains more suitable habitat. While some habitat for the white-nosed coati and lyre snake exists in both the northern and eastern PLDs, the northern PLD contains larger patches and higher suitability. The eastern PLD for badger and pronghorn were nearly identical, representing similar habitat preferences within the herbaceous-grassland cover type. The easternmost strand of Walnut Canyon's eastern PLD is east of the area identified as low-moderate quality for pronghorn by Ockenfels et al. (1996), however, observers were not able to access all lands during Ockenfels study, which may be the reason for the difference between the modeled PLD versus what is shown on the Ockenfels et al. (1996) maps.

Walnut Canyon's 30 km AOA encompassed 35 of the coarse-level linkages identified in the Wildlife Connectivity Assessment Report for Coconino County (AGFD 2011) (Figure 5.4.1-2; refer to Appendix G for a summary of these linkages). Six of the county's linkages, 34, 38, 39, 46, and small areas of 22, and 32, overlapped with Walnut Canyon's northern PLD. County linkage 17, and to a lesser extent 22 and 23, overlapped with Walnut Canyon's eastern PLD.

Coconino County linkages 34, 38, 39, 46, which include Elden Spring Road and Elden Pueblo, Rio de Flag, and Walnut Canyon NM were identified as important for mule deer, mountain lion, striped skunk (*Mephitis mephitis*), raccoon (*Procyon lotor*), gray fox (*Urocyon cinereoargenteus*), coyote (*Canis latrans*), elk, porcupine (*Erethizon dorsatum*), bats, Gunnison's prairie dog (*Cynomys gunnisoni*), and several bird species (i.e., waterfowl, bald eagle (*Haliaeetus leucocephalus*), turkey (*Meleagris gallopavo*), peregrine falcon, and neotropical migratory birds).

Coconino County linkage 17 is the largest linkage of all that overlap with Walnut Canyon's PLDs and includes the grassland north and east of San Francisco Peaks, east of Anderson Mesa. This linkage identified habitat

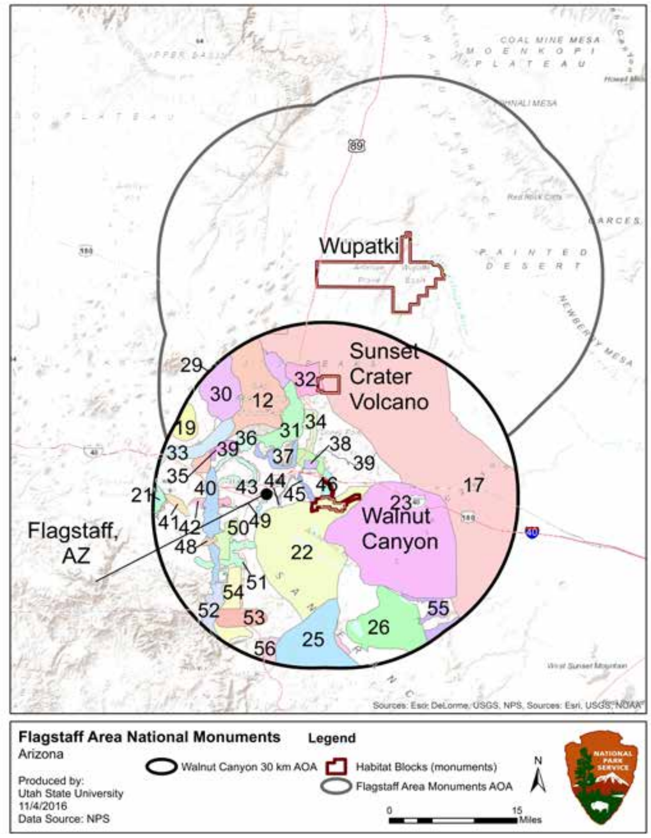


Figure 5.4.1-2. Thirty-five Coconino County wildlife linkages were located within Walnut Canyon NM's 30 km AOA. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction.

for pronghorn, Gunnison's prairie dog, black-tailed jackrabbit (*Lepus californicus*), golden eagle (*Aquila chrysaetos*), milk snakes, birds, and bats. Linkage 22, includes Walnut Canyon NM as well as the area south, encompassing Anderson Mesa and Antelope Park/Mormon Mountain. This linkage identified quality habitat for mountain lion, elk, mule deer, black bear, gray fox, raccoon, coyote, small mammals, bull snake (*Pituophis catenifer*), leopard frog (*Rana pipiens*), bats, tarantula (*Theraphosa apophysis*), and several birds, including northern goshawk (*Accipiter gentilis*),peregrine falcon, Mexican spotted owl (*Strix occidentalis lucida)*, neotropical migratory birds, turkey, and bald eagle.

While Walnut Canyon NM provides high quality habitat for bird species and actively surveys and manages several raptor species, birds were not included in the Arizona CorridorDesigner habitat connectivity evaluation since their movement, as function of GIS layers, cannot not be modeled (Beier et al. 2008). This is due to their ability to fly.

The threats associated within the five primary Coconino County linkages as they relate to Walnut Canyon NM's PLDs are discussed in the Threats section.

As with any model, there are several inherent assumptions and uncertainties. A model is intended to serve as a proxy, and in this assessment, each model is based on the premise that the landscape factors and weights selected for each species' habitat preferences remain the same for their movement needs. To the extent that this assumption is true, the models are more likely to provide accurate results. To further compound uncertainty, the error inherent in any dataset also affects the accuracy of results. And finally, the size and configuration of suitable habitat patches were not further analyzed for each species nor were any of the potential corridor routes ground-truthed, such as checking areas for new developments and/or barriers such as freeways, canals, or major fences that are only a pixel or two in width in the model and likely not captured in the analyses.

Instead, the PLD should be viewed as a starting point for a more in-depth investigation where specific conservation targets and goals, such as habitat restoration or barrier removal, can be identified and included in the overall linkage design. In addition, information such as wildlife passage locations, water sources, and telemetry data could be added to create a comprehensive linkage evaluation. According to Beier et al. (2008), the results obtained from the Arizona CorridorDesigner tools "should only be relied upon with corroboration of the methods, assumptions, and results by a qualified independent source," suggesting areas for field surveys and more detailed analysis to guide decisions about conservation goals.

Beier et al. (2008) included the following steps for creating a comprehensive linkage design from preliminary results:

- determine if you need to include focal species for which you could not build a corridor model
- remove redundant strands
- determine other conservation goals that should be included
- mitigate barriers (such as locating highway wildlife crossings)
- evaluate the land management in and adjacent to the mapped area.

In addition, an increasing number of studies are finding that habitat density has a great effect on wildlife populations (Monahan et al. 2012). "Among terrestrial species, Lande (1987) suggests that species with a large dispersal range, high fecundity, and high survivorship, may be able to persist when suitable habitat covers only 25-50% of the landscape, while species with low demographic potential may be lost when as much as 80% of the landscape remains suitable habitat" (as cited in Monahan et al. 2012). Grassland or forest density metrics could be added to a more-detailed, ground-truthed linkage design for further refinement and evaluation. Based on Stegner et al. (2017) findings of mammalian diversity in protected areas within the Colorado Plateau, certain wildlife such as pronghorn, mountain lion, and several water-dependent species are less common than what they expected when compared to historic range maps. In addition, all of the Flagstaff Area NMs showed a lower present-day mammal diversity when compared to historic records and their current NPSpecies lists. However, Walnut Canyon NM was closest to exhibiting the same present-day diversity as historical records indicated.

As the population within the city of Flagstaff continues to increase and sprawl toward the Flagstaff Area NMs, especially Walnut Canyon, increased habitat fragmentation will also likely continue (NPS 1996). The effects of habitat fragmentation as a result of development are varied and range from the direct mortality of animals on roads to the genetic isolation of wildlife populations that have become fragmented (AGFD 2011). Roadways are a well-known cause of fragmentation (e.g., Corlatti et al. 2009), especially fenced highways.

The wildlife barriers identified within the five primary Coconino County linkages (i.e., 17, 34, 38, 39, and 46) that overlap with Walnut Canyon NM's PLD include off-road vehicle use, Timberline development, highways I-40, and U.S. 89, BNSF Railroad, and Leupp and Elden Springs Roads (AGFD 2011). Among the mammals evaluated for Walnut Canyon's connectivity assessment, mountain lions and pronghorn were ranked highest for being particularly sensitive to roads. This has contributed to the isolation of pronghorn populations and interference with their seasonal migrations (Dodd et al. 2011, AGFD 2011).

In a two-year telemetry study of 37 pronghorn (about one-half captured on each side of U.S. Highway

89, researchers found that only one of the collared pronghorn crossed the road during the tracking period (Dodd et al. 2011); thirty animals, however, approached the highway to within 0.24 km (0.15 mi). Recent genetic work found that the pronghorn herd on each side of the highway differed from the other genetically, indicating restricted gene flow (Sprague 2010). Building upon these findings, a partnership of state and federal agencies, including Flagstaff Area NM resource management staff, private ranches, and nonprofit organizations began working together in 2013 to increase pronghorn habitat connectivity at the landscape level (NPS & AGFD 2014). Efforts to make fences more permeable to pronghorn included activities taken on NPS lands and on adjacent Coconino National Forest, Arizona State Trust lands, and Babbitt Ranches lands.

However, in 2004, ADOT began long-range planning to expand U.S. 89 to four lanes from around Wupatki's southern monument boundary northward to Cameron, Arizona (ADOT 2006). While the proposed expansion is located beyond Walnut Canyon's 30 km AOA, it will likely impact pronghorn movements occurring within portions of its AOA. The effect(s) on the ability of pronghorn and other mammals to cross a four-lane highway is currently being assessed (NPS and AGFD 2014), and if a wider highway exacerbates habitat fragmentation effects, and long-term fence modification efforts are not sufficient to mitigate the effects, an overpass may be the only effective means of maintaining connectivity.

Mountain lion is another mammal that is very sensitive to roads, and while it's known to use diverse habitats, its range has been restricted due to hunting and development (Currier 1983 as cited in Majika et al. 2007). Mountain lions require large areas of connected landscapes and riparian communities, such as the one within and surrounding Walnut Creek, for their survival needs (Majika et al. 2007). As the human population continues to increase surrounding the greater-Flagstaff area, associated development, including more roads and housing, especially within the Coconino County linkage for Turkey Hills - Picture Canyon - Elden Pueblo, which cites rural development as a primary threat (AGFD 2011), will likely degrade and/or permanently convert natural habitat if the needs of wildlife are not considered as part of the area's regional planning process.

Spatially Explicit Regional Growth Model (SERGoM)

To examine the population increase within the Flagstaff Area NM and Walnut Canyon NM AOAs, four projected housing density rasters (100 m [328.1 ft] resolution) for 1970, 2010, 2050, and 2100, (Figure 5.4.1-3) were evaluated using Theobald's (2005) Spatially Explicit Regional Growth Model (SERGoM) (NPS 2014a). SERGoM forecasts changes on a decadal basis using county specific population estimates and variable growth rates that are location-specific. Distribution of projected growth was based on accessibility to the nearest urban core, defined as development >100 ha (247 ac). The model assumed that housing density would not decline, which is consistent with population projections throughout all of Arizona.

ArcGIS Spatial Analyst's 'extract by mask' tool was used to clip the raster to the AOAs and a summary of the results is listed in Table 5.4.1-1. Most of the area within the Flagstaff Area AOA has been classified as rural and is expected to remain as such through the year 2100, however, a much higher (i.e., more concentrated) amount of development is located within Walnut Canyon NM's AOA due to its proximity to the city of Flagstaff and the development that is occurring north of Walnut Canyon (between Walnut Canyon and Sunset Crater Volcano NMs). The highest amount of exurban growth within Walnut Canyon's AOA occurred between 1970 and 2010, and the growth model predicts increasing suburban growth surrounding the monument, nearly doubling between 2010 to 2050 and again from 2050 to 2100.

This preliminary linkage design for Walnut Canyon NM is intended to assist resource managers and stakeholders to manage along ecological rather than political boundaries, promoting stewardship by comprehensively addressing resource needs in ways that lead to sustainability and cost-effectiveness. As such, this information should be used in conjunction with the more detailed information of individual monitoring and research programs at the monument.

The National Park System Advisory Board (NPSAB) identified "conservation at the landscape scale" as an important model to help guide NPS planning and management activities. According to NPSAB, transitioning from a model of standalone national parks into one of innovative partnering to protect landscapes that transcend administrative boundaries

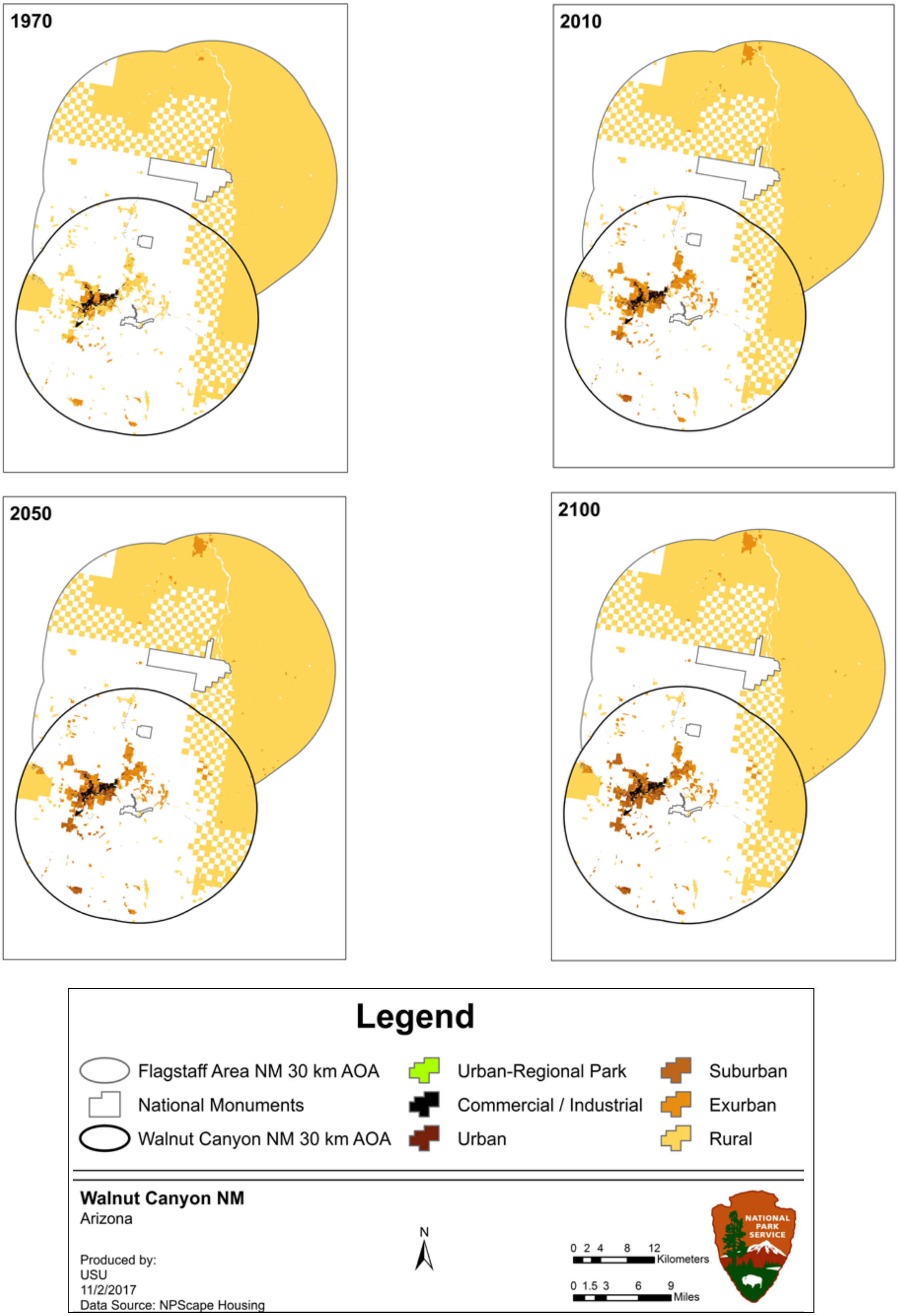


Figure 5.4.1-3. Spatially Explicit Regional Growth Model (SERGoM v3) housing density for four decades surrounding Flagstaff Area NMs, including Walnut Canyon NM. Data Sources: Theobold (2005) and NPS (2014a). The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction.

Table 5.4.1-1. Housing density classes.

Grouped Housing Density Class	% Area in Walnut Canyon NM's 30 km AOA				% Area in Flagstaff Area NMs' 30 km AOA			
	1970*	2010	2050	2100	1970	2010	2050	2100
Rural	90.3	75	73.7	73.4	97.7	93.6	93.2	93.1
Exurban	0.06	18.3	15.6	11.4	1.5	4.8	4.3	3.3
Suburban	0.39	3.6	7.6	12.1	0.09	0.85	1.8	2.8
Urban	0.016	0.17	0.22	0.25	0.004	0.04	0.05	0.06
Commercial / Industrial	2.9	2.9	2.9	2.9	0.67	0.67	0.67	0.67

Sources: Theobold (2005) and NPS (2014a).

* SERGoM dataset for 1970 does not add to 100%.

will help parks achieve shared conservation goals (NPSAB 2012a,b). This is not a new management concept or approach for the Flagstaff Area NM resource management staff even though this habitat connectivity evaluation is an initial attempt to identify and describe the potential finer-scale linkages between the Flagstaff Area NMs.

The many potential benefits of safeguarding habitat connectivity and corridors include allowing for the natural behavior of species to range across the landscape in their use of foraging or breeding sites; allowing for the dispersal of individuals from their natal ranges; increasing the immigration rate to an area, which could help maintain genetic variation within populations; providing habitat within corridors for resident species and those passing through; and facilitating shifts in the range of a population due to climate change (Crooks and Sanjayan 2006).

Walnut Canyon NM supports a high plant and animal diversity, making it an important biological hotspot in the region. The overlapping ecological communities create varied habitats for species usually separated by elevation, creating a rare compression of flora/fauna zones (NPS SCPN 2017b). NPS SCPN 2017b states that "the biodiversity supported by these habitats includes a high concentration of sensitive species and is thought to have contributed to the decision of prehistoric people to settle here."

The partnering and management efforts that Flagstaff Area NM resource management staff have developed and implemented for the Mexican spotted owl, with adjacent Coconino National Forest land managers, and USFWS biologists, along with the fence improvements along Wupatki's boundary to facilitate pronghorn movement across the landscape is crucial to conservation management. Applying scientific information to management actions has helped and will continue to improve resource conditions at the landscape-level surrounding the Flagstaff Area NMs. Due to Walnut Canyon's location within the forest and woodlands ecotype (dark green in Figure 5.4.1-4), it may be especially important to partner with land management agencies and organizations northwest and southeast of the monument, located within this same ecotype, to promote connectivity for wildlife species that rely upon these habitats.

This chapter was authored by Kim Struthers, NRCA Coordinator for Utah State University projects.

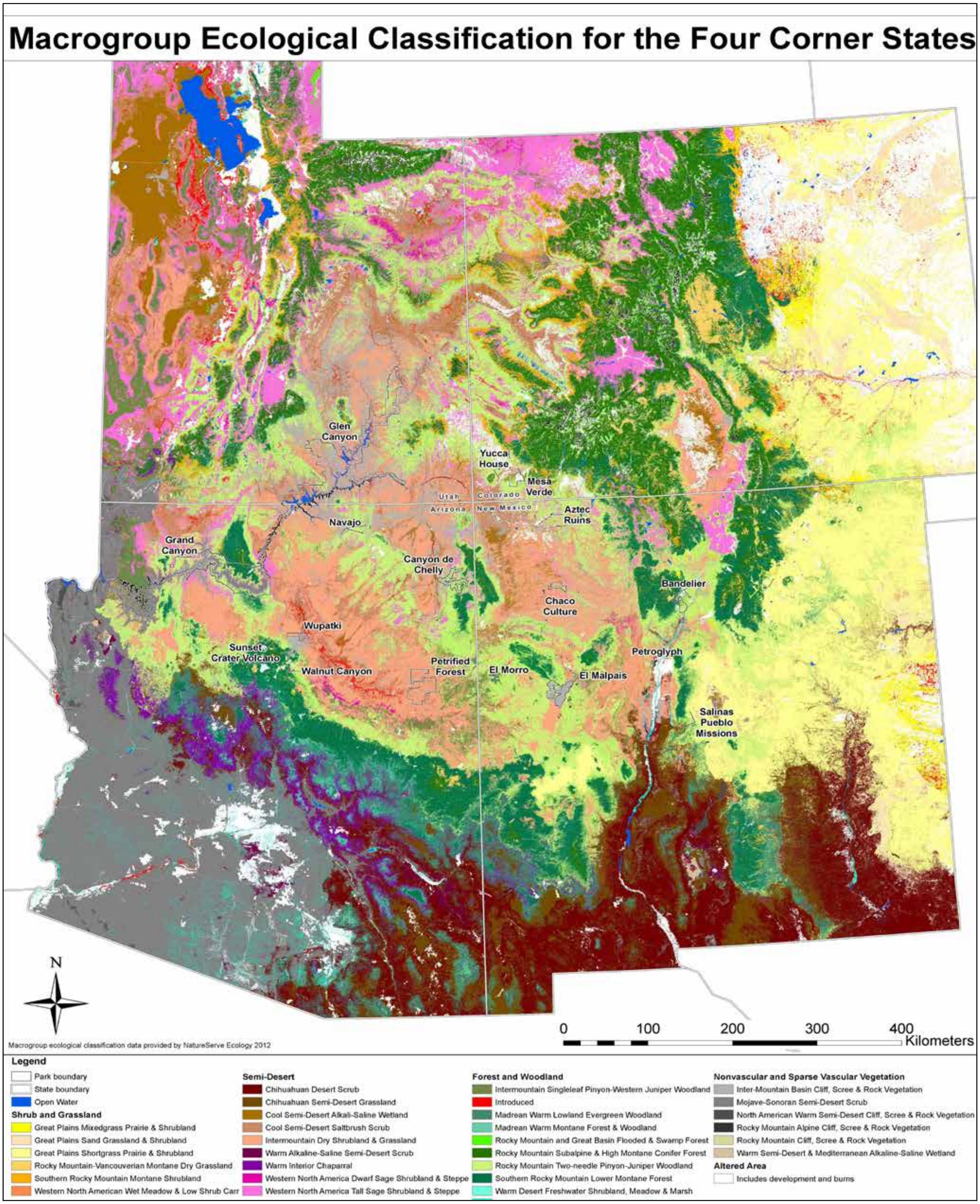


Figure 5.4.1-4. Walnut Canyon NM is located in the forest and woodland ecological vegetation type, which extends primarly to the southeast across Arizona into New Mexico. of wildlife species. Figure Credit: ©NatureServe Ecology (2012) and NPS SCPN (2012).

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Appendix A. Walnut Canyon NM Mammal and Herpetofauna Species Lists

Listed below are the mammal species that have been recorded at Walnut Canyon National Monument (NM). Sources used for the list were the Certified NPSpecies list for the national monument (dated 23 March 2016), and Drost (2009). Species listed by Drost (2009) were those recorded by him: 1) during field work in 2000-2004; and 2) based on his review of museum data and other sources. Some notes are also provided on specific species based on 2014-2015 data from camera traps at the Cherry Canyon pools. Species in the list below are separated by mammal group (i.e., order). A total of 58 species are in the table, includingtwo non-native species. The list of species was compared with lists of federally threatened and endangered species and those of Greatest Conservation Need (SGCN) in the state (Arizona Game and Fish Department [AGFD] 2012).

Table A.1. Mammals at Walnut Canyon NM.

Group	Common Name	Scientific Name	Drost (2009)
Ungulates	Bighorn sheep [1]	*Ovis canadensis*	X [1]
	Collared peccary	*Pecari tajacu*	X
	Domestic cattle (non-native)	*Bos taurus*	X
	Elk (non-native)	*Cervus canadensis* (or *elaphus*) [2]	X
	Mule deer	*Odocoileus hemionus*	X
	Pronghorn [3]	*Antilocapra americana americana*	X
Carnivores	American badger [4]	*Taxidea taxus*	X
	American black bear	*Ursus americanus*	X
	Bobcat	*Lynx rufus*	X
	Coyote	*Canis latrans*	X
	Gray fox	*Urocyon cinereoargenteus*	X
	Long-tailed weasel [4]	*Mustela frenata*	X
	Mountain lion	*Puma concolor*	X
	Northern raccoon	*Procyon lotor*	X
	Ringtail [4]	*Bassariscus astutus*	X
	Striped skunk	*Mephitis mephitis*	X
	Western spotted skunk [5]	*Spilogale gracilis*	X
	White-backed hog-nosed skunk [6]	*Conepatus leuconotus*	X
	White-nosed coati [7]	*Nasua narica*	X
Lagomorphs	Black-tailed jackrabbit	*Lepus californicus*	X
	Desert cottontail	*Sylvilagus audubonii*	X
Bats	Allen's big-eared bat	*Idionycteris phyllotis*	X
	Arizona myotis [3, 8]	*Myotis occultus*	X

[1] Species was listed by Drost (2009) as historic; not listed by NPSpecies.

[2] NPSpecies lists the elk as *Cervus elaphus*, while Drost (2009) lists it as *C. canadensis*.

[3] Listed as a Species of Greatest Conservation Need (SGCN, Tier 1A or 1B [out of 1A-1C]) with the State (AGFD 2012). None of the species are federally-listed as endangered or threatened.

[4] NPSpecies considers this species as "probably present."

[5] Drost listed as shown but indicated it was recorded by another as *S. putorius*; NPSpsecies lists as *S. putorius* (and notes "probably present). S. putorius was also noted as being recorded with a camera trap at the Cherry Canyon pools (2014-2015 data provided by the park).

[6] NPSpecies did not include this species, but included *Conepatus mesoleucus*.

[7] Most recent record from 1958 (Drost 2009). However, this species was recorded with camera traps at the Cherry Canyon pools in 2014-2015 (data provided by the park).

[8] Species was listed by by Drost (2009) but not by NPSpecies.

[9] Species was not listed by NPSpecies; however, the Eastern small-footed bat (*Myotis leibii*) was listed as probably present by NPSpecies.

Table A-1 continued. ***Mammals at Walnut Canyon NM.***

Group	Common Name	Scientific Name	Drost (2009)
Bats *continued*	Big brown bat	*Eptesicus fuscus*	X
	Big free-tailed bat [8]	*Nyctinomops macrotis*	X
	Brazilian (or Mexican) free-tailed bat [3]	*Tadarida brasiliensis*	X
	California Myotis	*Myotis californicus*	X
	Fringed myotis [4]	*Myotis thysanodes*	X
	Hoary bat [8]	*Lasiurus cinereus*	X
	Little brown bat	*Myotis lucifugus*	–
	Long-eared myotis	*Myotis evotis*	X
	Long-legged myotis [4]	*Myotis volans*	–
	Pallid bat [4]	*Antrozous pallidus*	X
	Silver-haired bat [4]	*Lasionycteris noctivagans*	X
	Spotted bat [3, 4]	*Euderma maculatum*	X
	Western pipistrelle	*Pipistrellus hesperus*	–
	Western small-footed bat [9]	*Myotis ciliolabrum*	X
	Yuma myotis [3, 8]	*Myotis yumanensis*	X
Rodents	Abert's squirrel	*Sciurus aberti*	X
	Arizona woodrat	*Neotoma devia*	X
	Botta's pocket gopher	*Thomomys bottae*	X
	Brush mouse	*Peromyscus boylii*	X
	Cliff chipmunk	*Tamias dorsalis*	X
	Deer mouse	*Peromyscus maniculatus*	X
	Golden-mantled ground squirrel	*Spermophilus lateralis*	X
	Gray-collared chipmunk [3]	*Neotamias cinereicollis*	X
	Mexican vole [3, 4]	*Microtus mexicanus*	–
	Mexican woodrat	*Neotoma mexicana*	X
	Mogollon vole [8]	*Microtus mogollonensis*	X
	North American porcupine	*Erethizon dorsatum*	X
	Northern grasshopper mouse [4]	*Onychomys leucogaster*	X
	Pinyon mouse	*Peromyscus truei*	X
	Rock squirrel	*Spermophilus variegatus*	X
	Stephens's woodrat [3]	*Neotoma stephensi*	X
	Western harvest mouse [4]	*Reithrodontomys megalotis*	X
	White-throated woodrat	*Neotoma albigula*	–
	White-tailed antelope squirrel [4]	*Ammospermophilus leucurus*	–
Insectivores	Merriam's shrew	*Sorex merriami*	X

[1] Species was listed by Drost (2009) as historic; not listed by NPSpecies.

[2] NPSpecies lists the elk as *Cervus elaphus*, while Drost (2009) lists it as *C. canadensis*.

[3] Listed as a Species of Greatest Conservation Need (SGCN, Tier 1A or 1B [out of 1A-1C]) with the State (AGFD 2012). None of the species are federally-listed as endangered or threatened.

[4] NPSpecies considers this species as "probably present."

[5] Drost listed as shown but indicated it was recorded by another as *S. putorius*; NPSpsecies lists as *S. putorius* (and notes "probably present). S. putorius was also noted as being recorded with a camera trap at the Cherry Canyon pools (2014-2015 data provided by the park).

[6] NPSpecies did not include this species, but included *Conepatus mesoleucus*.

[7] Most recent record from 1958 (Drost 2009). However, this species was recorded with camera traps at the Cherry Canyon pools in 2014-2015 (data provided by the park).

[8] Species was listed by by Drost (2009) but not by NPSpecies.

[9] Species was not listed by NPSpecies; however, the Eastern small-footed bat (*Myotis leibii*) was listed as probably present by NPSpecies.

Listed below are the reptile and amphibian species that have been recorded at Walnut Canyon NM. Sources used for the list were the NPSpecies list for the national monument (dated 23 March 2016), and Persons and Nowak (2006). Species listed by Persons and Nowak (2006) were those recorded by their field sampling efforts (in 2001-2003) and others' past, reliable observations or specimens. A total of 14 species have been documented in the park (noted as present), with an additional 9 species that may occur (high or medium probability). No non-native species have been reported. The list of species was compared with lists of federally threatened and endangered species and those of Greatest Conservation Need in the State (Arizona Game and Fish Department 2012, species designated as Tier 1A or 1B), but no such species were identified. Scientific names follow Brennan (2015); a number of changes have been made to scientific names since the Persons and Nowak report.

Table A.2. Herpetofauna at Walnut Canyon NM.

Group	Common Name	Scientific Name	Occurrence [1]
Reptiles	Black-tailed rattlesnake [2]	*Crotalus molossus*	High probability to occur
	Eastern fence lizard (also known as Plateau lizard)	*Sceloporus undulatus*	Present
	Gopher snake (or Bullsnake)	*Pituophis catenifer*	Present
	Great Plains skink [2]	*Plestiodon obsoletus*	Medium probability to occur
	Greater short-horned Lizard	*Phrynosoma hernandesi*	Present
	Lesser earless lizard [2]	*Holbrookia maculata*	Medium probability to occur
	Little striped whiptail [3]	*Aspidoscelis inornata*	Present
	Madrean alligator lizard [2]	*Elgaria kingii*	Medium probability to occur
	Many-lined skink	*Plestiodon multivirgatus*	Present
	Nightsnake [4]	*Hypsiglena torquata*	Probably present / High probability
	Ornate tree lizard	*Urosaurus ornatus*	Present
	Plateau striped whiptail	*Aspidoscelis velox*	Present
	Prairie rattlesnake [5]	*Crotalus viridis*	Present
	Ring-necked snake	*Diadophis punctatus*	Present
	Sonoran mountain kingsnake	*Lampropeltis pyromelana*	Present
	Striped whipsnake	*Coluber taeniatus*	Probably present / High probability
	Western patch-nosed snake	*Salvadora hexalepis*	Probably present / High probability
	Western terrestrial garter snake	*Thamnophis elegans*	Present
Amphibians	Canyon treefrog	*Hyla arenicolor*	Present
	Mexican spadefoot	*Spea multiplicata*	Present
	Plains spadefoot	*Spea bombifrons*	Probably present / Medium probability
	Red-spotted toad	*Anaxyrus punctatus*	Probably present / Medium probability
	Tiger salamander	*Ambystoma tigrinum*	Present

[1] Occurrence from Persons and Nowak (2006) and NPSpecies. "Present" indicates occurrence in the park according to both sources; "Probably present" is from NPSpecies, and "Medium" or "High" probability is from Persons and Nowak (2006).

[2] Species was not included on NPSpecies list.

[3] This species (common name or scientific name) was not listed by Brennan (2015). This species is also known as *Cnemidophorus inornatus*.

[4] Some resources, such as Brennan (2015) use the species name *chlorophaea* for this snake.

[5] Common name is listed as western rattlesnake in Persons and Nowak (2006), but the species has been reclassified as the prairie rattlesnake (*C. viridus*) vs. the western rattlesnake (*C. oreganus*) (SSAR 2016).

Appendix B. Scoping Meeting Participants and Report Reviewers

Table B.1. Scoping meeting participants.

Name	Affiliation and Position Title
Lisa Baril	Utah State University, Wildlife Biologist and Writer/Editor
Dr. Mark Brunson	Utah State University ,Professor and Principal Investigator
Kayci Cook-Collins	Flagstaff Area National Monuments, Superintendent
Michael M. Jones	Flagstaff Area National Monuments, GIS Specialist
Lisa Leap	Flagstaff Area National Monuments, Chief of Resources
Karla Mingus	Flagstaff Area National Monuments, Compliance Specialist
Kim Struthers	Utah State University, NRCA Project Coordinator and Writer/Editor
Mark Szydlo	Flagstaff Area National Monuments, Biologist
Lisa Thomas	NPS Southern Colorado Plateau Inventory and Monitoring Network, Program Manager
Patty Valentine-Darby	Utah State University, Biologist and Writer/Editor
Paul Whitefield	Flagstaff Area National Monuments, Natural Resource Specialist

Table B.2. Report reviewers.

Name	Affiliation and Position Title	Section(s) 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 Intermountain Region Office, Natural Resource Condition Assessment Coordinator	Regional Program Level Coordinator and Peer Review Manager
Donna Shorrock	National Park Service Intermountain Region Office, Natural Resource Condition Assessment Coordinator (former)	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
Lisa Leap	National Park Service Flagstaff Area National Monuments, Chief of Resources	Park Expert Reviewer for Birds, Soundscape, Air Quality, Non-native Plants Assessments
Paul Whitefield	National Park Service Flagstaff Area National Monuments, Natural Resource Specialist	Park Expert Reviewer
Mark Szydlo	National Park Service Flagstaff Area National Monuments, Biologist	Park Expert Reviewer
Gwenn M. Gallenstein	Flagstaff Area National Monuments / Museum of Northern Arizona, Museum Curator (Acting Chief)	Viewshed, Walnut Creek Riparian, and Mexican Spotted Owl Assessments
Lisa Thomas	National Park Service Southern Colorado Plateau I&M Network, Program Manager	All Condition Assessments
Megan Swan	National Park Service Southern Colorado Plateau I&M Network, Botanist and Acting Program Manager	Cherry Pools and Walnut Creek Riparian Assessments
Mark Meyer	National Park Service Air Resources Division, Visual Resource Specialist	Viewshed Assessment
Li-Wei Hung	National Park Service Natural Sounds and Night Skies Division, Research Scientist	Night Sky Assessment and Data
Emma Brown	National Park Service Natural Sounds and Night Skies Division, Acoustical Resource Specialist	Soundscape Assessment and Data

Table B.2 continued. Report reviewers.

Name	Affiliation and Position Title	Section(s) Reviewed or Other Role
Jim Cheatham	National Park Service Air Resources Division, Park Planning & Technical Assistance	Air Quality Assessment and Data
Ksienya Pugacheva	National Park Service Air Resources Division, Natural Resource Specialist	Air Quality Assessment
Stephen Monroe	Northern Arizona University, Senior Research Specialist	Cerry Pools, Walnut Creek Riparian Assessments
Shaula Hedwall	U.S. Fish and Wildlife Service, Biologist	Mexican Spotted Owl Assessment
Todd Chaudhry	National Park Service Intermountain Region Office, Colorado Plateau Cooperative Ecosystem Studies Unit, Research Coordinator	Ponderosa Pine Assessment
Jeff Conn	National Park Service Southwest Exotic Plant Management Team, Manager	Non-native Invasive Plants Assessment
Mike Wrigley	National Park Service Intermountain Region Office, Biological Resources Chief	Birds Assessment
Michael Martin	National Park Service Water Resources Division, Hydrologist	Conducted on-site riparian habitat rapid assessment September 2016 and co-authored Walnut Creek Riparian Area assessment via NPS STAR request.
Joel Wagner	National Park Service Water Resources Division, Wetlands Program Leader	
Christine Taliga	National Park Service / Natural Resources Conservation Service, Liaison	

Appendix C. Viewshed Analysis Steps

The process used to complete Flagstaff Area National Monuments' viewshed analyses is listed below.

Downloaded 12 of the 1/3 arc second national elevation dataset (NED) grid (roughly equivalent to a 30 m digital elevation model [DEM]) from The National Map Seamless Server (http://seamless.usgs.gov/) (USGS 2016a) and created a mosaic dataset. The x and y values for the NED are in arc seconds while the z data are in meters. The DEMs were reprojected into NAD83 Albers Meter to get all data in meters and into a geographic extent that covered the entire area.

Prepared observation point layers for viewshed analyses by importing GPSd points for all vantage point locations selected for viewshed analysis. Exported data to a shapefile. Added field named "OFFSETA" (type = double) to shapefile and set value to an observer height of 1.68 m (~5'6").

Ran Viewshed Analysis using the Viewshed Tool in ESRI's ArcGIS 10.2, Spatial Analyst Toolbox, ran viewsheds using the following inputs.

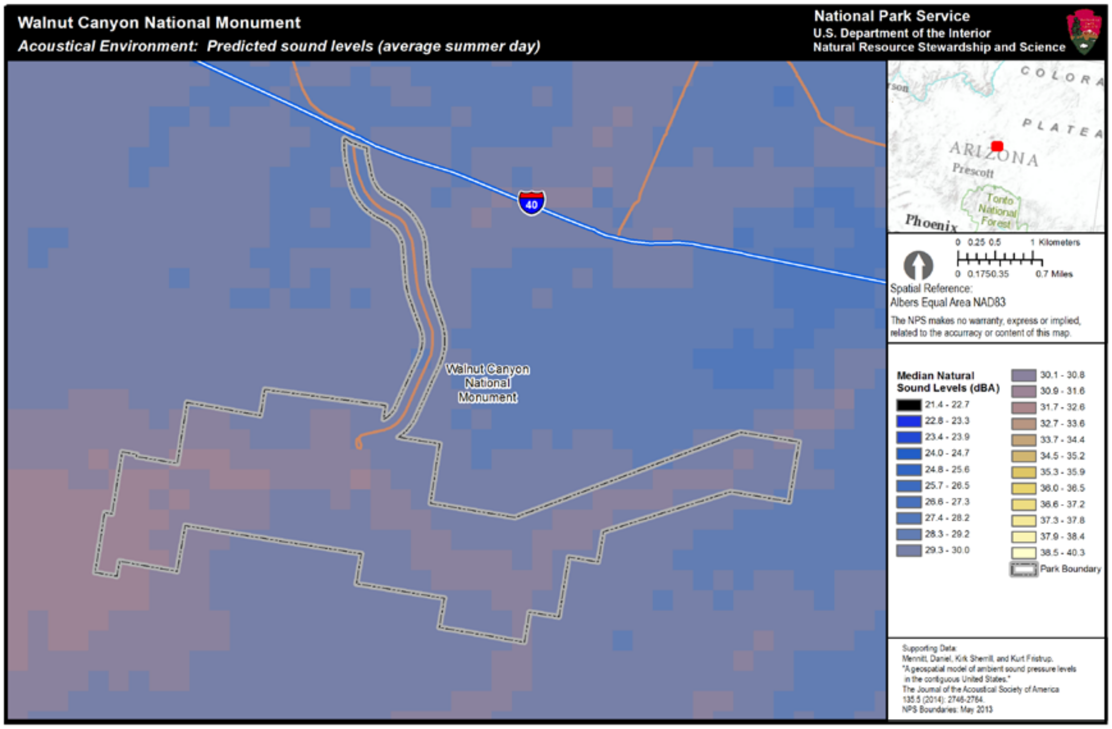
- Input raster = 1/3 arc second NED
- Input point observer feature = obs_point.shp.

The rasters were reclassified into visible areas only to create the maps. The Observer Point Tool in Spatial Analyst was used, creating a composite viewshed, which showed all combined visible areas. A 97 km (60 mi) buffer was created surrounding the monument, reprojected into the Albers Equal Area Conic USGS projection, then used as the AOA for the NPS NPScape's housing and road density rasters using NPScape tools (NPS 2011d). A text attribute field was added to the dataset for the area of analysis identifier (NPS 2015b).

Housing (CONUS, Density, SERGoM, 1970 - 2100, Metric Data (ESRI 9.3 File Geodatabase) (Theobald 2005) and road (United States and Canada, Density - All Roads, ESRI, 2005, Metric Data (ESRI 9.3 File Geodatabase) (ESRI 2014) GIS datasets were downloaded from NPScape's website at http://science.nature.nps.gov/im/monitor/npscape/gis_data.cfm?tab=1.

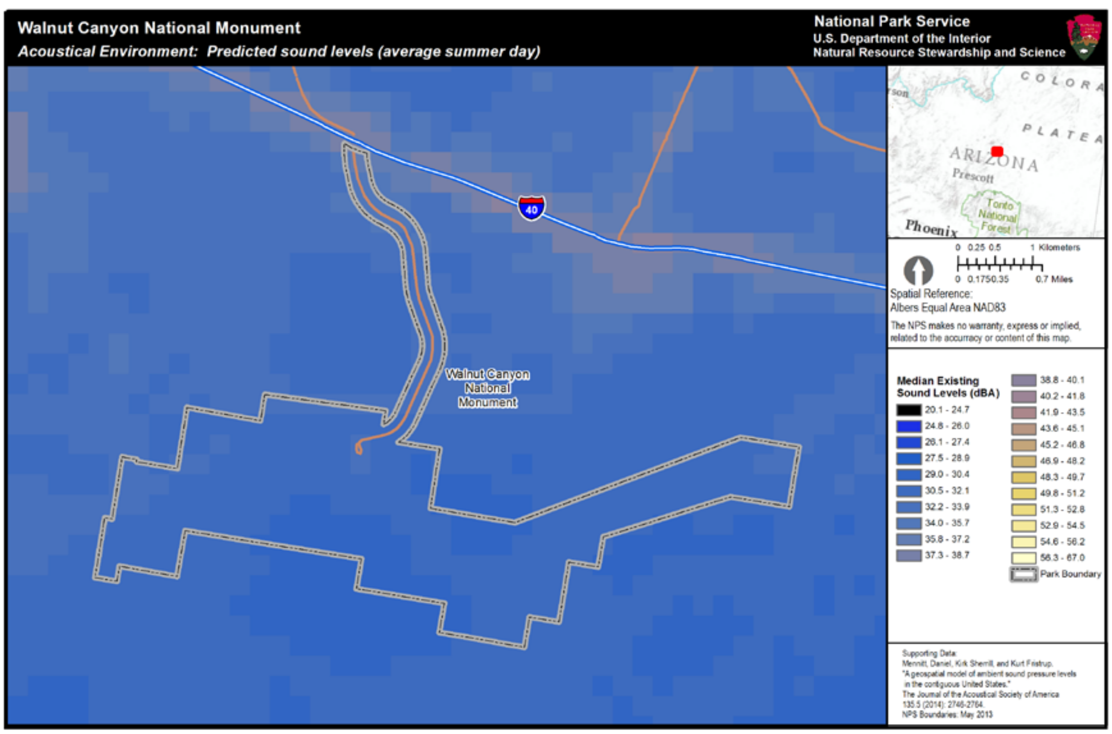
Standard Operating Procedures for both density tools (NPS 2014a,b) were followed based on NPScape instructions: https://irma.nps.gov/DataStore/Reference/Profile/2193329 and https://irma.nps.gov/DataStore/Reference/Profile/2193334.

Appendix D. Geospatial Sound Model Maps



NPS Natural Sounds & Night Skies Division and NPS Inventory and Monitoring Program MAS Group 20160622

Figure D-1. Natural CONUS soundscape model zoomed to Walnut Canyon NM. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction. Figure Credit: NPS Natural Sounds and Night Skies Division.



NPS Natural Sounds & Night Skies Division and NPS Inventory and Monitoring Program MAS Group 20160622

Figure D-2. Existing CONUS soundscape model zoomed to Walnut Canyon NM. Figure Credit: NPS Natural Sounds and Night Skies Division. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction.

Mennitt et al. (2013) developed a geospatial sound model by mapping sound pressure levels on a continental U.S. scale. The model included biological, climatic, geophysical, and anthropogenic factors to assess expected sound pressure levels for natural and existing conditions. The model suggested that the area within and surrounding Walnut Canyon NM had a natural L_{50} dBA average of 30.07 (Figure D-1) and an existing L_{50} dBA average of 31.41(Figure D-2) (Emma Brown, Acoustical Resource Specialist, NPS Natural Sounds and Night Skies Division, provided Excel spreadsheet with values). The L_{50} represents the sound level reported that is exceeded 50 percent of the stated time period.

The impact of anthropogenic sound sources to the national monument's soundscape, which is the existing L_{50} dBA minus natural L_{50} dBA, was estimated to be an average of 1.3 dBA (map is included in the assessment). For further details refer to the soundscape assessment in this report.

As NSNSD's predictive soundscape model continues to be developed and refined, it is intended to help monument staff anticipate impacts by projecting future developments that have the potential to degrade soundscape condition.

Appendix E. Background on Bird Species of Conservation Concern Lists

This appendix provides background information on the organizations and efforts to determine species of birds that are in need of conservation. One component of the bird condition assessment was to examine species occurrence in a conservation context. We compared the list of species that occur at Walnut Canyon National Monument (NM) to lists of species of conservation concern developed by several organizations. There have been a number of such organizations that focus on the conservation of bird species. Such organizations may differ, however, in the criteria they use to identify and/or prioritize species of concern based on the mission and goals of their organization. They also range in geographic scale from global organizations such as the International Union for Conservation of Nature (IUCN), who maintains a "Red List of Threatened Species," to local organizations or chapters of larger organizations. This has been, and continues to be, a source of potential confusion for managers and others who need to make sense of and apply the applicable information. In recognition of this, the U.S. North American Bird Conservation Initiative (NABCI) was started in 1999; it represents a coalition of government agencies, private organizations, and bird initiatives in the U.S. working to ensure the conservation of North America's native bird populations. Although there remain a number of sources at multiple geographic and administrative scales for information on species of concern, the NABCI has made great progress in developing a common biological framework for conservation planning and design.

One of the developments from the NABCI was the delineation of Bird Conservation Regions (BCRs) (U.S. North American Bird Conservation Initiative 2014). Bird Conservation Regions are ecologically distinct regions in North America with similar bird communities, habitats, and resource management issues.

The purpose of delineating these BCRs was to:

- facilitate communication among the bird conservation initiatives;
- systematically and scientifically apportion the U.S. into conservation units;
- facilitate a regional approach to bird conservation;
- promote new, expanded, or restructured partnerships; and
- identify overlapping or conflicting conservation priorities.

Conservation Organizations Listing Species of Conservation Concern

Below we present a summary of some of the organizations that list species of conservation concern and briefly discuss the different purposes or goals of each organization.

U.S. Fish & Wildlife Service

The Endangered Species Act, passed in 1973, is intended to protect and recover imperiled species and the ecosystems upon which they depend. It is administered by the U.S. Fish and Wildlife Service (USFWS) and the Commerce Department's National Marine Fisheries Service (NMFS). USFWS has primary responsibility for terrestrial and freshwater organisms, while the responsibilities of NMFS are mainly marine wildlife, such as whales, and anadromous fish.

The USFWS also protects birds under the Migratory Bird Treaty Act (MBTA; USFWS 2016b). This act "makes it illegal for anyone to take, possess, import, export, transport, sell, purchase, barter, or offer for sale, purchase, or barter, any migratory bird, or the parts, nests, or eggs of such a bird except under the terms of a valid permit issued pursuant to Federal regulations" (USFWS 2016b). An up-to-date list of the bird species protected by the Act (1,026 birds) can be found in the Federal Register (USFWS 2013). At least one of four criteria need to be met for a species to be listed under the Act: 1) it is covered by the Canadian Convention of 1916, as amended in 1996; 2) it is covered by the Mexican Convention of 1936, as amended in 1972; 3) it is listed in the annex to the Japanese Convention of 1972, as amended; and/or 4) it is listed in the appendix to the Russian Convention of 1976. Note that in the condition assessment, we did not compare the list of species recorded at Walnut Canyon NM to the MBTA list. However, at least some of these species are included in the other species of conservation concern lists we used (see next sections).

USFWS Birds of Conservation Concern

The USFWS has responsibilities for wildlife, including birds, in addition to endangered and threatened species. The Fish and Wildlife Conservation Act, as amended in 1988, further mandates that the USFWS "identify species, subspecies, and populations of all migratory nongame birds (i.e., Birds of Conservation Concern) that, without additional conservation actions, are likely to become candidates for listing under the Endangered Species Act" (USFWS 2008a). The agency's 2008 effort, *Birds of Conservation Concern*, is one effort to fulfill the Act's requirements. The report includes both migratory and non-migratory bird species (beyond those federally-listed as threatened or endangered) that USFWS considers the highest conservation priorities. Three geographic scales are included-- National, USFWS Regional, and the NABCI BCRs. The information used to compile the lists came primarily from the following three bird conservation plans: the Partners in Flight (PIF) North American Landbird Conservation Plan, the U.S. Shorebird Conservation Plan, and the North American Waterbird Conservation Plan. The scores used to assess the species are based on factors such as population trends, distribution, threats, and abundance.

North American Bird Conservation Initiative

A group of experts from the North American Bird Conservation Initiative (NABCI) determined U.S. bird species most in need of conservation action (Rosenberg et al. 2014). The NABCI publishes a Watch List every few years in conjunction with a state of the birds report. The 2014 Watch List contains 233 species, most of which are protected by the MBTA, and some of which are protected by the ESA. However, some species are in critical need of attention to prevent them from becoming endangered or threatened. By producing the Watch List, NABCI hopes to encourage conservation of species, especially those under the greatest threat of extinction. The Watch List has two primary levels of concern: a "Red Watch List," which contains species with extremely high vulnerability due to small population, small range, high threats, and rangewide declines; and a "Yellow Watch List," which contains species that are either restricted in range (small range and population) or are more widespread but have concerning declines and high threats (Rosenberg et al. 2014). The NABCI team assessed all birds in the U.S. using the PIF Species Assessment Database (www.rmbo.org/pifassessment/; Rosenberg et al. 2014). According to Rosenberg et al. (2014) the database "ranks species according to their vulnerability due to population size, range size (breeding and non-breeding), population trend, and future threats (breeding and non-breeding). Species are included on the Watch List if they exhibit a threshold of high combined vulnerability across all these factors."

Partners in Flight

Partners in Flight is a cooperative effort among federal, state, and local government agencies, as well as private organizations. One of its primary goals, relative to listing species of conservation concern, is to develop a scientifically based process for identifying and finding solutions to risks and threats to landbird populations. Their approach to identifying and assessing species of conservation concern is based on biological criteria to evaluate different components of vulnerability (Panjabi et al. 2005). Each species is evaluated for six components of vulnerability: population size, breeding distribution, non-breeding distribution, threats to breeding, threats to non-breeding, and population trend. The specific process is presented in detail in the species assessment handbook (Panjabi et al. 2005).

The PIF assessments are conducted at multiple scales. At the broadest scale, the North American Landbird Conservation Plan (Rich et al. 2004) identifies what PIF considers "Continental Watch List Species" and "Continental Stewardship Species." Continental Watch List Species are those that are most vulnerable at the continental scale, due to a combination of small and declining populations, limited distributions, and high threats throughout their ranges (Panjabi et al. 2005). Continental Stewardship Species are defined as those species that have a disproportionately high percentage of their world population within a single Avifaunal Biome during either the breeding season or the non-migratory portion of the non-breeding season.

More recently, PIF has adopted BCRs, the common planning unit under the NABCI, as the geographic scale for updated regional bird conservation assessments. These assessments are available via an online database (http://rmbo.org/pifassessment) maintained by the Rocky Mountain Bird Observatory. At the scale of the individual BCRs, these same principles of concern (sensu Continental Watch List Species) or stewardship (sensu Continental Stewardship Species) are applied at the BCR scale. The intention of this approach is to emphasize conservation of species where it is most relevant, as well as the recognition that some species may be experiencing dramatic declines locally even if they are not of high concern nationally, etc. There are two categories (concern and stewardship) each for Continental and Regional levels. The details of the criteria for inclusion in each can be found in Panjabi et al. (2005), and a general summary is as follows. Note that in our Chapter 4 bird assessment, we did not use the two stewardship categories.

Criteria for Species of Continental Importance

A. Continental Concern (CC)

- Species is listed on the Continental Watch List (Rich et al. 2004).
- Species occurs in significant numbers in the BCR.
- Future conditions are not enhanced by human activities.

B. Continental Stewardship (CS)

- Species is listed as Continental Stewardship Species (Rich et al. 2004).
- Relatively high density (compared to highest density regions) and/or a high proportion of the species occur in the BCR.
- Future conditions are not enhanced by human activities.

Criteria for Species of Regional Importance

Regional scores are calculated for each species according to which season(s) they are present in the BCR. The formulae include a mix of global and regional scores pertinent to each season (see Panjabi et al. 2005 for details). The criteria for each category are:

A. Regional Concern (RC)

- Regional Combined Score > 13 (see Panjabi et al. 2005 for details).
- High regional threats or moderate regional threat combined with significant population decline.
- Occurs regularly in significant numbers in the BCR.

B. Regional Stewardship (RS)

- Regional Combined Score > 13 (see Panjabi et al. 2005 for details).
- High importance of the BCR to the species.
- Future conditions are not enhanced by human activities.

Arizona Species of Greatest Conservation Need

Under Arizona's State Wildlife Action Plan (2012-2022), SGCN have been designated in the state (Arizona Game and Fish Department [AGFD] 2012). Of the 347 vertebrate SGCN statewide, 145 are birds. The plan includes three tiers, Tier 1A, 1B, and 1C. Of the 145 birds considered SGCN, 12 are Tier 1A, 56 are Tier 1B, and 77 are Tier 1C. Tier 1A contains "those species for which the Department has entered into an agreement or has legal or other contractual obligations, or warrants the protection of a closed season. Tier 1B represents the remainder of the vulnerable species. Tier 1C contains those species for which insufficient information is available to fully assess the vulnerabilities and therefore need to be watched for signs of stress. This tier replaces the species of unknown status from the Comprehensive Wildlife Conservation Strategy" (AGFD 2012). Species listed as federally endangered, threatened, or candidate species, and those considered "endangered wildlife" by the State are Tier 1A species. We compared the list of species for Walnut Canyon NM to the list of birds of SGCN in the State plan. In Chapter 4, we reported only birds in the two highest tiers (except we noted 1C species when they also appeared on at least one other of the lists we reviewed).

Appendix F. Walnut Canyon NM Bird List

Listed in the table below are the bird species recorded at Walnut Canyon National Monument (NM) according to: a 1969 list of species compiled within the park over 34 years by 15 different observers (Haldeman and Clark 1969); a 1999-2001 study of birds during the breeding season in ponderosa pine habitat before and after prescribed fire (Short 2002); an inventory during the breeding season in ponderosa pine and canyon riparian habitats (Holmes et al. 2011); and the NPSpecies list of birds for the park (NPS 2016b). The Short (2002) and Holmes et al. (2011) results were obtained using standardized bird sampling methods. For descriptions of each survey effort, see the Data and Methods section of the Birds condition assessment. Note that while surveys were conducted during the breeding season, the species observed were not necessarily breeding during the surveys in the park (although evidence of breeding was recorded for some species). Also, the Haldeman and Clark (1969) and NPSpecies lists (NPS 2016) included birds recorded outside of the breeding season.

A total of 121 species are contained in the table. Of these 121 species, a total of 80 were recorded during one or both of the surveys of Short (2002) and Holmes et al. (2011). However, recall that not all habitats within the park were surveyed during these two efforts. Ten of the 121 species are listed by NPS (2016) but not by the other lists or surveys. Thirteen of the species are not listed by NPS (2016). See the Chapter 4 condition assessment for species that are listed as species of conservation concern (a general term) by various governmental and non-governmental organizations. One federally listed bird species (the Mexican Spotted Owl [*Strix occidentalis lucida*]) is known to occur in the national monument.

Table F.1. Walnut Canyon NM birds list.

Common Name	Scientific Name	Haldeman & Clark (1969)	Short (2002)	Holmes et al. (2011): Ponderosa Pine	Holmes et al. (2011): Riparian	NPS (2016b)
Acorn woodpecker	*Melanerpes formicivorus*	X	X	X	X	X
American crow	*Corvus brachyrhynchos*	X	–	X	X	X
American kestrel	*Falco sparverius*	X	–	X	X	X
American robin	*Turdus migratorius*	X	X	X	–	X
American three-toed woodpecker	*Picoides dorsalis*	–	X	–	–	X
Ash-throated flycatcher	*Myiarchus cinerascens*	X	X	X	X	X
Bald eagle	*Haliaeetus leucocephalus*	X	–	–	–	X
Band-tailed pigeon	*Patagioenas fasciata*	X	X	X	X	X
Black phoebe	*Sayornis nigricans*	–	–	–	–	X
Black-capped chickadee	*Poecile atricapillus*	X	–	–	–	X
Black-chinned hummingbird	*Archilochus alexandri*	X	–	X	X	X
Black-chinned sparrow	*Spizella atrogularis*	–	–	–	–	X
Black-headed grosbeak	*Pheucticus melanocephalus*	X	X	X	X	X
Black-throated gray warbler	*Setophaga nigrescens*	X	X	X	–	X
Blue-gray gnatcatcher	*Polioptila caerulea*	X	–	–	–	X

[1] National Monument staff conduct nesting surveys for this species.

[2] The subspecies that occurs in the park is the Mexican spotted owl (*Strix occidentalis lucida*), a federally threatened species.

[3] Species was observed in 1933 (Haldeman and Clark 1969).

[4] Western scrub-jay was split into two species; Woodhouse's scrub-jay occurs in Arizona.

Table F.1 continued. Walnut Canyon NM birds list.

Common Name	Scientific Name	Haldeman & Clark (1969)	Short (2002)	Holmes et al. (2011): Ponderosa Pine	Holmes et al. (2011): Riparian	NPS (2016b)
Bohemian waxwing	*Bombycilla garrulus*	–	–	–	–	X
Brewer's blackbird	*Euphagus cyanocephalus*	X	–	–	–	X
Brewer's sparrow	*Spizella breweri*	–	–	–	–	X
Broad-tailed hummingbird	*Selasphorus platycercus*	X	X	X	X	X
Brown creeper	*Certhia americana*	X	X	X	X	X
Brown-crested flycatcher	*Myiarchus tyrannulus*	X	–	–	–	–
Brown-headed cowbird	*Molothrus ater*	–	X	X	–	–
Bullock's oriole	*Icterus bullockii*	X	–	X	–	X
Bushtit	*Psaltriparus minimus*	X	X	–	X	X
Canyon wren	*Catherpes mexicanus*	X	–	X	X	X
Cassin's finch	*Carpodacus cassinii*	X	–	–	–	X
Cedar waxwing	*Bombycilla cedrorum*	X	–	–	–	X
Chipping sparrow	*Spizella passerina*	X	X	X	–	X
Clark's nutcracker	*Nucifraga columbiana*	X	–	–	–	X
Cliff swallow	*Petrochelidon pyrrhonota*	–	–	–	X	–
Common nighthawk	*Chordeiles minor*	X	–	–	–	X
Common poorwill	*Phalaenoptilus nuttallii*	X	–	–	–	X
Common raven	*Corvus corax*	X	X	X	X	X
Cooper's hawk	*Accipiter cooperii*	X	X	X	–	X
Cordilleran flycatcher	*Empidonax occidentalis*	X		X	X	X
Dark-eyed junco	*Junco hyemalis*	X	X	X	X	X
Downy woodpecker	*Picoides pubescens*	X	–	–	–	X
Dusky flycatcher	*Empidonax oberholseri*	–	–	X	–	–
Eurasian collared-dove	*Streptopelia decaocto*	–	–	X	–	–
Evening grosbeak	*Coccothraustes vespertinus*	X	–	–	–	X
Ferruginous hawk	*Buteo regalis*	X	–	–	–	X
Flammulated owl	*Otus flammeolus*	X	–	–	–	X
Golden eagle [1]	*Aquila chrysaetos*	X	–	–	–	X
Grace's warbler	*Setophaga graciae*	X	X	X	X	X
Gray flycatcher	*Empidonax wrightii*	–	X	–	–	X
Great blue heron	*Ardea herodias*	–	–	X	–	–
Great horned owl	*Bubo virginianus*	X	X	X	–	X
Greater roadrunner	*Geococcyx californianus*	X	–	–	–	X
Green-tailed towhee	*Pipilo chlorurus*	X	–	–	X	X
Hairy woodpecker	*Picoides villosus*	X	X	X	X	X
Hepatic tanager	*Piranga flava*	X	X	X	–	X
Hermit thrush	*Catharus guttatus*	X	X	X	X	X

[1] National Monument staff conduct nesting surveys for this species.

[2] The subspecies that occurs in the park is the Mexican spotted owl (*Strix occidentalis lucida*), a federally threatened species.

[3] Species was observed in 1933 (Haldeman and Clark 1969).

[4] Western scrub-jay was split into two species; Woodhouse's scrub-jay occurs in Arizona.

Table F.1 continued. Walnut Canyon NM birds list.

Common Name	Scientific Name	Haldeman & Clark (1969)	Short (2002)	Holmes et al. (2011): Ponderosa Pine	Holmes et al. (2011): Riparian	NPS (2016b)
Hermit warbler	*Dendroica occidentalis*	–	–	–	–	X
Horned lark	*Eremophila alpestris*	X	–	–	–	X
House finch	*Carpodacus mexicanus*	X	–	X	X	X
House wren	*Troglodytes aedon*	X	–	X	X	X
Juniper titmouse	*Baeolophus ridgwayi*	X	–	X	X	X
Lark sparrow	*Chondestes grammacus*	–	–	X	–	–
Lazuli bunting	*Passerina amoena*	X	–	–	–	X
Lesser goldfinch	*Carduelis psaltria*	X	X	X	X	X
Lewis's woodpecker	*Melanerpes lewis*	X	–	–	–	X
Loggerhead shrike	*Lanius ludovicianus*	–	–	–	–	X
MacGillivray's warbler	*Geothlypis tolmiei*	X	–	–	–	X
Merlin	*Falco columbarius*	–	–	–	–	X
Mountain bluebird	*Sialia currucoides*	X	–	X	–	X
Mountain chickadee	*Poecile gambeli*	X	X	X	X	X
Mourning dove	*Zenaida macroura*	X	X	X	X	X
Northern flicker	*Colaptes auratus*	X	X	X	X	X
Northern goshawk [1]	*Accipiter gentilis*	X	X	–	–	X
Northern mockingbird	*Mimus polyglottos*	X	–	X	X	X
Northern pygmy-owl	*Glaucidium gnoma*	X	–	X	X	X
Olive warbler	*Peucedramus taeniatus*	–	–	X	–	–
Olive-sided flycatcher	*Contopus cooperi*	X	X	–	–	X
Orange-crowned warbler	*Vermivora celata*	–	–	–	–	X
Painted redstart	*Myioborus pictus*	–	–	–	X	–
Peregrine falcon [1]	*Falco peregrinus*	–	–	–	X	X
Pine siskin	*Carduelis pinus*	X	–	X	–	X
Pinyon jay	*Gymnorhinus cyanocephalus*	X	–	X	X	X
Plumbeous vireo	*Vireo plumbeus*	–	X	X	X	X
Prairie falcon	*Falco mexicanus*	X	–	–	–	X
Purple finch	*Haemorhous purpureus*	X	–	–	–	–
Purple martin	*Progne subis*	X	X	X	X	X
Pygmy nuthatch	*Sitta pygmaea*	X	X	X	X	X
Red crossbill	*Loxia curvirostra*	X	X	X	–	X
Red-breasted nuthatch	*Sitta canadensis*	X	–	–	–	X
Red-faced warbler	*Cardellina rubrifrons*	X	X	X	X	X
Red-naped sapsucker	*Sphyrapicus nuchalis*	–	–	X	–	X
Red-tailed hawk	*Buteo jamaicensis*	X	X	X	X	X

[1] National Monument staff conduct nesting surveys for this species.

[2] The subspecies that occurs in the park is the Mexican spotted owl (*Strix occidentalis lucida*), a federally threatened species.

[3] Species was observed in 1933 (Haldeman and Clark 1969).

[4] Western scrub-jay was split into two species; Woodhouse's scrub-jay occurs in Arizona.

Table F.1 continued. ***Walnut Canyon NM birds list.***

Common Name	Scientific Name	Haldeman & Clark (1969)	Short (2002)	Holmes et al. (2011): Ponderosa Pine	Holmes et al. (2011): Riparian	NPS (2016b)
Rock wren	*Salpinctes obsoletus*	X	–	X	X	X
Ruby-crowned kinglet	*Regulus calendula*	X	–	X	–	X
Rufous hummingbird	*Selasphorus rufus*	X	–	–	–	X
Say's phoebe	*Sayornis saya*	X	–	–	–	X
Scott's oriole	*Icterus parisorum*	–	–	–	–	X
Sharp-shinned hawk	*Accipiter striatus*	X	–	–	–	X
Spotted owl [1, 2]	*Strix occidentalis* [2]	–	–	–	X	X
Spotted towhee	*Pipilo maculatus*	–	–	–	X	X
Steller's jay	*Cyanocitta stelleri*	X	X	X	X	X
Summer tanager	*Piranga rubra*	X	–	–	–	–
Townsend's solitaire	*Myadestes townsendi*	X	–	X	–	X
Townsend's warbler	*Setophaga townsendi*	X	–	–	–	X
Turkey vulture	*Cathartes aura*	X	–	X	X	X
Violet-green swallow	*Tachycineta thalassina*	X	X	X	X	X
Virginia's warbler	*Vermivora virginiae*	X	X	X	X	X
Warbling vireo	*Vireo gilvus*	X	X	–	–	X
Western bluebird	*Sialia mexicana*	X	X	X	X	X
Western kingbird	*Tyrannus verticalis*	X	–	–	X	X
Western meadowlark	*Sturnella neglecta*	X	–	–	–	–
Western tanager	*Piranga ludoviciana*	X	X	X	X	X
Western wood-pewee	*Contopus sordidulus*	X	X	X	X	X
White-breasted nuthatch	*Sitta carolinensis*	X	X	X	–	X
White-crowned sparrow	*Zonotrichia leucophrys*	X	–	–	X	X
White-throated swift	*Aeronautes saxatalis*	X	–	X	X	X
Wild turkey	*Meleagris gallopavo*	X	–	–	–	X
Williamson's sapsucker	*Sphyrapicus thyroideus*	X	–	X	–	X
Willow flycatcher	*Empidonax traillii*	X [3]	–	–	–	X
Wilson's warbler	*Wilsonia pusilla*	X	–	–	X	X
Woodhouse's scrub-jay [4]	*Aphelocoma woodhouseii* [4]	X	–	–	X	X
Yellow warbler	*Setophaga petechia*	X	–	–	X	X
Yellow-bellied sapsucker	*Sphyrapicus varius*	X	–	–	–	–
Yellow-breasted chat	*Icteria virens*	–	–	–	–	X
Yellow-rumped warbler	*Dendroica coronata*	X	X	X	X	X
TOTAL NUMBER	121 species	96	42	62	53	108

[1] National Monument staff conduct nesting surveys for this species.

[2] The subspecies that occurs in the park is the Mexican spotted owl (*Strix occidentalis lucida*), a federally threatened species.

[3] Species was observed in 1933 (Haldeman and Clark 1969).

[4] Western scrub-jay was split into two species; Woodhouse's scrub-jay occurs in Arizona.

Appendix G. Habitat Connectivity Analysis

The workflow used to complete Flagstaff Area National Monuments' habitat connectivity analysis is listed in Table G-1. Outputs included habitat suitability models (HSM), patch models (PMs), and corridor models (CMs) for each species. Models were based on habitat preferences from four datasets: (1) land cover, (2) elevation, (3) topography, and (4) distance from roads. Depending on a species' particular needs, these preferences were weighted accordingly using the opinions of subject matter experts.

Table G-1. GIS-based habitat connectivity assessment workflow adapted from Beier et al. (2008).

Process / Step	Description	Selection
Define Area of Analysis	The area identified to address wildlife movement needs.	30 km (18.6 mi) ecological buffer (Monahan et al. 2012)
Select Wildland Blocks	Areas of publicly owned or other land expected to remain in a relatively natural condition for at least 50 years.	Flagstaff Area National Monuments: Wupatki NM, Sunset Crater Volcano NM, and Walnut Canyon NM
Select Focal Species	Species that collectively serve as an 'umbrella' for all native species and ecological processes.	Nine native species either found in one or all three monuments with Arizona CorridorDesigner habitat models
Identify Landscape Factors	Landscape factors are based on species' life needs such as food, cover, safety from hazards (e.g. roads), etc.	Land cover, elevation, topography, and distance from roads were selected as the landscape factors for each model.
Identify Landscape Metrics	Categories of landscape factor attributes.	47 land cover classes grouped into 10 categories; topography grouped into 4 topographic positions; elevation ranged from -1 - 3,846 m (3.3 - 12,625 ft); and roads were mapped as a land cover type and calculated as distance to nearest road.
Identify Resistance Values of Each Pixel Class	Establishes the "link between the non-ecological GIS information and the ecological-behavioral aspects of the mobility of the organism or process" (Adriaensen et al. 2003 as cited in Beier et al. (2008)).	Resistance values were based on literature review and expert opinion for each species (refer to Majka et al. (2007) Excel spreadsheet); landscape factor classes were weighted for all 10 species.
Identify Combining Factor Resistances	Method of combining inability to move through an area (i.e., resistance) due to landscape factors.	Weighted geometric mean
Identify Corridor Terminus	The area within a wildland block that ends the modeled corridor.	Habitat patches within monuments
Delineate Habitat Patches	Areas of habitat that can support reproduction by the focal species.	Thresholds for habitat quality, minimum area suitable for breeding, and how edge effects affects each species are identified as patches.
Decide How to Model Corridor Dwellers	A species that requires more than one generation for gene flow to occur between wildland blocks.	Assigned the lowest resistance value to habitat patches.
Decide How Continuous Swaths of Low-Resistance Pixels Are Identified (Travel cost map)	Areas that are easy for a given species to travel within may be disconnected (either by natural or unnatural features) and not form a continuous area or swath. So a method for connecting low resistance pixels (i.e., areas easy to travel) needs to be selected.	Each pixel's cost is calculated as the lowest possible cumulative resistance or travel cost from that pixel to habitat block terminuses.
Identify Corridor Width	For corridor dwellers, width should be substantially more than a home range width and use iterative mapping to identify acceptable number and severity of bottlenecks.	Increasingly wide corridors were displayed as nested polygons in a graded cost map, with each polygon defined by the largest cumulative travel costs allowed. The larger the polygon, the higher the cost.

G.1. Area of Analysis and Habitat Blocks

The NPScape landscape dynamics monitoring project recommended evaluating landscape attributes within a 30 km (18.6 mi) area of analysis (AOA). This scale captured ecological processes, such as wildland fires and some animal movements as well as dispersal patterns (Monahan et al. 2012) of park resources. The habitat blocks or protected areas of interest for maintaining habitat connectivity included the three national monuments: Wupatki, Walnut Canyon, and Sunset Crater Volcano. In total, these monuments protect a little over 17,000 ha (~42,000 ac) of public land and are expected to remain in a natural condition in perpetuity. Each of the three buffers were dissolved, creating one area totaling 7,489 km^2 (2,891.5 mi^2). The monuments comprised 2.3% of the entire AOA.

G.2. Focal Wildlife Species

Animals move within or among habitats to obtain the resources they need for survival (i.e., water, food, cover, and mates), and different species move at different scales (such as mountain lions compared to the Wupatki pocket mice). As a result, some species may be more affected (or affected sooner) by habitat fragmentation. Beier et al. (2008) suggested selecting focal species to serve as an 'umbrella' for the remaining species and natural processes not evaluated when developing habitat linkages/connectivity. Beier et al. (2008) further suggested that species selection include some that are: (1) area-sensitive, (2) habitat specialists, (3) dispersal limited, (4) sensitive to barriers, or (5) otherwise ecologically important. Beier et al. (2008) emphasized that the goal of identifying linkages should be "to conserve or restore a functioning wildland network that maintains ecological processes and provides for the movement of all native species between wildland [habitat] blocks." Table G-2 lists the species selected for habitat connectivity analysis for each national monument and Table G-3 summarizes each species' habitat preferences. Of the 16 mammals and 12 reptile and amphibian parameterized models included as raw data in the Arizona CorridorDesigner toolbox, a total of nine native species were known to occur at either all monuments (5 species) or

Table G-2. Arizona CorridorDesigner wildlife species known to occur at one or all Flagstaff Area National Monuments.

Common Name	Scientific Name	Species Selection Criteria	Wupatki	Walnut Canyon	Sunset Crater Volcano
American badger	*Taxidea taxus*	Large home range; many protected lands are not large enough to ensure species' life cycle.	X	X	X
American black bear	*Ursus americanus*	Requires habitat variety; low population densities makes them vulnerable to habitat fragmentation.	X	X	X
American pronghorn	*Antilocapra americana*	Susceptible to habitat fragmentation and human development; sensitive to barriers.	X	X	X
Black-tailed jack rabbit	*Lepus californicus*	Important seed dispersers and prey for other species; frequently killed by vehicles.	X	–	–
Kit fox*	*Vulpes macrotis*	Susceptible to habitat conversion and fragmentation.	X	–	–
Lyre snake	*Trimorphodon biscutatus*	Susceptible to habitat fragmentation.	–	X	–
Mountain lion	*Puma concolor*	Requires a large area of connected landscapes to support even minimum self sustaining populations.	X	X	X
Mule deer	*Odocoileus hemionus*	Important prey species; road systems may affect the distribution and welfare of species.	X	X	X
White-nosed coati	*Nasua narica*	Appears to be dispersal limited.	–	X	–

* Listed as a Species of Greatest Conservation Need in Arizona (AGFD 2012).

Table G-3. Wildlife species habitat preferences.

Common Name	Land Cover	Elevation	Topography	Distance From Roads
American badger	Prefer grasslands and other open habitats	Lower	Flat terrain	No aversion; high mortality
American black bear	Require habitat variety	Often mountainous	Prefer to bed in locations with 20-60% slopes	Movements dependent on food supply; males have greater dispersal
American pronghorn	Areas of grasses and scattered shrubs with rolling hills or mesas	Gentle terrain	Prefer slopes < 30%	Right-of-way fences are major factor limiting movement
Black-tailed jack rabbit	Prefers open country	—	—	Frequently killed by vehicles
Kit fox*	Prefer desert grasslands and desert scrub with sandy soils for digging dens	Variable spatial patterns depending on prey, habitat quality, and precipitation	Variable spatial patterns depending on prey, habitat quality, and precipitation	Variable spatial patterns depending on prey, habitat quality, and precipitation
Lyre snake	All vegetation types and strongly associated with rocks and outcrops	up to 2,255.5 m (7,400 ft)	Mountain slopes	—
Mountain lion	Found throughout Arizona in rocky or mountainous areas; diverse habitat	304.8 - 914.4 m (1,000-3,000 ft)	Varied	Sensitive to vehicles
Mule deer	In northern Arizona inhabit yellow pine, spruce-fir, buckbrush, snowberry, and aspen habitats	—	Home ranges of mule deer vary depending upon the availability of food and cover	Home ranges of mule deer vary depending upon the availability of food and cover
White-nosed coati	Primarily a forest species	No constraints	No preference	Males tend to be hit by vehicles

Source: Majka et al. (2007)

Table G-4. Landscape factor weights used in species habitat models.

Species Common Name	Land Cover	Elevation	Topography	Distance From Roads
	Percentages (%)			
American badger	65	7	15	13
American black bear	75	10	10	5
American pronghorn	45	—	37	18
Black-tailed jack rabbit	70	10	10	10
Kit fox	75	—	15	10
Lyre snake	—	10	80	10
Mountain lion	70	—	10	20
Mule deer	80	—	15	5
White-nosed coati	95	—	—	5

Source: CorridorDesigner Species Scores Excel Spreadsheet (Majka et al. 2007)

at one monument only (4 species). These nine species serve as the "umbrella" for the remaining species known to occur at each of the monuments.

G.3. Habitat Suitability and Patch Models

The Habitat Suitability Models (HSMs) were developed using the weighted geometric mean of the parameters selected for each species' life cycle and survival needs from four raster datasets: land cover, elevation, topography, and distance from roads. The factor weights assigned within each data set for each species analyzed are listed in Table G-4. The 30 m x 30 m pixels within each of the four rasters were combined using the geometric mean method to identify resistance through an area. Resistance factors for the parameterized habitat models were linearly stretched to a 0 (worst) – 100 (best) scale. The patch models (PMs) were developed using the results from each species' HSM. The HSMs and PMs for each species analyzed are shown in Figures G-1 through G-18.

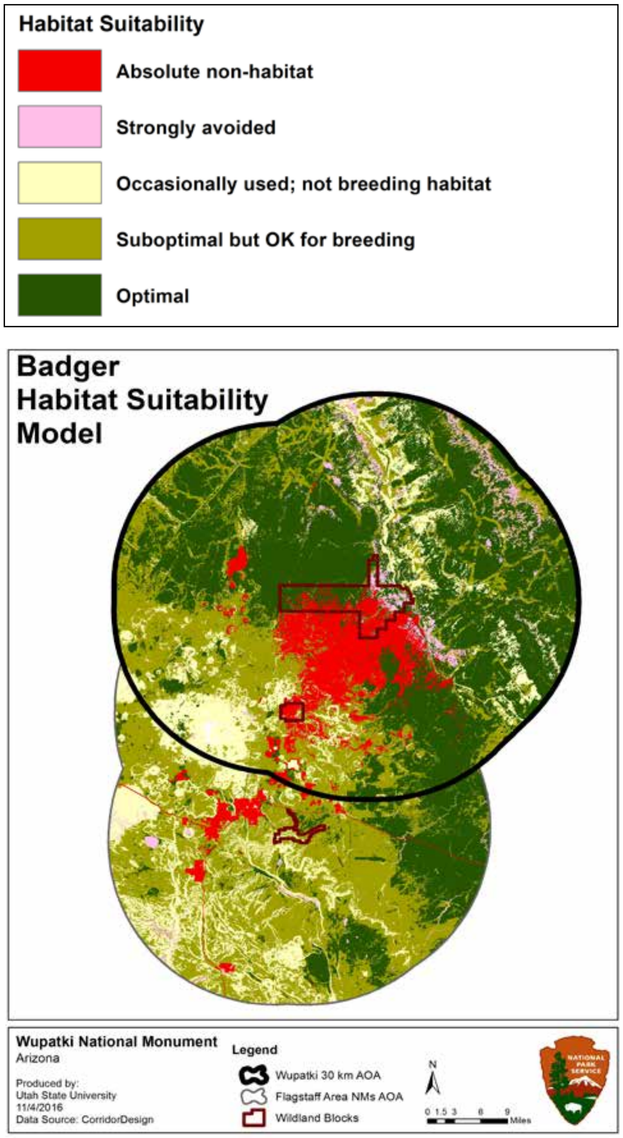


Figure G-1. American badger habitat suitability model. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction.

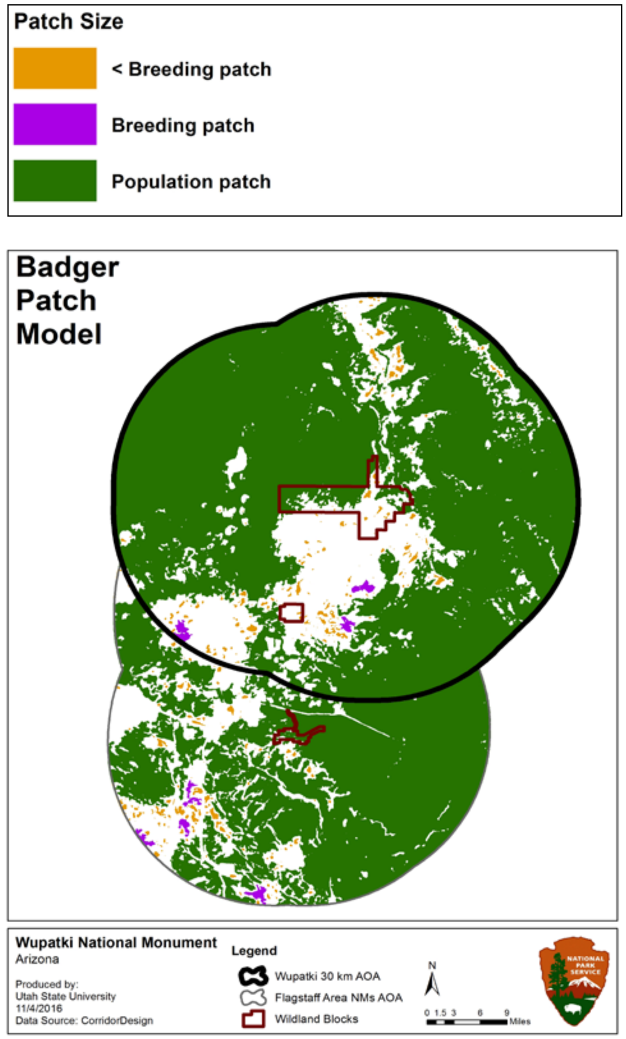


Figure G-2. American badger patch size model. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction.

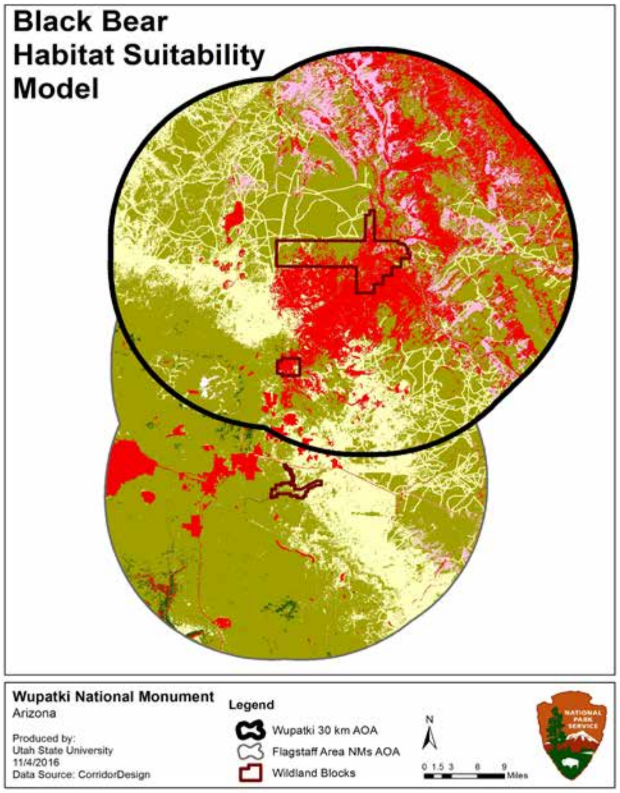


Figure G-3. **Black bear habitat suitability model. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction.**

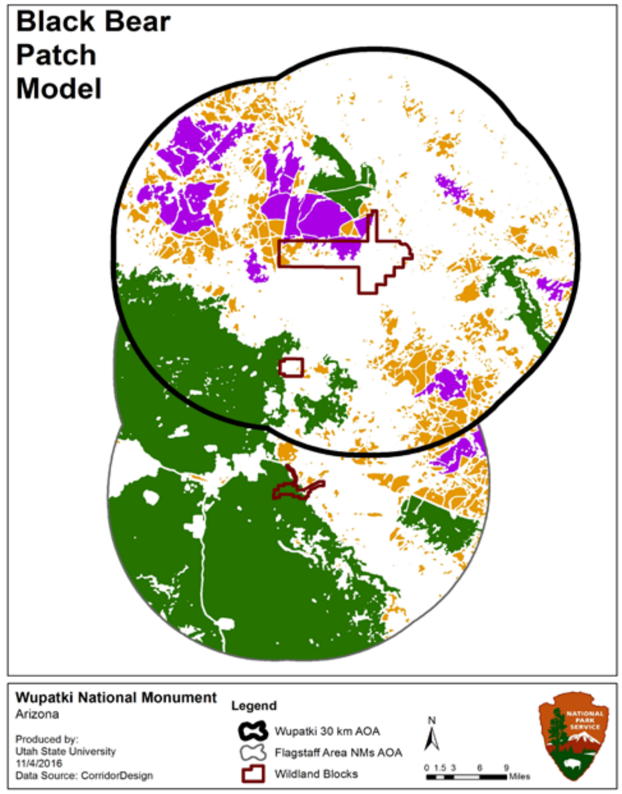


Figure G-4. **Black bear patch size model. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction.**

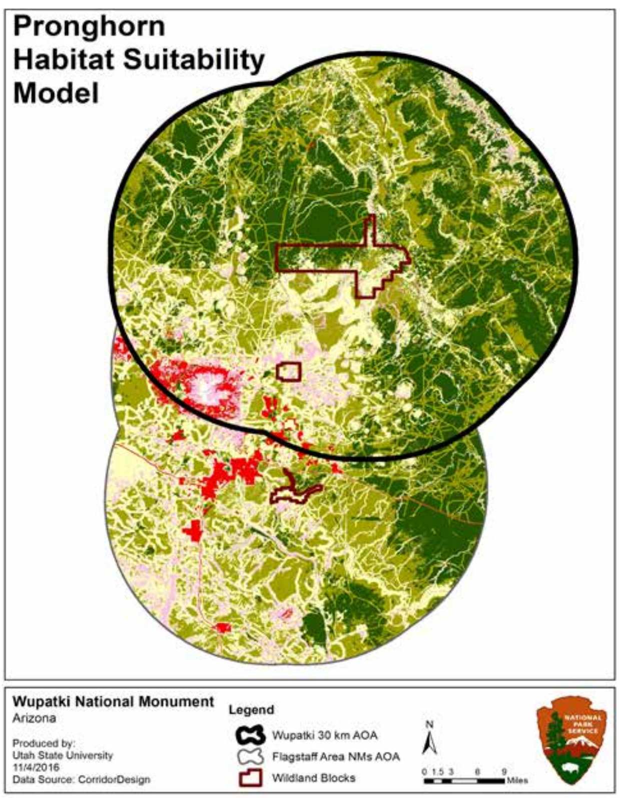


Figure G-5. **American pronghorn habitat suitability model. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction.**

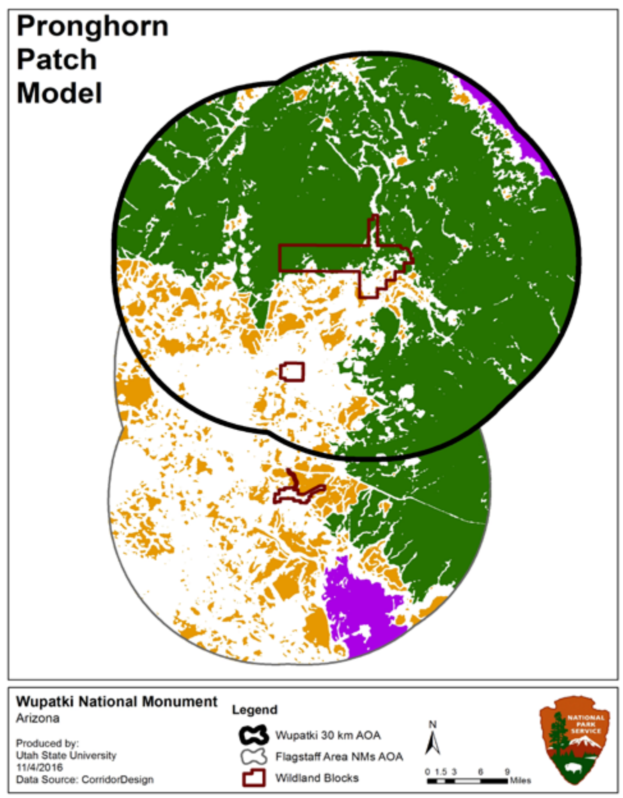


Figure G-6. **American pronghorn patch size model. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction.**

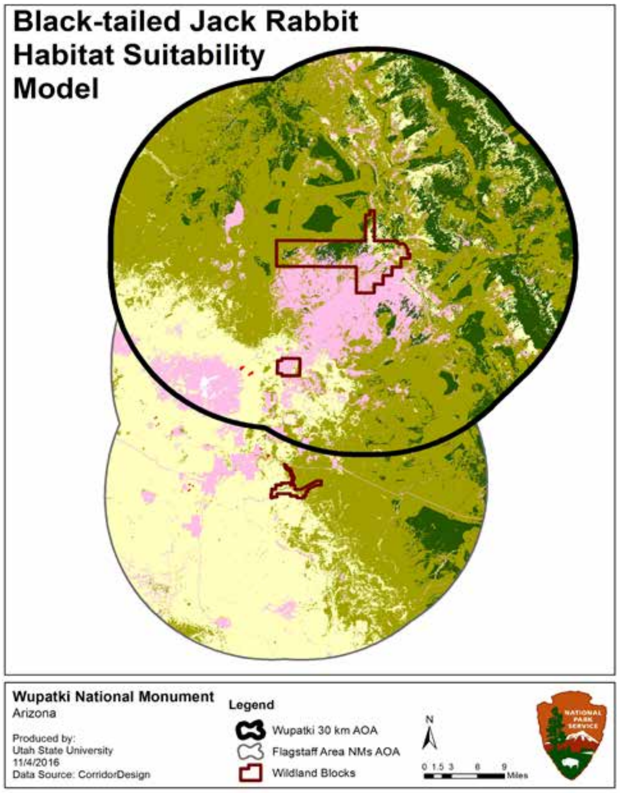


Figure G-7. Black-tailed jack rabbit habitat suitability model. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction.

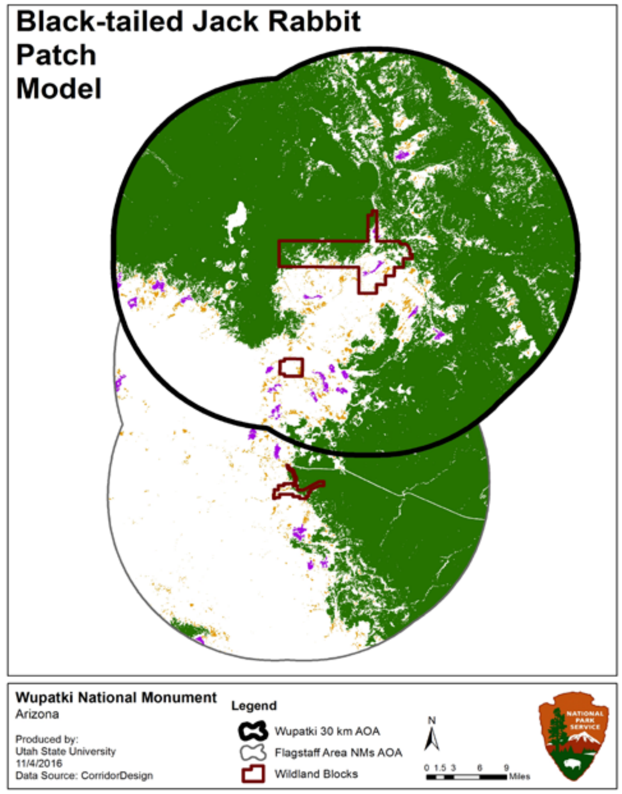


Figure G-8. Black-tailed jack rabbit patch size model. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction.

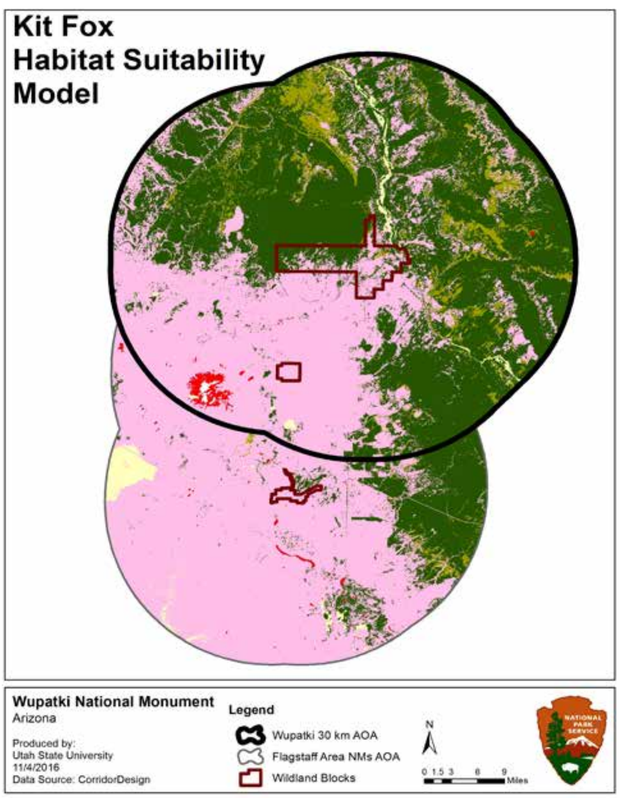


Figure G-9. Kit fox habitat suitability model. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction.

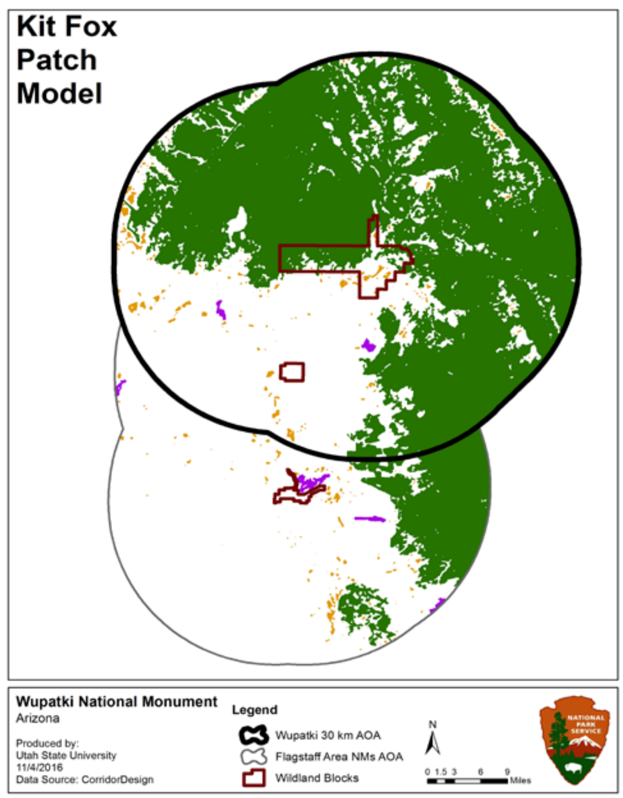


Figure G-10. Kit fox patch size model. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction.

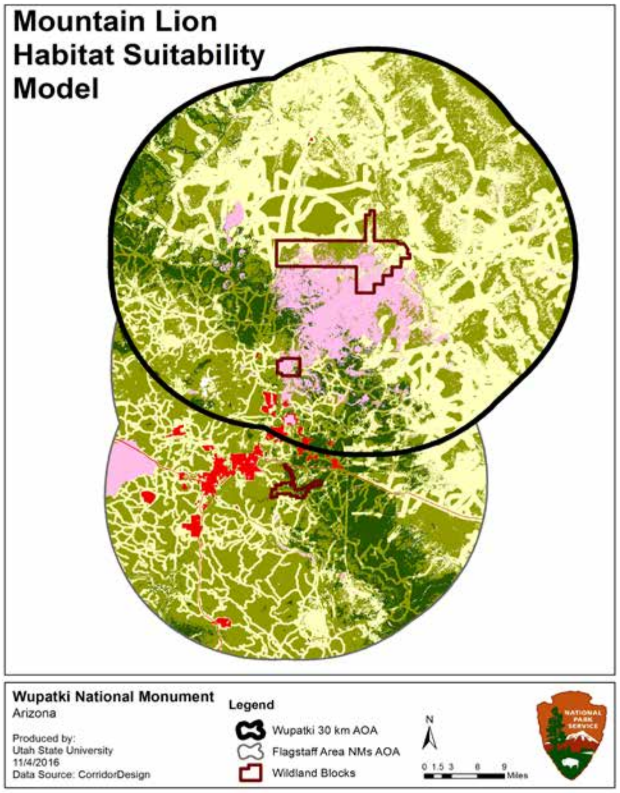


Figure G-11. Mountain lion habitat suitability model. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction.

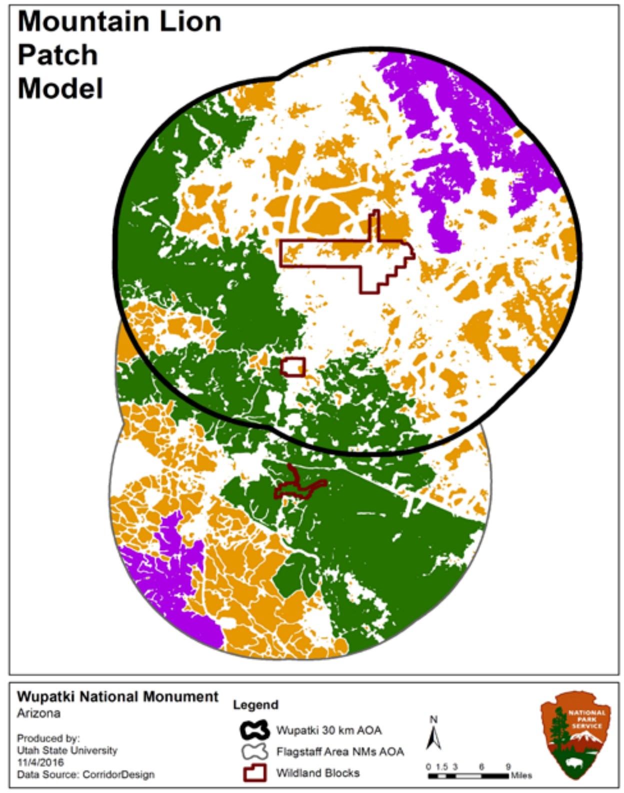


Figure G-12. Mountain lion patch size model. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction.

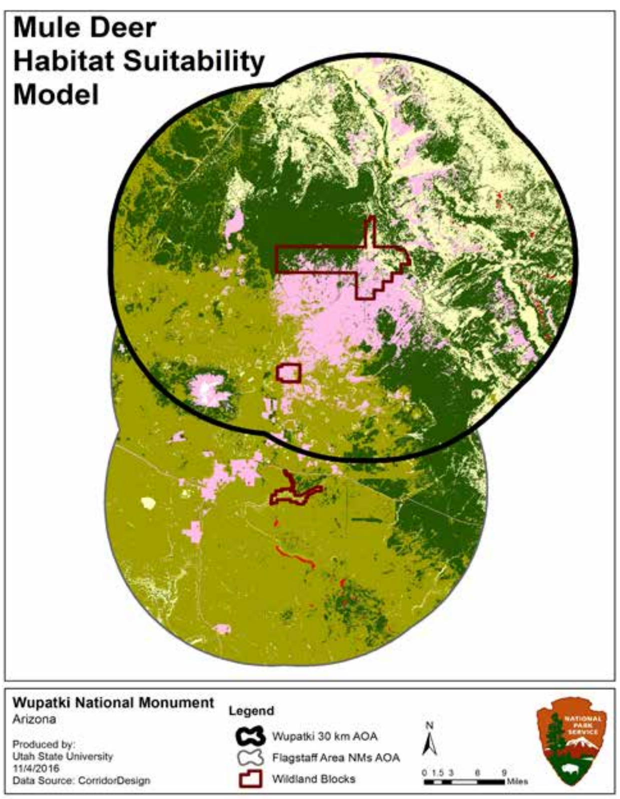


Figure G-13. Mule deer habitat suitability model. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction.

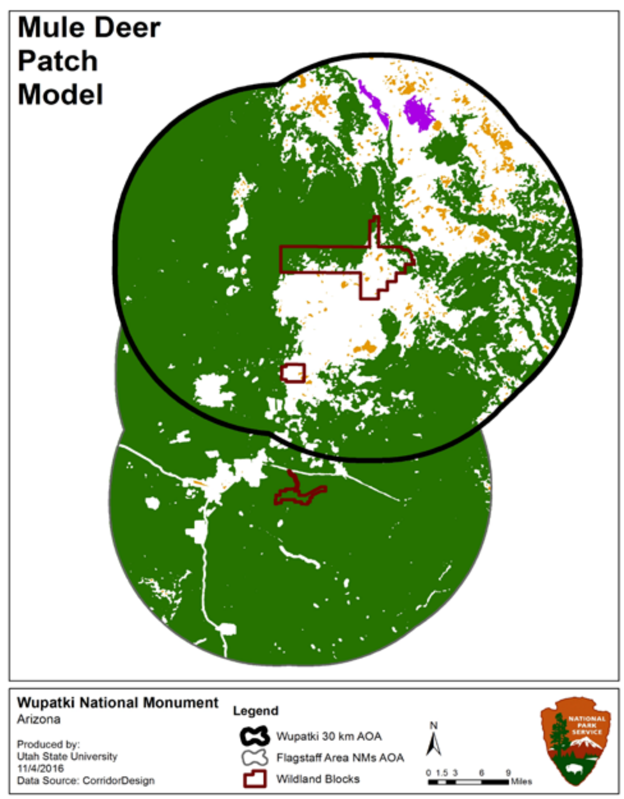


Figure G-14. Mule deer patch size model. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction.

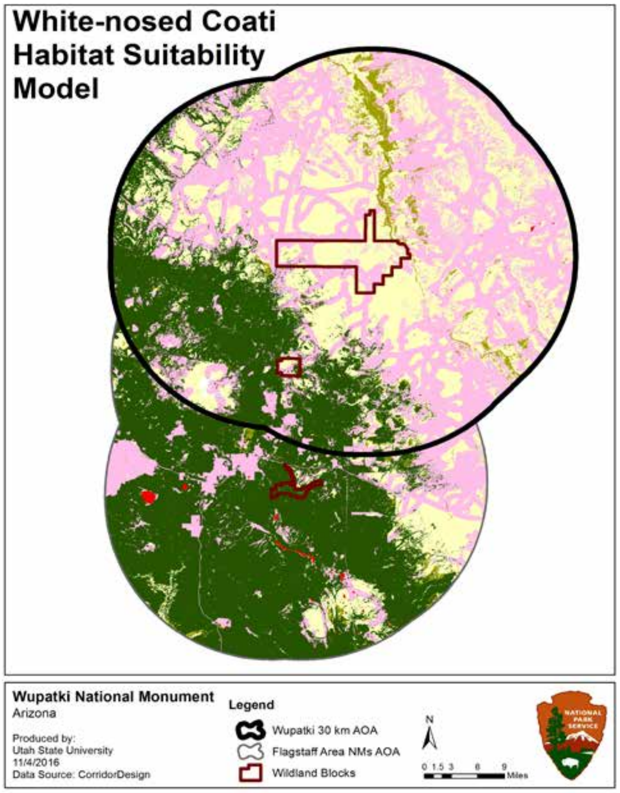


Figure G-15. White-nosed coati habitat suitability model. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction.

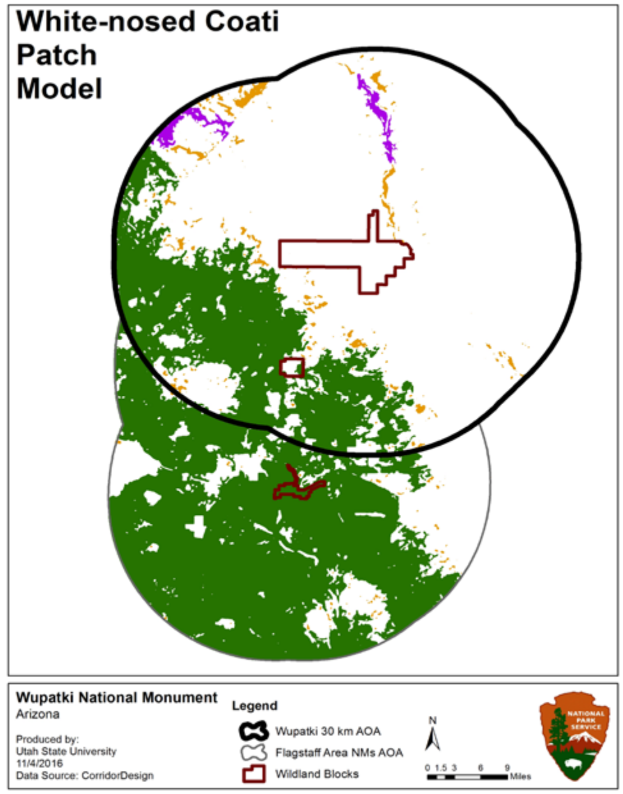


Figure G-16. White-nosed coati patch size model. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction.

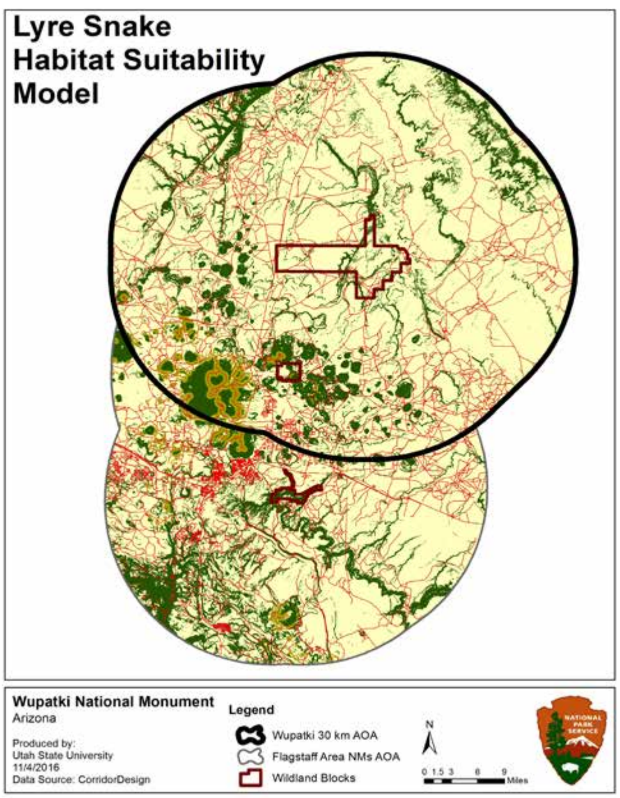


Figure G-17. Lyre snake habitat suitability model. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction.

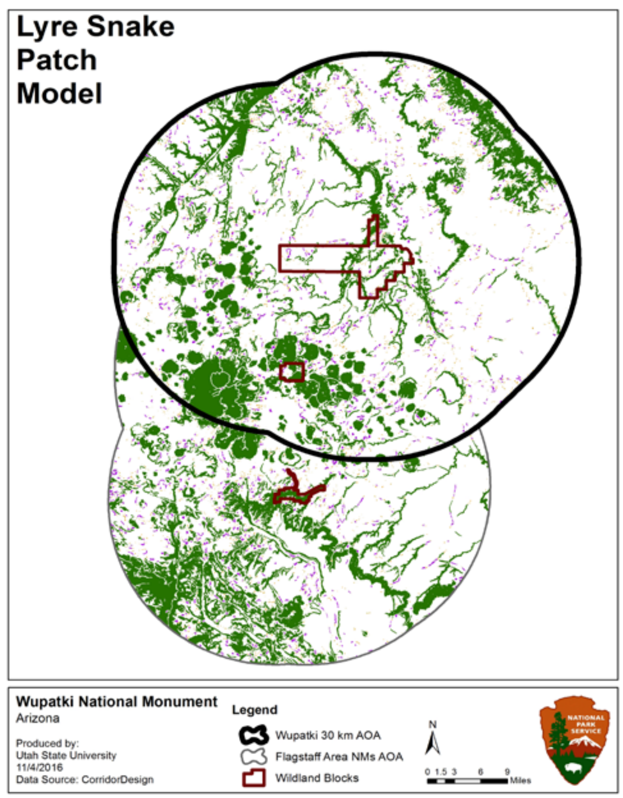


Figure G-18. Lyre snake patch size model. The NPS owns an easement in this road, but the road is under U.S. Forest Service jurisdiction.

G.4. Corridor Models

Corridor models (CMs) were created using the HSMs and PMs for each species to calculate the cumulative movement (travel cost) resistance within a given area. The process included five steps as follows: 1) calculated species patch sizes 2) found starting patches within the first habitat block. If no cores were within the block then patches were selected instead. 3) found starting patches within the second habitat block. If no cores were within the block then patches were selected instead.

4) Converted HSM to cost model and calculated cost distance in first and second rasters then combined cost distance rasters into one total accumulative cost grid/corridor model. 5) sliced corridor model into 11 different widths (i.e., 0.1%, 1-10%). The least-cost corridors selected for each species were unioned, producing one preliminary linkage design that showed potential areas of connectivity to facilitate movements of selected species between monuments.

G.5. Degree of Conservation

The linkage design model was used to clip the USGS GAP Protected Areas Database (2016c) conservation status dataset. There are four GAP categories that vary based on degree of protection and management mandates. Flagstaff Area NMs are GAP Status 1 lands. All GAP categories are described below.

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

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

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

GAP Status 4: No known mandate for protection and include legally mandated easements (USGS 2016c).

G.6. Coconino County Wildlife Linkages

A total of 40 wildlife linkages, identified in the *Wildlife Connectivity Assessment Report* for Coconino County (AGFD 2011a), were located within the entire Flagstaff Area NM AOA (Table G-6). Fifteen were within Wupatki's AOA, 35 were within Walnut Canyon's AOA, and 29 were within Sunset Crater Volcano's AOA.

Table G-6. Coconino County wildlife linkages that are within the Flagstaff Area NMs' 30 km AOA.

Area	#	Name	Species	Threats	WUPA	WACA	SUCR
Northern Coconino County	6	Utah - San Francisco Peaks	Raptors, bats	Powerlines, increasing off-highway vehicle use, proposed wind and solar developments, exotic species (cheatgrass, Russian thistle, snakeweed)	X	–	X
	12	South Rim - San Francisco Peaks Woody Ridge / Bellemont Area	mule deer, elk, Gunnison's prairie dog	Hwy 64, development in foothills on north side of the Peaks along FR 418, I-40	X	X	X
	13	Coconino Plateau	Elk, mule deer, pronghorn	Hwy 64	X	–	–
	15	Wupatki National Monument – Navajo Reservation	Pronghorn, small mammals, herpetofauna	Little Colorado River (for some species)	X	–	X

Table G-6 continued. ***Coconino County wildlife linkages that are within the Flagstaff Area NMs' 30 km AOA.***

Area	#	Name	Species	Threats	WUPA	WACA	SUCR
Central Coconino County	17	Grassland north and east of San Francisco Peaks - east of Anderson Mesa	Pronghorn, Gunnison's prairie dog, jackrabbit, golden eagle, milk snakes, birds, bats	Hwy 89A, Leupp Rd, Meteor Crater Rd, FR 69, grazing and shrub encroachment, planned Red Gap pipeline, Grapevine wind development, BSNF Railroad, State Lands	X	X	X
	19	Dog Knobs - Ebert Mtn.-Govt. Prairie	Pronghorn, mule deer, black bear, mountain lion	Highway 180, fencing	–	X	X
	20	Mesa Butte - Kendrick	Mountain lion, elk, pronghorn	Highway 180	X	–	X
	21	Garland Prairie - Govt. Prairie	Pronghorn, mule deer, black bear, turkey, elk	Roads, railroad, urban development, I-40	–	X	–
	22	Walnut Canyon - Anderson Mesa - Antelope Park/ Mormon Mtn.	Mountain lion, elk, mule deer, black bear, northern goshawk, Mexican spotted owl, neotropical migratory birds, turkey, northern leopard frog, bats, bald eagle, peregrine falcon, tarantula, gray fox, raccoon, coyote, small mammals, bull snakes	Lake Mary Rd, recreation, crayfish invasion	–	X	X
	23	Youngs and Mormon/Padre Canyons Area	Pronghorn, elk, mule deer, white-tailed deer	Recreation	–	X	X
	25	Mormon Mtn. - Hutch Mtn.	Mexican spotted owl, forest bats, wintering bald eagle, northern leopard frog, other amphibians	High-severity landscape-level fire, forest restoration treatments, Lake Mary Rd	–	X	–
	26	Ashurst/ Kinnikinik - Mormon Lake	Tiger salamander, northern leopard frog, other amphibians	OHV use, Lake Mary Rd	–	X	–
	28	East of Kendrick - Government Hills	Pronghorn	Roads, development, recreation	X	–	X
	29	Kendrick - Hochderfer Hills	Black bear, elk, Mexican spotted owl	Highway 180	X	X	X
	30	San Francisco Peaks - North of Peaks	Mountain lion, pronghorn, elk, mule deer, black bear, badger, northern goshawk, Mexican spotted owl, Gunnison's prairie dog, turkey, northern leopard frog, Mexican vole, bats, neotropical migratory birds	FR 418, OHV use of illegal trails, traffic on FR 151, recreation	X	X	X
	31	San Francisco Peaks - Mt. Elden/Timberline	Mountain lion, deer, bear, northern goshawk, Mexican spotted owl, Gunnison's prairie dog, turkey, bats, neotropical migratory birds	Illegal OHV trails, traffic on Schultz Pass Rd, recreation	X	X	X
	32	San Francisco Peaks – Sunset Crater and O'Leary Peak	Elk, northern goshawk, mountain lion	Mining, off-highway vehicle use, urban development, Sunset National Monument entrance road, Hwy 89	X	X	X
	33	San Francisco Peaks - Observatory Mesa - Bellemont	Elk, mountain lion, mule deer, badger, Gunnison's prairie dog	I-40, urban and suburban development	X	X	X

Table G-6 continued. Coconino County wildlife linkages that are within the Flagstaff Area NMs' 30 km AOA.

Area	#	Name	Species	Threats	WUPA	WACA	SUCR
Flagstaff Area	34	Elden Spring Road - Landfill	Mule deer, mountain lion, striped skunk, raccoon, gray fox, coyote	Hwy 89 current use and future widening, OHV use, Timberline development, Timberline Trail development and trailhead at Elden Springs Rd	X	X	X
	35	Hwy 180 Meadows	Gunnison's prairie dog, ferruginous hawks, burrowing owls, other meadow species	Highway 180, development	–	X	X
	36	Peaks - Woody Ridge	Pronghorn, mountain lion, elk, mule deer, black bear, badger, northern goshawk, Gunnison's prairie dog, Mexican spotted owl, neotropical migratory birds, turkey, leopard frog, Mexican vole, bats, raptors	Highway 180, urban and suburban development, recreation	–	X	X
	37	Elden Foothills	Mountain lion, mule deer, bats	Urban and suburban development, recreation, illegal mountain bike trail use	X	X	X
	38	Turkey Hills - Picture Canyon - Elden Pueblo	Elk, mule deer, turkey, bald eagle, peregrine falcon, neotropical migratory birds, porcupine, bats, Gunnison's prairie dog, bats	Rural development, OHV recreation	–	X	X
	39	Rio de Flag	Neotropical migratory birds, waterfowl, bald eagle, bats	Hwy 89 current use and future widening, OHV use, Timberline development, Timberline Trail development and trailhead at Elden Springs Rd	X	X	X
	40	Woody Ridge	Pronghorn, mountain lion, black bear, elk, mule deer, badger, northern goshawk, Gunnison's prairie dog, Mexican spotted owl, neotropical migratory birds, turkey, leopard frog, Mexican voles, bats	Highway I-40, traffic and recreation along Woody Mountain Rd (FR 231), some fuels reduction treatments Notes: I-40 telemetry data should	–	X	X
	41	Rogers Lake - Volunteer Canyon	Elk, pronghorn, deer, turkey, black bear, mountain lion, northern leopard frog, bald eagle, bats, Gunnison's prairie dog	Recreation, military training	–	X	–
	42	Dry Lake - Rogers Lake	Pronghorn, elk, mule deer, black bear, turkey, Mexican spotted owl, bald eagle, Gunnison's prairie dog, northern goshawk, northern leopard frog, Mexican vole, neotropical migratory birds, bats	Suburban development, recreation, traffic on Woody Mountain Road	–	X	X
	43	Bow and Arrow	Neotropical migratory birds, bats, striped skunk	Urban and suburban development, Lake Mary Rd, Lone Tree Rd, invasive plants	–	X	X
	44	Hoffman Tank Area	Neotropical migratory birds, Gunnison's prairie dog, bats, elk	Suburban and rural development, invasive plants	–	X	X
	45	Peaceful Valley - Campbell Mesa	Bald eagle, neotropical migratory birds, Gunnison's prairie dog, elk, mule deer, porcupine, bats	Suburban development, recreation	–	X	X

Table G-6 continued. Coconino County wildlife linkages that are within the Flagstaff Area NMs' 30 km AOA.

Area	#	Name	Species	Threats	WUPA	WACA	SUCR
Flagstaff Area *continued*	46	Rio de Flag - Walnut Canyon	Mountain lion, bald eagle, northern goshawk, neotropical migratory birds	I-40 expansion	–	X	X
	48	Black Pass	Pronghorn, mountain lion, elk, mule deer, black bear, badger, northern goshawk, Gunnison's prairie dog, Mexican spotted owl, neotropical migratory birds, turkey, leopard frog, Mexican vole, bats	State Route 89A, recreation, some fuels reduction treatments	–	X	–
	49	Sinclair Wash	Neotropical migratory birds, bats	Urban/suburban/commercial development, Milton Avenue, Beulah Road, Interstate 40, invasive plants, trash, stormwater	–	X	X
	50	Oak Cr. Canyon	White-tailed deer, black bear, javelina, elk	Highway 89A, recreation	–	X	X
	51	Schoolhouse Draw - Pumphouse Wash and Fry Canyon	Mountain lion, elk, deer, black bear, hawks, Gunnison's prairie dog, Mexican spotted owl, waterfowl, bald eagle, neotropical migratory birds, turkey, leopard frog, bats	I-17 and Hwy 89, suburban/rural development, OHV use on illegal trails, recreation and traffic along FR 237	–	X	X
	52	Mexican Pocket/ Pumphouse Wash/Village of Oak Creek	Turkey, black bear, elk, mule deer, mountain lion, Abert's squirrel, Mexican spotted owl	Summer dispersed camping, off-highway vehicle use, State Route 89A, forest thinning	–	X	–
	53	Newman Park - Willard Springs	Arizona black rattlesnake, elk, reptiles	I-17, shooting range	–	X	–
	54	Pumphouse Wash - Munds Canyon	Elk, mule deer, turkey	Off-highway vehicle use	–	X	–
South-central Coconino County	55	Anderson Mesa Summer - Winter Range	Pronghorn, elk	Fencing, proposed wind development, conifer encroachment	–	X	–
	56	Robber's Roost / Dutch Tank Area Morman Lk Area	Turkey, elk, javelina	I-17	–	X	–
TOTAL NUMBER OF LINKAGES IN EACH 30 km AOA					15	35	29

Source: AGFD (2011).

NPS 360/145011, May 2018

National Park Service
U.S. Department of the Interior

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