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Natural Resource Stewardship and Science

Cedar Breaks National Monument

Natural Resource Condition Assessment

Natural Resource Report NPS/NCPN/NRR—2018/1631

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Natural Resource Report NPS/NCPN/NRR—2018/1631

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Contents

Contents (continued)

Contents (continued)

Page

Figures

Page

Figures (continued)

Figures (continued)

Page

Tables

Tables (continued)

Tables (continued)

Appendices

Page

Executive Summary

The Natural Resource Condition Assessment (NRCA) Program, administered by the National Park Service's (NPS) Water Resources Division, provides a multidisciplinary synthesis of existing scientific data and knowledge about current conditions of important national park natural resources through the development of a park-specific report. The NRCA process for Cedar Breaks National Monument (NM) began with a meeting that was held on April 11, 2017 with staff from the monument, Zion National Park (NP), NPS Intermountain Region Office, NPS Northern Colorado Plateau Inventory and Monitoring Network (NCPN), and Utah State University.

Cedar Breaks NM was established in 1933 to preserve the "multicolored geologic spectacle of the Cedar Breaks amphitheater, scenic vistas, and natural and cultural resources of scientific interest for public appreciation, education, recreation, and enjoyment." Eleven of the monument's natural resources , grouped into five broad categories, were selected for current condition assessment reporting. The five categories included landscapes, air and climate, geology and soils, water, and biological integrity, which included wildlife and vegetation resources.

The monument's viewsheds were considered to be in good condition, and night sky, soundscape, and geology were rated as good to moderate concern. Non-native invasive plants and mammals were of moderate concern and air quality and upland vegetation were rated as moderate to significant concern. None of the resources were exclusively rated as of significant concern; however, conditions for three resources, springs and seeps, birds, and unique vegetation, are unknown due to a lack of current data from which to evaluate conditions and represent data gaps.

Cedar Breaks NM is a park that faces many threats including increasing temperatures due to climate change, especially given the high elevations at the monument, and an ever-increasing human population within and surrounding Cedar City, Utah. Monument management has developed a proactive science program that partners with other parks, agencies, and the local community. These partnerships will become even more important in maintaining or influencing monument resource conditions and identifying necessary adaptations in a rapidly changing environment.

Acknowledgements

We thank Cedar Breaks NM, Zion NP, and NCPN staff for assistance in gathering data; establishing indicators, measures, and reference conditions; and for reviewing drafts of the assessments and chapters. NCPN's inventory and/or monitoring data for the upland vegetation, non-native invasive plants, springs and seeps, birds, and mammals informed conditions for these resources at Cedar Breaks.

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

And finally, to all of the additional reviewers and contributors, who are listed in Appendix B and in each Chapter 4 assessment, respectively, we thank you. Your contributions have increased the value of Cedar Breaks NM's NRCA report.

Cedar Breaks Amphitheater. 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 frame-works;[2]
- identify or develop reference conditions/values for comparison against current conditions;[3]
- emphasize spatial evaluation of conditions and GIS (map) 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 of

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-on 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

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 time frame 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

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

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.

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

indicator, reflecting differences in existing data and knowledge bases across the varied study components.

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

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

However, it is important to note that NRCAs do not establish management targets for study indicators. That process must occur through park planning 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 a NRCA project for each of the approximately 270 parks served by the NPS I&M Program. For more information on the NRCA program, visit 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
(longer-term strategic planning)
- Communicate succinct messages regarding current resource conditions to government program managers, to Congress, and to the general public ("resource condition status" reporting).

Yellow-bellied marmot at Cedar Breaks NM. Photo Credit: NPS.

Chapter 2. Introduction and Resource Setting

2.1. Introduction

2.1.1. Enabling Legislation/Executive Orders

Cedar Breaks National Monument (NM) was established in 1933 to preserve the "multicolored geologic spectacle of the Cedar Breaks amphitheater, scenic vistas, and natural and cultural resources of scientific interest for public appreciation, education, recreation, and enjoyment" (NPS 2015a). The monument's unique resources and values are further described in its five significance statements as follows (text excerpted from NPS (2015a)):

> *Geology*- The rugged escarpment or "breaks" for which the Cedar Breaks National Monument was named are the result of recent tectonic uplift in highly erosive limestone strata that continues to shape this striking landscape and its features. Geologic strata exposed in the monument represent some of the youngest, and therefore the highest and last, in a sequence of sedimentary rocks that characterize the Colorado Plateau and that accumulated over 600 million years to a thickness of 15,000 feet.
>
> *Physical geography*- The 2,500 foot westward-facing escarpment of the Cedar Breaks amphitheater presents a magnificent scene in brilliant colors of towering hoodoos, terraced cliffs, arches, bridges, deeply cut canyons, and exposed strata. The combination of an exceptional rate of erosion, high elevation, and brilliantly colored formations is distinctive among NPS units.
>
> *High-elevation flora and fauna*- Cedar Breaks National Monument protects a variety of distinctive flora and fauna, including intensely beautiful wildflower displays, ancient bristlecone pines more than 1,600 years old, and subalpine wildlife. These species have adapted to the severity of climate and weather on the high elevations of the Markagunt Plateau, contributing to the resilience and integrity of the greater subalpine ecosystem.
>
> *Peoples' use of the land*- Cedar Breaks protects evidence of some of the highest elevation prehistoric sites within the national park system, representing the astonishing ability

of humans to adapt to extreme and at times harsh environments.

Visitor experience- Located at over 10,000 feet, Cedar Breaks offers opportunities to experience one of the most easily accessible high elevation units in the national park system. Visitors experience a diversity of recreational and educational opportunities within the quiet solitude, colorful beauty, dark night skies, and endless vistas of the monument, through cross-country skiing, snowshoeing, and snowmobiling, viewing the spectacular summer wildflowers and watchable wildlife, backcountry hiking red rock canyons and streams below the amphitheater, or appreciating the changing colors of autumn. The designated research natural area within the monument provides an important venue for researchers to study a relatively pristine area of the rapidly developing American West.

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

Cedar Breaks NM is located in southwest Utah (Figure 2.1.2-1), in Iron County, about 29 km (18 mi) east of Cedar City, on the western edge of the Markagunt Plateau. The monument preserves 2,491 ha (6,155 ac) that is surrounded on all sides by the Dixie National Forest (NF) (Figure 2.1.2-2), with the exception of an approximately 1.6 km (1.0 mi) section of private land along its eastern boundary (NPS 2015a). The 2,850 ha (7,043 ac) Ashdown Gorge Wilderness Area within the Dixie NF lies along the western and northern border of the monument (USFS 2017). Designated wilderness areas are afforded the highest level of protection from resource extraction and development (USFS 2017), providing additional protection for monument resources. A majority (78%) of the monument below the rim has been recommended for inclusion in the National Wilderness Preservation System and is managed as a Research Natural Area (NPS 2015a).

<u>Population</u>

The current U.S. Census Bureau data show that Utah is the fastest growing state in the nation (U.S. Census Bureau 2016a). As of July 1, 2016, the population estimate for Iron County was 49,937, representing an increase of 8.2% since April 1, 2010 (U.S. Census Bureau no date).

<u>Climate</u>

SNOTEL (SNOwpack TELemetry) climate monitoring site, Midway Valley, is located within 5 km (3.1 mi) of the monument's south boundary and has collected data from 1980-present (2017) at an elevation of 3,340 m (10,958 ft). SNOTEL sites are located at high elevations (i.e., mountainous areas), and collect real-time snow water equivalent, snow depth, precipitation, temperature, and other climatic variables data at hourly intervals (Witwicki 2013). Climate in the higher elevation area of the monument is characterized by short, cool summers and long, cold

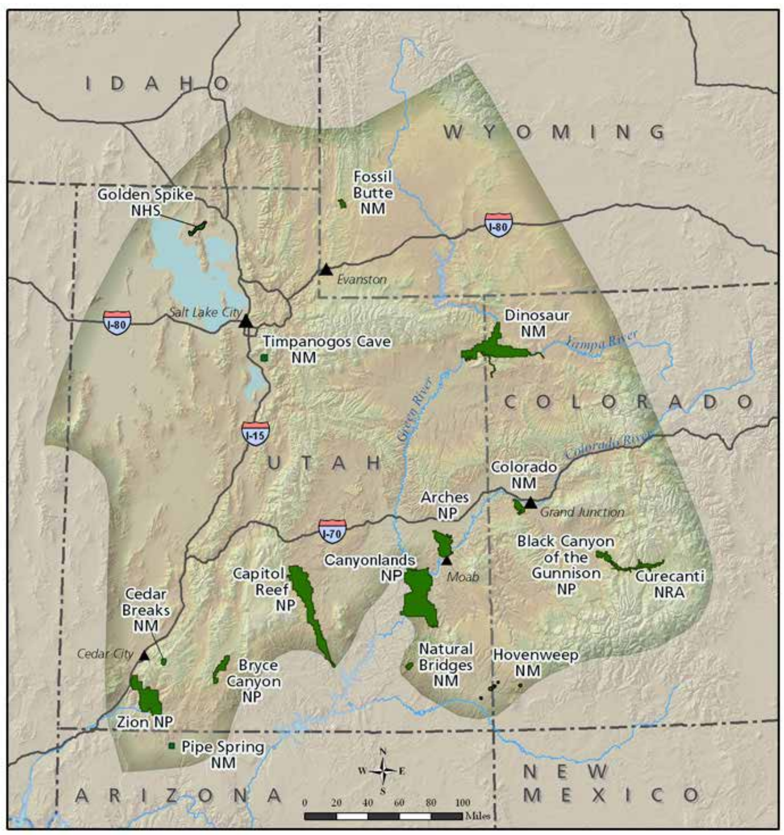


Figure 2.1.2-1. Cedar Breaks is located in southwest Utah and is one of 16 park units within the NPS Northern Colorado Plateau Inventory and Monitoring Network. Figure Credit: NPS NCPN 2016.

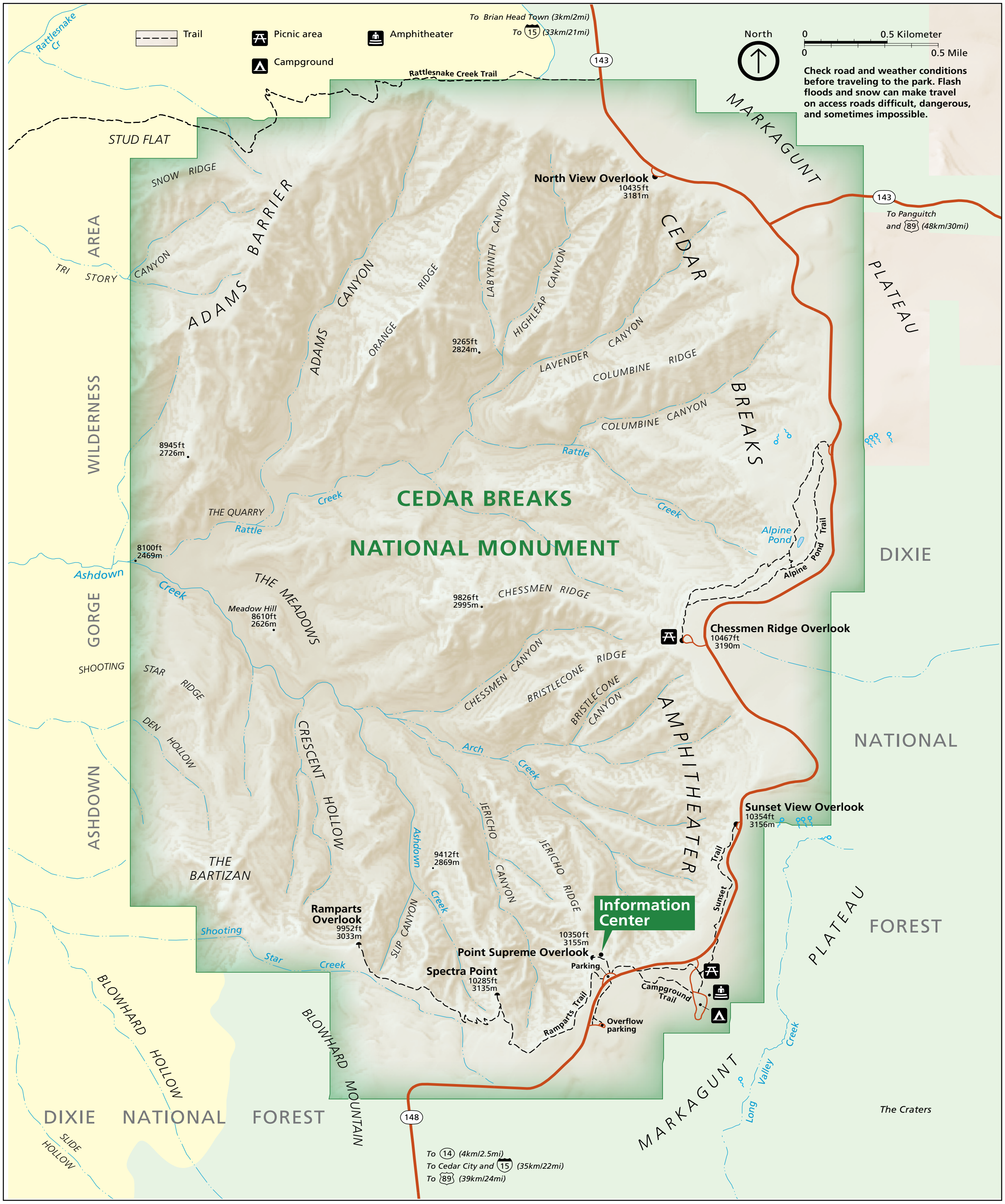


Figure 2.1.2-2. Cedar Breaks NM is located along UT-148, approximately 29 km (18 mi) east of Cedar City, Utah. Figure Credit: NPS.

winters, with deep and drifting snow from November to mid-May (Tendick et al. 2011). Annual snowfall averages 917 cm (361 in), but summer monsoonal storms during July and August also contribute to the monument's total annual precipitation (Tendick et al. 2011). Temperatures remain above freezing only during the months of June-September (NPS NCPN 2016).

2.1.3. Visitation Statistics

Visitation data for Cedar Breaks NM are available from 1934-2016 (NPS Public Use Statistics Office 2017). The total number of visitors each year has been steadily increasing, with the highest number of visitors, 899,676, occurring in 2016 (Figure 2.1.3-1). The months with the highest average number of visitors over the recording period were June-September.

2.2. Natural Resources

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

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

Ecological Units

Cedar Breaks NM is located in the Utah High Plateaus and Mountains Section within the Northern Colorado Plateau Inventory and Monitoring Network (NCPN), along with Bryce Canyon and Zion NPs. Elevations within the monument range from 2,469 m (8,100 ft) on the western side of the park to 3,250 m (10,662 ft) in the northeast section of the park above the amphitheater rim (Evenden et al. 2002). Cedar Breaks NM represents the highest elevation park throughout the entire Northern Colorado Plateau Network parks and monuments (Evenden et al. 2002).

Watershed Units

Eighty-six percent of the national monument is located within the Ashdown Creek watershed, which covers a total area of 69.4 km^2 (26.8 mi^2) (U.S. Geological

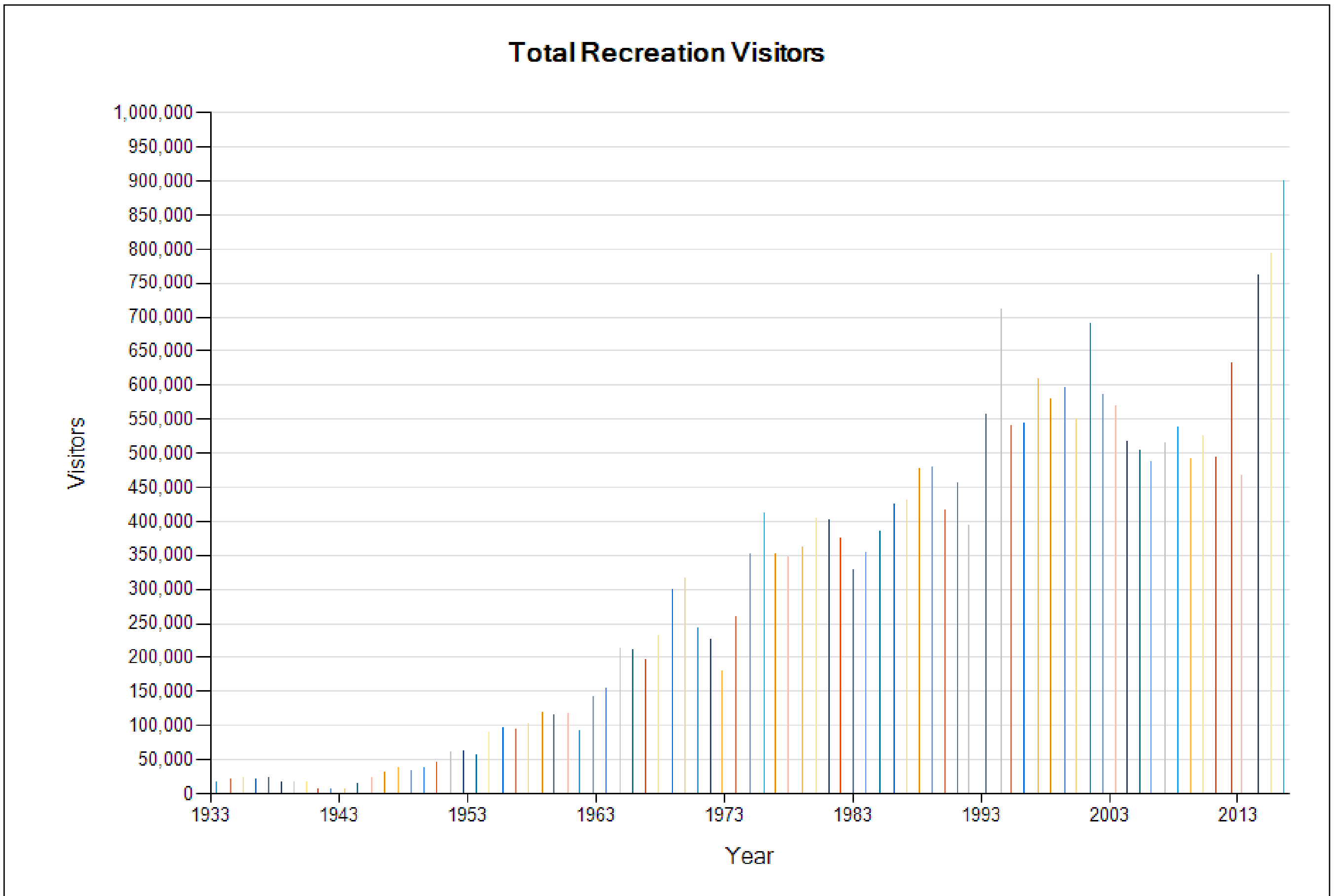


Figure 2.1.3-1. Total number of annual visitors to Cedar Breaks NM from 1934-2016. Figure Credit: NPS Public Use Statistics Office 2017.

Survey [USGS 2014]). The monument accounts for 30.8% of the Ashdown Creek watershed area. The remaining 14% of the monument's area is located in Upper Mammoth Creek and Midway Valley-Midway Creek watersheds (Figure 2.2.1-1).

NPScape Landscape-scale

Most of Cedar Breaks NM's natural resources (e.g., viewshed, night sky, soundscape, vegetation, wildlife, etc.) are affected by landscape-scale processes, and this broader perspective can provide more comprehensive information to better understand resource conditions throughout the monument. Studies have shown that natural resources rely upon the larger, surrounding area to support their life cycles (Coggins 1987 as cited in Monahan et al. 2012), and most parks are not large enough to encompass self-contained ecosystems for the resources found within their boundaries. This is especially important for Cedar Breaks NM's natural resources due to its relatively small size and to the increasing population and associated developments surrounding Cedar City, Utah. As a result and when feasible, landscape-scale indicators and measures were included in the monument's condition assessments to provide an ecologically relevant, landscape-scale context for reporting resource conditions. NPS NPScape metrics were used to report on these these landscape-scale measures, providing a framework for conceptualizing human effects (e.g., housing densities, road densities, etc.) on landscapes (NPS 2014a,b).

2.2.2. Resource Descriptions

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 a park. Cedar Breaks NM provides its visitors with many developed and accessible overlooks that afford sweeping vistas of the geologic features for which the monument was established. Most of the surrounding landscape is undeveloped. The Dixie NF and designated wilderness help to protect the area from future development, maintaining the views in a primarily natural state.

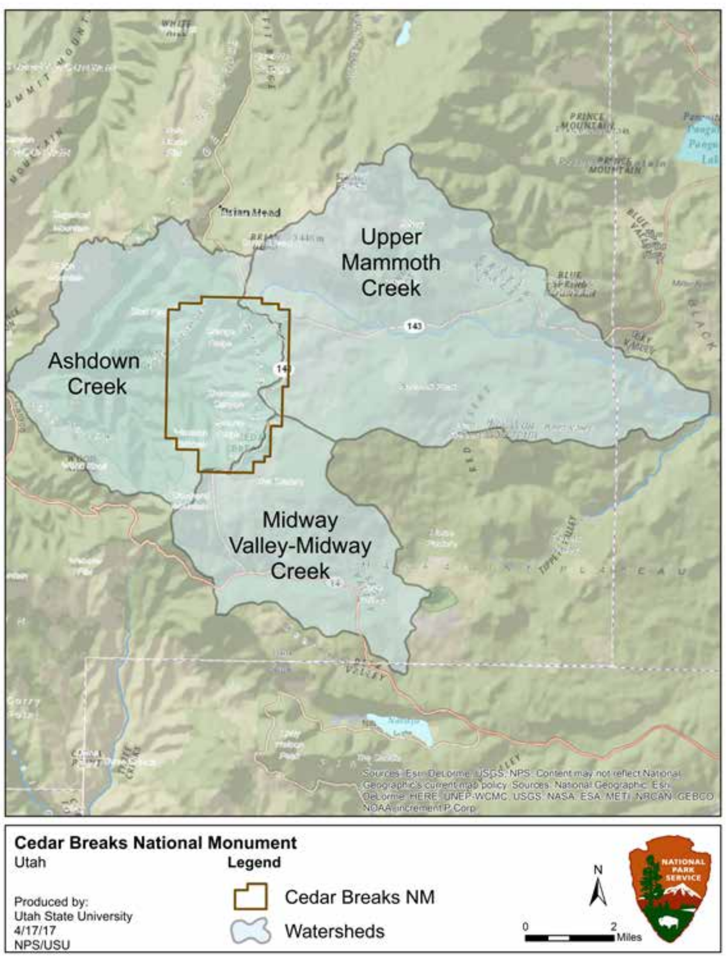


Figure 2.2.1-1. Cedar Breaks is located in three watersheds.

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). Maintaining a dark night sky was identified in Cedar Breaks NM's Foundation Document as fundamental to protecting the wilderness setting and biodiversity of the park (NPS 2015a). In 1976 approximately 78% of the park was recommended for inclusion in the National Wilderness Preservation System. In 2017, the International Dark Sky Association (IDA) designated Cedar Breaks NM as a Dark Sky Park (IDA 2017). The NPS Natural Sounds and Night Skies Division (NSNSD) scientists conducted an assessment of Cedar Breaks NM's night sky condition at Brian Head Peak, just north of the monument, during 2003, 2004, and 2006. The preliminary results of those surveys were used to evaluate the monument's night sky condition.

Soundscape

Soundscapes at Cedar Breaks NM are important to the monument's natural and cultural resources and to the visitor experience (NPS 2015a). Low levels of anthropogenic sound (or no anthropogenic sound) help to better relay to the visitor what the area would have been like prior to modern development.

The monument's recommended wilderness, provides opportunities for human solitude and a haven for native wildlife. The Wilderness Monitoring Report for the monument (i.e., Booth-Binczik 2014) recognizes the integral role the soundscape plays in the wilderness environment and includes a measure for monitoring its condition; this measure is the same as the one used in the soundscape assessment (the geospatial model). NSNSD scientists conducted acoustical monitoring in 2012, and the preliminary results were used in the soundscape assessment; however, as of December 2017, a full analysis of the data has yet to be completed.

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. (U.S. Federal Register 1970)). Like most NPS areas, Cedar Breaks 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, however, there is a visibility monitor (BRCA1, UT) nearby from which to derive trend. To date, seven plants in the national monument are known to be ozone sensitive species (Bell in review, Kohut 2004).

Geology and Water

The monument was established in 1933 to preserve the distinctive geologic formations found in the colorful breaks (NPS 2015a), which are located along the western edge of the Markagunt Plateau. The plateau was uplifted 1,219 m (4,000 ft) by the Hurricane Fault, and over millions of years, the colorful geologic features— spires, fins, pinnacles, canyons, and hoodoos, have eroded from ancient limestones found in the Pink Cliffs of the Claron Formation. The same processes that created the breaks are at work today as unstable hoodoos crumble and new ones form.

Water is the primary erosive force in Cedar Breaks NM. With more than 250 days of frost per year, water seeping into cracks in the rock freezes and expands, exerting extreme pressure that splits rock apart (NPS 2016a). Chemical weathering from acidic rain and slope failures caused by intense rainstorms also sculpt the landscape (Thornberry-Ehrlich 2006). These natural forces occur on a time scale that is visible to the average human observer. Rockfall, slope failures, and crumbling hoodoos are sometimes observed by monument visitors.

In spite of the high amount of precipitation that falls in the area, very little water remains on the surface due to the highly fractured geologic layers. Aside from Ashdown Creek, springs and seeps represent the only perennial source of water in the monument, which serve as very important resources for a variety of wildlife and plants.

Vegetation

The vegetation in Cedar Breaks NM ranges from low elevation, sparsely vegetated breaks below the rim to montane forests and subalpine meadows at the highest elevations above the rim (Tendick et al. 2011).Variable topography, soil moisture, and erosional processes drive plant distribution patterns throughout the monument (Tendick et al. 2011). The lowlands within Cedar Breaks NM are dominated by ponderosa pine (*Pinus ponderosa*), blue spruce (*Picea pungens*), and Douglas-fir (*Pseudotsuga menziesii*), with an understory of Rocky Mountain maple (*Acer glabrum*), greenleaf manzanita (*Arctostaphylos patula*), and Oregon grape (*Mahonia repens*) (Evenden et al. 2002, Haymond et al. 2003). Uplands within the monument are dominated by Englemann's spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*), with an understory of monkshood (*Aconitum columbianum*), Oregon grape, and gooseberry (*Ribes* spp.), and subalpine meadows of grasses, sedges, and forbs, which include a wide variety of wildflowers (Evenden et al. 2002, Haymond et al. 2003). Even though the breaks region within the monument is characterized by some of the harshest environmental conditions, most of the monument's rare plants, including narrow endemics such as spiked ipomopsis (*Ipomopsis spicata* ssp. *tridactyla*) and Panguitch buckwheat (*Eriogonum panguicense* var. *alpestre*), thrive in this region.

Wildlife

Inventories have been conducted throughout the national monument to record the presence of birds, herpetofauna, and mammals. Both birds and mammals were selected as condition assessment topics, but amphibians and reptiles (herpetofauna) were not and are instead listed in Appendix A.

A total of 12 herpetofauna species (four amphibians and eight reptiles) are included on the monument's NPSpecies list, but only one, boreal chorus frog (*Pseudacris maculata*) is confirmed as present within the monument (NPS 2017a).

Birds

In the early 2000s, the U.S. Geological Survey (USGS) conducted avian inventories at four national park units within the Northern Colorado Plateau Inventory and Monitoring Network (NCPN), including Cedar Breaks NM. Prior to this inventory at the monument, the only additional information on birds was a checklist with no information on abundance or distribution (Johnson et al. 2003). The inventory by Johnson et al. (2003) used point count surveys and incidental and nighttime surveys during the breeding seasons of 2001 and 2002, as well as area searches during the winters of 2001-2003. No comprehensive (i.e., group-wide) avian monitoring at the national monument has been conducted since the Johnson et al. (2003) work, but the NPSpecies list for the park (NPS 2017a) has continued to be updated based on credible records and observations. Some other recent observations of birds within the national monument are also available and described in the Chapter 4 condition assessment. A total of 147 birds have been identified for Cedar Breaks NM.

Mammals

The most recent inventory of mammals was conducted by the USGS throughout NCPN parks (Haymond et al. 2003), including Cedar Breaks NM. Haymond et al. (2003) conducted fieldwork in the monument in 2001 and 2002 and recorded 32 species, representing 64% of the total listed for the monument. Additional sightings have been made by monument staff and volunteers. Monument staff have also created a database to track credible sightings and plan on implementing a citizen science project to observe the talus patches for signs of American pika (*Ochotona princeps*), a species of management concern at the monument.

The American pika is a small mammal, 15.2-20.3 cm (6-8 in) in length, with an average life span of 3-4 years (and up to 7 years; USFWS 2014). Pikas typically reside in areas of loose rock in alpine and subalpine mountain areas ranging from central British Columbia and Alberta in the north to the Rocky Mountains in northern New Mexico and the Sierra Nevada Mountains in California (USFWS 2010). The species' historical and current geographical ranges include cool and moist portions of California, Nevada, Washington, Oregon, Montana, Idaho, Wyoming, Colorado, Utah, and New Mexico, as well as the Canadian provinces of British Columbia and Alberta.

Pikas are generalist herbivores, but primarily feed on forbs and graminoids (USFWS 2014). Its breeding season occurs primarily in March-April, and females produce one or two litters of three or four young (USFWS 2014). Predators of the species include hawks,

Figure 2.2.2-1. Little sunflower is one of the many wildflowers that occur at Cedar Breaks NM. Photo Credit: NPS.

owls, eagles, coyotes, foxes, bobcats, and weasels, among many other species (Smith and Weston 1990). MacArthur and Wang (1974) and Smith (1974) found that brief exposure to temperatures greater than 25.5 °C (77.9 °F) can lead to pika mortality if individuals are prevented from thermoregulating by changing their behavior.

2.2.3. Resource Issues Overview

Climate Change

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

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

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

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 on record for the monument.

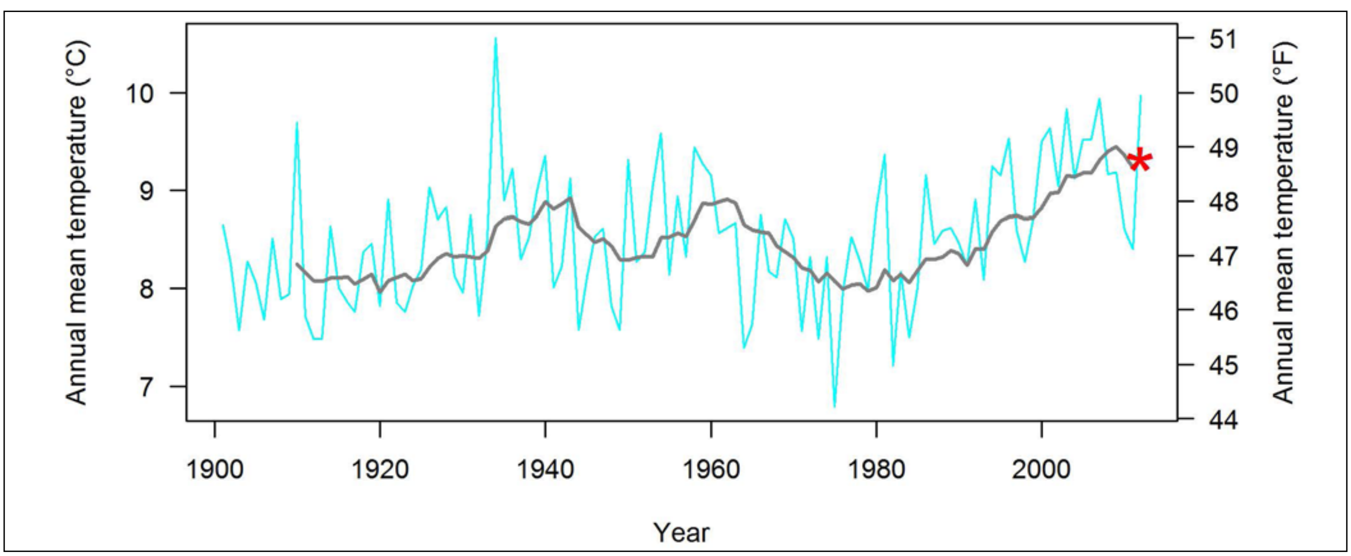


Figure 2.2.3-1. Time series used to characterize the historical range of variability and most recent percentile for annual mean temperature at Cedar Breaks NM (including areas within 30-km [18.6-mi] of the park's boundary). Figure Credit: Monahan and Fisichelli (2014).

Climate predictions are that the Southwest will likely continue to become warmer and drier with climate change (Garfin et al. 2014, Monahan and Fisichelli 2014). Kunkel et al. (2013) estimates that temperatures could rise between 2.5 °C (37 °F) and 4.7 °C (40 °F) for 2070-2099 (based on climate patterns from 1971-1999).

Mammals

Alpine mammals are considered to be one of the most vulnerable due to global warming (Wilkening et al. 2015). The inability to relocate may isolate species or result in extirpation. American pika populations have already become locally extirpated in some mountainous areas in the United States (Wilkening et al. 2015) and are known for being temperature-sensitive. Because their upper-critical (lethal) temperature cannot tolerate internal body temperatures much higher than their resting body temperature of 40.3°C (104 °F); they are typically found at progressively higher elevations farther south in their range (USFWS 2010). The American pika is considered a climate-sensitive sentinel species (Garrett et al. 2011), which may serve as the "canary in the coal mine" for the monument signaling warming temperatures as a result of climate change.

Vegetation

Historically, the monument's uplands were heavily grazed by cattle and sheep, but grazing became more limited after Cedar Breaks's establishment as a national monument in 1933 (Tendick et al. 2011). Today, grazing is currently excluded with a boundary fence, although livestock trespass may occasionally occur if the fence is damaged (Tendick et al. 2011). Although grazing is largely excluded, other disturbances, including the invasion of subalpine meadows by non-native species, conifer encroachment of upland meadows, bark beetle outbreaks, and sudden aspen decline, are of concern for upland plant communities (Witwicki 2010). Recovery from these types of disturbances is often slow as a result of the monument's limited growing season and usually harsh conditions (Witwicki et al. 2013).

All roads in the monument occur in the uplands, which are vectors for non-native species dispersal (Dewey and Anderson 2005). Other disturbed areas, such as around buildings, trails, and observation points, are also prone to the establishment of non-native plants (Dewey and Anderson 2005). Smooth brome (*Bromus inermis*) and dandelion (*Taraxacum officinale*) are the most widespread non-native plant species in the monument (NPS 2015a).

Geology

While natural erosional processes dominate the geologic features in Cedar Breaks NM, anthropogenic impacts can accelerate erosion and damage or destroy sensitive geologic features (NPS 2015a), as well as park facilities. Areas of high visitor use, including scenic overlooks and along trails are of interest, especially where the geologic material is susceptible to slope failure and/or rockfall.

Additional details pertaining to a variety of resource threats, concerns, and data gaps can be found in each Chapter 4 condition assessment and in Chapter 5.

2.3. Resource Stewardship

2.3.1. Management Directives and Planning Guidance

In addition to NPS staff input based on the monument's purpose, significance, and fundamental resources and values, and other potential resources/ecological drivers of interest, the NPS Washington (WASO) level programs guided the selection of key natural resources for this condition assessment. This included the NCPN, 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 assessments.

NCPN 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. Cedar Breaks NM is part of the NCPN, which includes 15 additional parks. Through a rigorous multi-year, interdisciplinary scoping process, NCPN selected a number of important physical, chemical, and/or biological elements and processes for long-term monitoring. These ecosystem elements and processes are referred to as 'vital signs', and their respective monitoring programs are intended to provide high-quality, long-term information on the status and trends of those resources. Air quality, climate, land surface phenology, landscape dynamics, and upland vegetation were selected for monitoring at Cedar Breaks NM by NCPN (NPS NCPN 2016).

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 Cedar Breaks NM in 2015 (NPS 2015a) and was used to identify some of the

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

primary natural features throughout the monument for the development of its NRCA.

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 NCPN I&M and research conducted by other scientists and programs, Washington level programs, including I&M NPScape, Climate Change Response Program, Natural Sounds and Night Skies, and Air Resources, Divisions provided a wealth of information to assist in the development of the monument's condition assessments.

Cedar Breaks National Monument's NRCA scoping meeting was held on April 11, 2017. Photo Credit: NPS.

Chapter 3. Study Scoping and Design

The Natural Resource Condition Assessment (NRCA) for Cedar Breaks National Monument (NM) was coordinated by the National Park Service (NPS) Intermountain Region Office (IMRO), Utah State University (USU), and the Colorado Plateau Cooperative Ecosystem Studies Unit through task agreements, P14AC00749 and P15AC01212. The NRCA scoping process was a collaborative effort between the staffs of Cedar Breaks NM and NPS Northern Colorado Plateau Inventory and Monitoring Network (NCPN), the NPS IMRO NRCA Coordinator, and USU's NRCA team.

Preliminary scoping for Cedar Breaks NM's NRCA began on January 24, 2017 with a conference call. Prior to the call, USU staff reviewed Cedar Breaks NM's foundation document (NPS 2015a), the monument and Northern Colorado Plateau Inventory and Monitoring Network websites (NPS 2016b, NPS NCPN 2016), and the NPS integrated resource management applications: IRMA portal (NPS 2016c). The NPS Natural Resource Stewardship and Science Directorate (NRSS) divisions provided data for night sky, soundscape, air quality, and geology topics (NPS 2016d).

Based on the information gathered from these sources, an initial list of potential focal resources for the monument's NRCA was developed and discussed during the January conference call. Cedar Breaks NM's conference call participants, Superintendent, Paul Roelandt, and Acting Resources Manager, Bryan Larsen, discussed and refined the list of resources.

USU NRCA writers reviewed reports and data sets to determine logical arrangement of the prioritized resources. USU writers then developed the Phase I draft indicators, measures, and reference conditions for the 11 preliminary focal resources selected by monument staff. These tables served as the primary discussion guide during Cedar Breaks NM's on-site NRCA scoping workshop.

The NRCA workshop and field outing was held over a three day period from April 10-12, 2017 at Cedar Breaks NM's administrative offices (a list of meeting attendees is included in Appendix B). During the workshop, meeting participants reviewed, discussed, and refined the Phase I tables, which formed the basis of USU's study plan for the monument's NRCA report. Additional data sets and reports were identified for the selected focal resources. Monument staff also identified threats, issues, and data gaps for each natural resource topic, which are discussed in each Chapter 4 condition assessment.

3.1. Study Design

3.1.1. Indicator Framework, Focal Study Resources and Indicators

An NRCA report represents a unique assessment of key natural resource topics for each park. For the purposes of Cedar Breaks NM's NRCA, 11 focal resources were selected for assessment, which are listed in Tables 3.1.1-1 - 3.1.1-5. Due to USU's timeline and budget constraints, this list of resources *does not* include every natural resource of interest to monument staff, rather the list is comprised of the natural resources and processes that were of greatest interest/concern to monument staff at the time of this effort.

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

Table 3.1.1-1. Cedar Breaks 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
	Scenic and Historic Integrity	Conservation Status
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
	Geospatial Model	L_{50} Impact

Table 3.1.1-2. Cedar Breaks 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

Table 3.1.1-3. Cedar Breaks NM natural resource condition assessment framework based on the NPS Inventory & Monitoring Program's Ecological Monitoring Framework for geology and soils.

Resource	Indicators	Measures
Geology	Known Deterioration of Geological or Paleontological Resources	Anthropogenic Incidents
	Known Deterioration of Geological or Paleontological Resources	Rockfall or Slope Failures
	Seismic Activity	Presence/Absence of Earthquakes

3.1.2. Reporting Areas

The primary focus of the reporting area was within Cedar Breaks NM's legislative boundary; however, some of the data and analyses encompassed areas beyond its boundary. The monument is surrounded by the U.S. Forest Service's almost two million acre-Dixie National Forest, which is the largest national forest in Utah (Utah.com 2017), and had additional information that was used for some of Cedar Breaks NM's resource condition assessments.

Natural resources assessed at the landscape level included viewshed, night sky, and soundscape. The

Table 3.1.1-4. Cedar Breaks NM natural resource condition assessment framework based on the NPS Inventory & Monitoring Program's Ecological Monitoring Framework for water.

Resource	Indicators	Measures
Springs and Seeps	Water Quantity	Spring Discharge
	Water Quantity	Water Rights
	Water Quality	Specific Conductance
	Water Quality	pH
	Water Quality	Dissolved Oxygen
	Water Quality	Temperature
	Bacteria	Fecal coliform
	Bacteria	Total coliform
	Biodiversity	Plant Presence
	Biodiversity	Aquatic Invertebrate Presence
	Biodiversity	Herpetofauna Presence

NPS NRSS Natural Sounds and Night Skies Division provided the data and reports for the night sky and soundscape assessments. Since the monument was inaccessible to vehicular traffic due to snow, Bryan Larsen will take the GigaPan panoramas for the monument's viewshed assessment after the monument reopens for the season.

3.1.3. 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 assistance in condition reporting. Following the NPS NRCA guidelines (NPS 2010a), each Chapter 4 condition assessment included the following six sections:

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.

Table 3.1.1-5. Cedar Breaks NM natural resource condition assessment framework based on the NPS Inventory & Monitoring Program's Ecological Monitoring Framework for biological integrity.

Resource	Indicators	Measures
Vegetation	Community Composition and Structure	Species Richness
	Community Composition and Structure	Tree Density by Size Class (#/ha)
	Community Composition and Structure	Crown Health
	Forest Health	Bark Beetle Infestation (ha)
	Forest Health	Fuels Volume (tons/ha)
	Forest Health	Vegetation Condition Class
	Productivity	NDVI
Unique and Distinctive Vegetation	Prevalence	Population Size
	Prevalence	Frequency
Non-native and Invasive Plants	Potential to Alter Native Plant Communities	NatureServe Invasive Species Impact Rank
	Rate of Invasion	% of New Non-native Species of Total Species Detected Over Time
	Prevalence	Frequency
	Prevalence	Cover
Birds	Species Occurrence	Temporal Comparison of Species Presence / Absence
	Species Occurrence	Absence of Non-native Species
	Species Occurrence	Presence of Species of Conservation Concern
Mammals	Species Occurrence	Presence/Absence of Species
	Species Occurrence	Absence of Non-native Species
	Species Occurrence	Species of Conservation Concern
	American Pika Occurrence	Presence/Absence in Monument

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 3.1.3-1 shows the condition/trend/confidence level scorecard used to describe the condition for each assessment, and Table 3.1.3-2 provides examples of conditions and associated interpretations.

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

Arrows inside the circles signify the trend of the indicator/measure. An upward pointing arrow

Table 3.1.3-1. Indicator symbols used to indicate condition, trend, and confidence in the assessment.

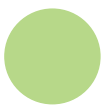
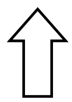
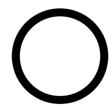
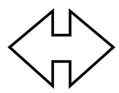
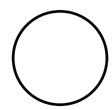
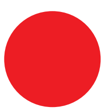
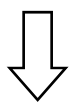
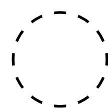
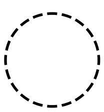
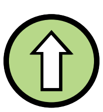
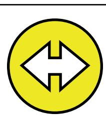
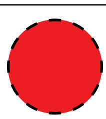
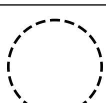
Condition Status		Trend in Condition		Confidence in Assessment	
	Resource is in good condition.		Condition is Improving.		High
	Resource warrants moderate concern.		Condition is unchanging.		Medium
	Resource warrants significant concern.		Condition is deteriorating.		Low
	An open (uncolored) circle indicates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

Table 3.1.3-2. 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.

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 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 Conditions

Chapter 4 delivers current condition reporting for the 11 important natural resources and indicators selected for Cedar Breaks 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.

Blue flax, a native wildflower in Cedar Breaks NM. Photo Credit: NPS.

4.1. Viewshed

4.1.1. Background and Importance

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

Aside from the minor developed area along the eastern boundary and a small inholding within the Ashdown Gorge Wilderness Area, much of the landscape surrounding Cedar Breaks NM is undeveloped, providing visitors the opportunity to immerse themselves in a natural landscape (Figure 4.1.1-1).

<u>Visitor Experience</u>

Viewsheds are considered an important part of the visitor experience at Cedar Breaks NM, and features on the visible landscape influence a visitor's enjoyment, appreciation, and understanding of the monument (NPS 2015a). Visitors to the monument are provided opportunities to immerse themselves in the wilderness where experiences become more remote from anthropogenic sights and sounds, offering an opportunity to literally "visualize" their connection to nature. These views represent much more than just scenery; they represent a way to better understand the connection between self and nature. 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.

4.1.2. Data and Methods

The indicator and measures used for assessing the condition of Cedar Breaks NM's viewshed were based on studies related to perceptions people hold toward various features and attributes of scenic landscapes. In general, there has been a wealth of research demonstrating that people tend to prefer natural landscapes over human-modified landscapes (Zube et al. 1982, Kaplan and Kaplan 1989, Sheppard 2001, Kearny et al. 2008, Han 2010). Human-altered components of the landscape (e.g., roads, buildings,

Figure 4.1.1-1. The amphitheater in Cedar Breaks NM. Photo Credit: NPS.

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 generalization for natural landscape preferences, studies have also shown that not all human-made structures or features have the same impact on visitor preferences. Visitor preferences can be influenced by a variety of factors including cultural background, familiarity with the landscape, and their environmental values (Kaplan and Kaplan 1989, Virden and Walker 1999, Kaltenborn and Bjerke 2002, Kearney et al. 2008).

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

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). Integrity focuses on the features of the landscape related to non-contributing human alteration/development. Key

Key Observation Points

Three key observation points were selected by monument staff (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 various road densities datasets. Note that GigaPan images were not available for Chessman Ridge. These locations were chosen based on viewsheds that were accessible to the public, were located upon a prominent landscape feature, and were inclusive of natural resources and scenic views.

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 two of the three key observation point using a Canon PowerShot digital camera and the GigaPan Epic 100 system, a robotic camera mount coupled with stitching software in June 2017 (Figure 4.1.2-2).

A series of images were automatically captured and the individual photographs were 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 was presented in Table 4.1.2-1.

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 National Park Service:

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

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

The foreground is the zone where visitors should be able to distinguish variation in texture and color, such as the relatively subtle variation among vegetation patches, or some level of distinguishing clusters of tree boughs. Large birds and mammals would likely be visible throughout this distance class, as would small

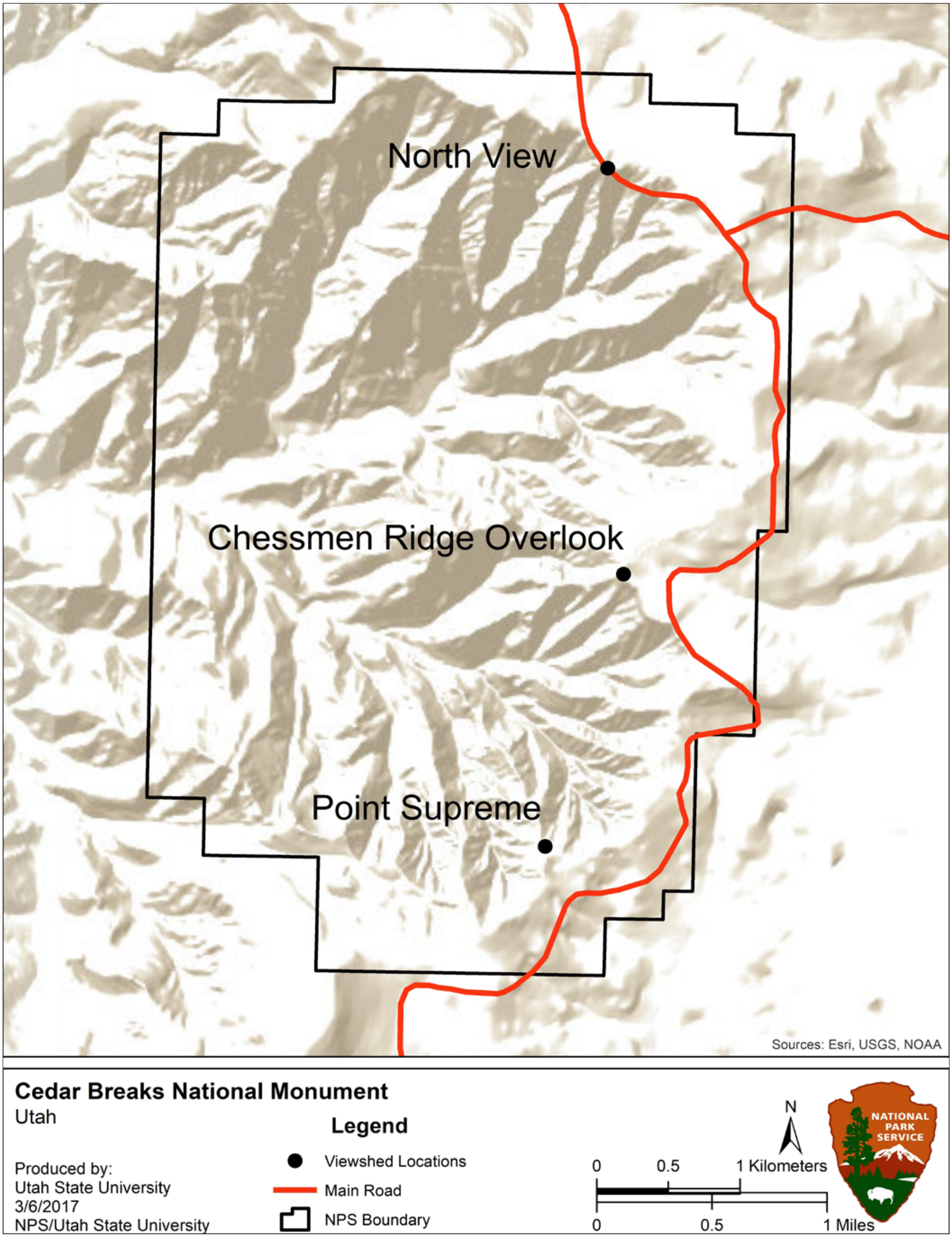


Figure 4.1.2-1. Locations of 2017 viewshed monitoring locations at Cedar Breaks NM.

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

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

Size

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

We considered the features on the landscape surrounding Cedar Breaks NM as belonging to one of six size classes (Table 4.1.2-2), which reflect the preference groups reported by studies. Using some

Table 4.1.2-1. 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

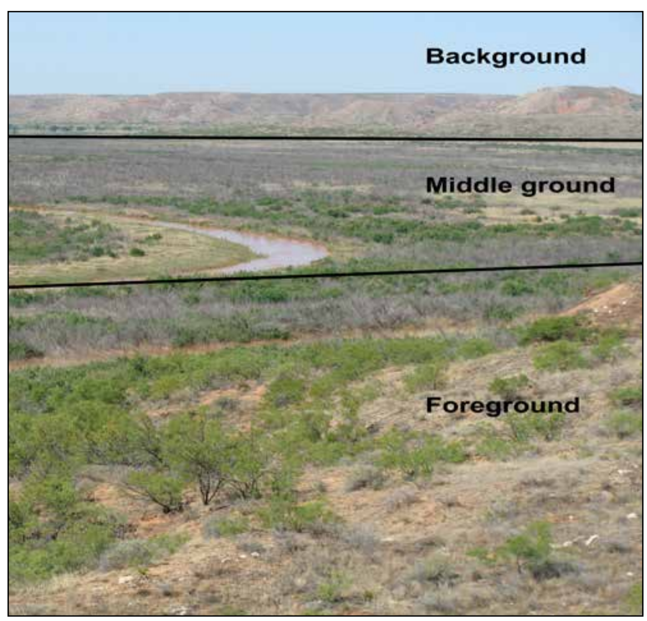


Figure 4.1.2-3. An example of foreground, middle ground, and background distance classes.

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 was consistent with the findings of Kearney et al. (2008) who found that darker color was one of the factors contributing to a feature blending in with its environment and therefore preferred.

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

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,

Table 4.1.2-2. 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

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).

Viewshed Analysis

Viewshed analyses were conducted to evaluate areas that were visible and non-visible from a given observation point using ArcGIS (Geographic Information System) Spatial Analyst Viewshed tool. We identified the viewshed Area of Analysis (AOA) as a 97 km (60 mi) area surrounding each of the three key observation points. The viewshed analyses were

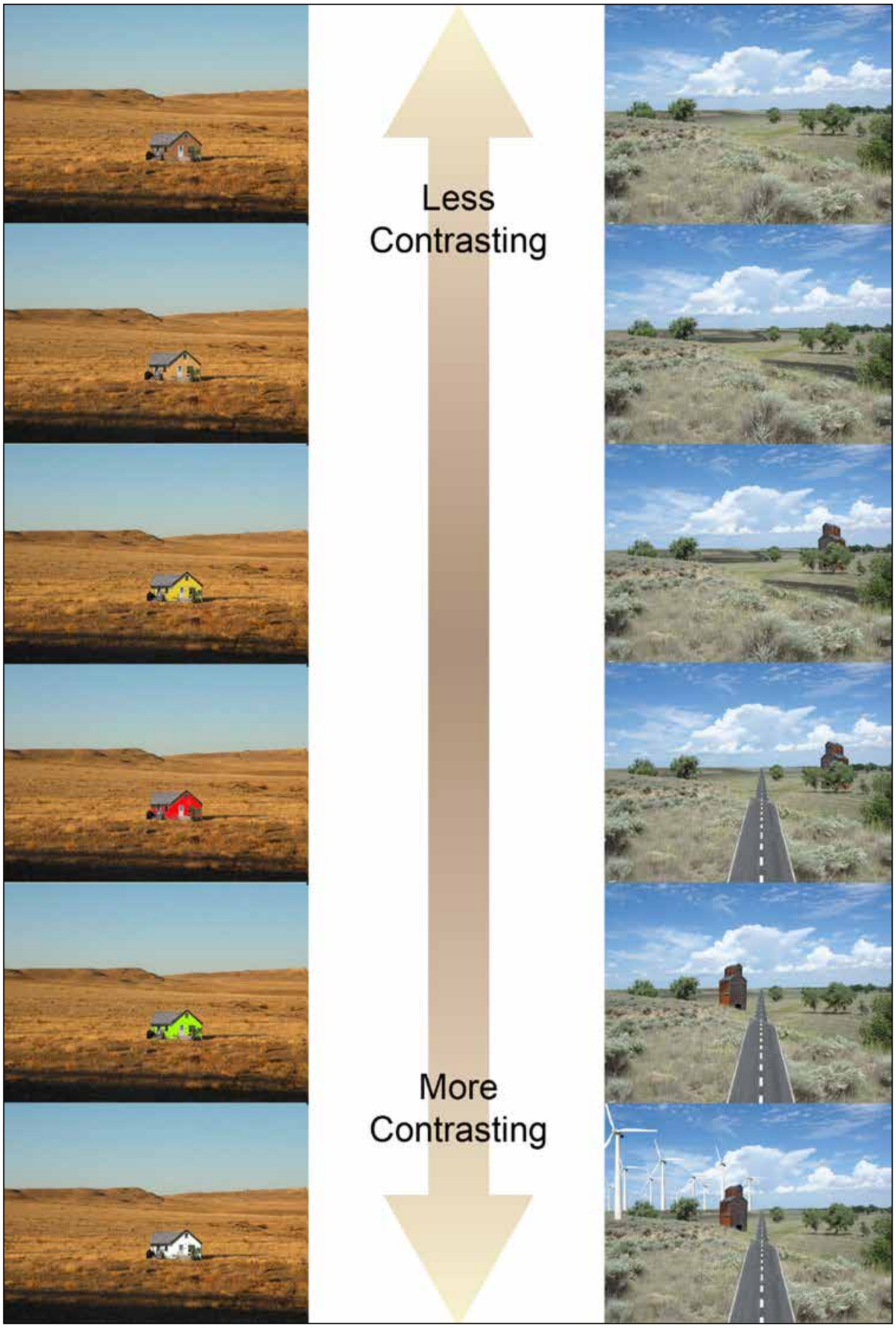


Figure 4.1.2-4. Graphic illustration of how color (left) and shape (right) can influence whether features were in harmony with the environment, or were in contrast.

calculated for this area since it represents the distance to which the average observer may distinguish landscape features (USFS 1995). We used the USGS' National Elevation Datasets (NED) at 1/3 arc-second resolution (approximately 10 m / 32.8 ft resolution) to determine which areas should be visible from each observation point based on elevation within the AOA (USGS 2016a). The viewshed analysis for each location was used to support the GigaPan images described for the previous measure. The three AOAs were then combined to create a composite viewshed. Composite viewsheds are a way to show multiple viewsheds as

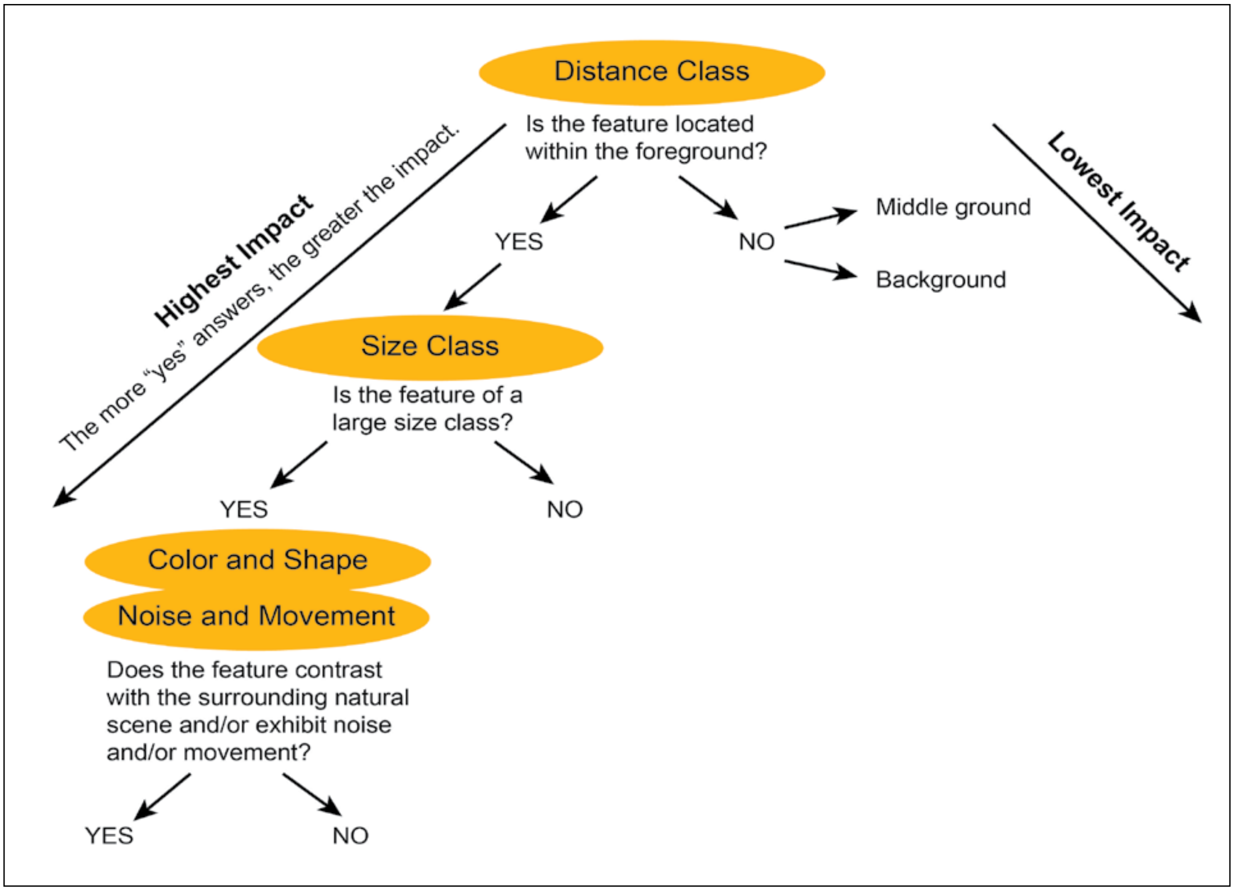


Figure 4.1.2-5. Conceptual framework for hierarchical relationship of characteristics that influence the conspicuousness of features within a viewshed.

one, providing an overview of the visible/non-visible areas across all observation points. The analysis assumes that the viewsheds were not hindered by non-topographic features such as vegetation; the observer was at ground level viewing from a height of 1.68 m (5.5 ft), which is the average height of a human; and visibility did not decay due to poor air quality. Additional details are listed in Appendix C. The composite viewshed was used to support the following two measures (i.e., extent of development and conservation status).

Extent of Development

The extent of development provides a measure of the degree to which the viewshed was 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).

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 2016e, Monahan et al. 2012). NPScape data include seven major categories (measures), three of which were used in the viewshed condition assessment: housing, roads, and conservation status. These metrics were used to evaluate resource conditions from a landscape-scale perspective and to provide information pertaining to threats and conservation opportunities related to scenic views surrounding Cedar Breaks NM. NPScape data were consistent, standardized, and collected in a repeatable fashion over time, and yet were flexible enough to provide analyses at many spatial and temporal scales. The NPScape datasets used in this analysis were described in the sections that follow.

Housing Density

The NPScape 2010 housing density metrics were derived from Theobald's (2005) Spatially Explicit Regional Growth Model, SERGoM 100 m (328 ft) resolution housing density rasters. SERGoM forecasts changes on a decadal basis using county specific population estimates and variable growth rates that were location-specific. The SERGoM housing densities were grouped into six classes as shown in Table 4.1.2-3. 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. The 2010 output was overlaid with the composite viewshed from the three key observation locations in order to visualize housing density within the monument's viewshed. Using the output from this analysis, we also calculated the percent change in housing density from 1970 to 2010 using ArcGIS Spatial Analyst's Raster Calculator tool.

Road Density
The U.S. Census Bureau's TIGER/Line Shapefiles (U.S. Census Bureau 2016b) were used to calculate the road density within the monument's AOA. The Feature Class Code values in the dataset were used to identify road types. According to NPScape's road density standard operating procedure (NPS 2014b), "highways were defined as interstates (FCC: A10-A19) or major roads (FCC: A20-A38, excluding ferry routes). New road density rasters, feature classes, and statistics were generated from these data. Finally, the road density output was overlaid with the composite viewshed from the three key observation locations in order to visualize density within the monument's viewshed.

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

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

Table 4.1.2-3. 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

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

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

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

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

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

Table 4.1.3-1. Reference conditions used to assess viewshed.

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 blended into the landscape.	The distance, size, color and shape, and movement and noise of some of the noncontributing features were conspicuous and detracted from the natural and cultural aspects of the landscape.	The distance, size, color and shape, and movement and noise of the noncontributing features dominated the landscape and significantly detracted from the natural and cultural aspects of the landscape.
	Extent of Development	Road and housing densities were low.	Road and housing densities were moderate, with minor intrusion on the viewshed.	Road and housing densities were high.
	Conservation Status	Scenic conservation status was high. The majority of land area in the monument's viewshed was considered GAP Status 1 or 2.	Scenic conservation status was moderate. The majority of land area in the monument's viewshed was considered GAP Status 3.	Scenic conservation status was low. The majority of land area in the monument's viewshed was considered GAP Status 4.

4.1.4. Condition and Trend

Conspicuousness of Non-contributing Features

The stitched GigPan images for two of the three locations are shown in Figures 4.1.4-1 and -2. From the North View vantage point, the stone retaining wall and gravel ground surface were visible in the foreground, but these non-contributing features were generally not conspicuous due to their low profile and color (Figure 4.1.4-1). However, a conspicuous social trail was visible in the foreground. Although the retaining wall discourages visitors from using the social trail, it occurs along a ridge line and at least some visitors are likely to cross the retaining wall and walk out to the ridge, which would further impact the viewshed. The viewshed includes the breaks in the foreground and middle ground, and the Ashdown Gorge Wilderness Area in the middle ground and background. Other areas of the Dixie National Forest not included in the wilderness area were also visible. In the national forest, an unpaved road was visible in the background, but was generally not conspicuous without binoculars. Both the National Oceanic and Atmospheric NEXRAD (Next Generation Weather Radar) system and Federal Aviation Administration's radar dome were visible to the south. Although these non-contributing features were distant, their shape and position above the tree line make them conspicuous. Cedar City was also visible in the background to the south but because of its distance, the city did not significantly detract from the total viewshed. Overall, the viewshed from this location was good.

At Point Supreme, a stone and log retaining wall was visible in the foreground, but this non-contributing feature did not detract from the viewshed, especially since its purpose is to protect visitors and prevent social trails (Figure 4.1.4 -2). Similar to North View, the viewshed included the breaks in the foreground and middle ground, and the Ashdown Gorge Wilderness Area and other parts of the Dixie National Forest in the middle ground and background. To the north and in the background just below Brian Head

Figure 4.1.4-1. The viewshed from North View Overlook in Cedar Breaks NM.

Figure 4.1.4-2. The viewshed from Point Supreme Overlook in Cedar Breaks NM.

Peak, a road was visible but was fairly inconspicuous given its distance. To the southwest, the Federal Aviation Administration's radar dome was also visible. This feature was fairly conspicuous given its shape, reflectivity, and height above the trees. As with the other locations, Cedar City, Utah was visible in the background but was generally inconspicuous given its distance. Overall, however, the viewshed from this location was good.

The viewshed analyses were consistent with the panoramic images. Figure 4.1.4-3 shows the area and extent that should be visible from each key observation location. In general, areas to the west northwest of the monument were visible at a distance of at least 97 km (60 mi). The viewshed in other directions was blocked except for parts of the foreground and some of the middle ground within the monument, but this was a result of natural landscape features. The analysis reveals that the North View Overlook has a narrow but distant viewshed. The viewshed at Chessman Ridge Overlook and Point Supreme were virtually identical except for a small visible area to the southwest at Chessman Ridge Overlook. Although the total viewshed for the monument was small it was in good condition. Few non-contributing features were present at the observation locations, and most of them were either too distant to be conspicuous or blended well with their surroundings. Therefore, we consider the condition for this measure to be good. Trend is unknown and confidence is high.

Extent of Development

The composite viewshed overlaid with housing density and road density is shown in blue in Figures 4.1.4-4 and 4.1.4-5, respectively. Based on data compiled in NPScape (Budde et al. 2009 and Monahan et al. 2012), housing densities surrounding the monument were low (Table 4.1.4-1). The majority of all housing consisted of private undeveloped lands (53%) and densities less than 1.5 units/km^2 (28%). The white spaces within this boundary indicate no census data; thus, housing densities could not be calculated for these areas. However, these data originated with the U.S. Census Bureau, and units with unknown densities were probably not reported, which likely indicates undeveloped areas. From 1970 to 2010, 41% of the AOA showed no change in housing density, while 58% of the AOA showed an increase in housing density. Only 1% of the AOA declined in housing density.

Total road density within the 97 km (60 mi) AOA surrounding the monument was 1.0 km/km^2. Figure 4.1.4-4 shows road density by various classes. Road density within the monument's viewshed was less dense than it was elsewhere in the AOA and was representative of a relatively rural landscape. Based on these results, the current condition for this measure is good. Trend is unchanging and confidence is medium since the data were modeled.

Conservation Status

Figure 4.1.4-6 shows the amount of land within the composite viewshed and AOA. Of the total AOA, 80% was categorized in one of the four GAP status classes. The majority (66%) of land area within the AOA was within GAP Status 3, or permanently protected lands managed for multiple uses (e.g., mining or logging). Only 11% of land within the AOA was GAP Status 1 (permanently protected lands managed for biodiversity and natural processes) or GAP Status 2 (permanently protected lands managed for biodiversity but with

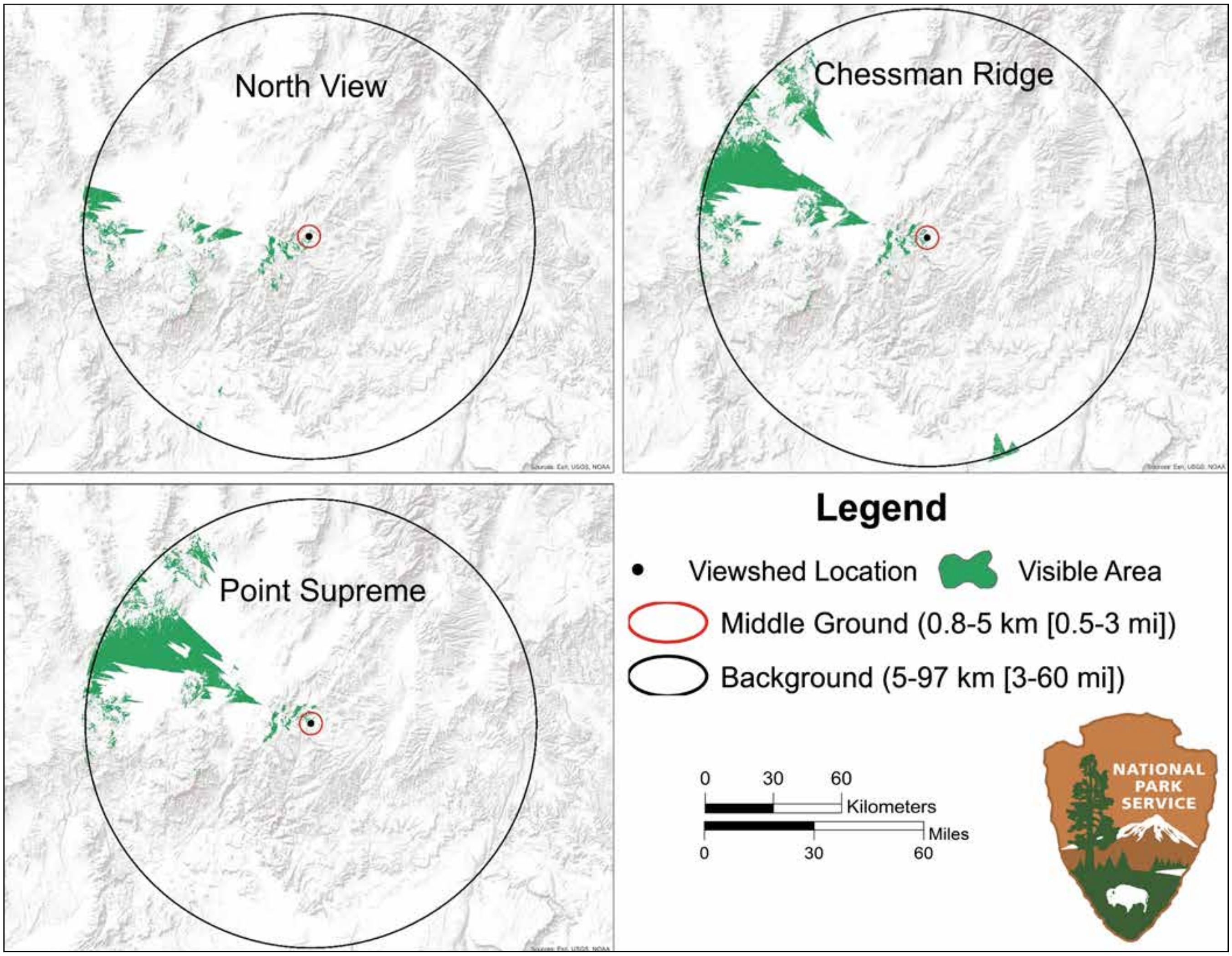


Figure 4.1.4-3. Visible areas from each of the three key observation locations in Cedar Breaks NM.

suppression of disturbances). Finally, only 3% of land was considered GAP status 4 (no known protections). The remaining 20% of land was not classified in any of the GAP status categories, which indicates private land.

Figure 4.1.4-7 shows the land management agencies that administer land within the AOA. The BLM administers the majority (46%) of land in the AOA, followed by the U.S. Forest Service (21%). Most of the remaining lands are managed by the State of Utah. Areas visible from the monument were located largely within private lands or GAP Status 3 lands, most of which are managed by the BLM.

While there were some areas where scenic conservation status was high (e.g., Ashdown Gorge Wilderness), many of the land management agencies responsible for the lands that were visible from Cedar Breaks NM's observation points allow for extractive uses or were private lands, therefore, we consider conservation status for to be of moderate concern. Trend is unknown and, since these results were based on modeled data, confidence is medium.

Overall Condition, Trend, Confidence Level, and Key Uncertainties

Based on this assessment, the viewshed condition at Cedar Breaks NM is good (Table 4.1.4-2). There were few non-contributing features in the monument's viewshed as observed from the three key observation locations, and those that were present blended relatively well with the natural landscape or were generally too distant to be conspicuous. The composite viewshed shown in blue in Figures 4.1.4-3 show that views to the south and east were blocked, but this was a result of natural features of the landscape. The housing and road density analyses

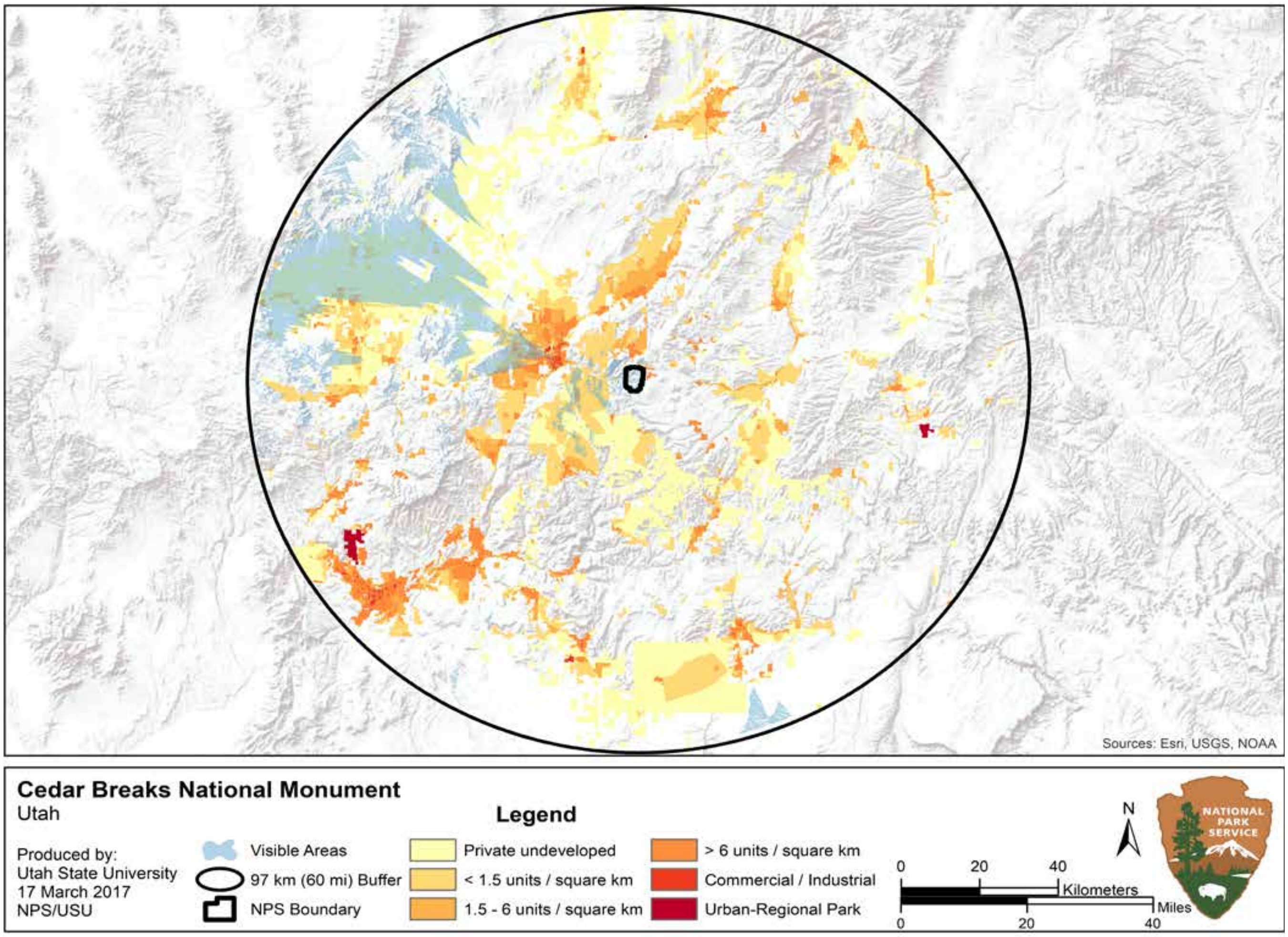


Figure 4.1.4-4. Housing density and visible areas in and around Cedar Breaks NM.

show that the region surrounding the monument was mostly rural. This assessment represents baseline condition for Cedar Breaks NM's viewshed; therefore, we could not report on trend. Two of the three measures were assigned medium confidence and one was assigned high confidence. Factors that influence confidence level include age of the data (<5 yrs unless the data were 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 extent of development and conservation status because they were based entirely on modeled data, whereas the conspicuousness of non-contributing features measure was supported by panoramic images collected in the field. The overall confidence is medium.

Key uncertainties include the resolution of the digital elevation model used to determine visible areas from each vantage point, which was 10 m (32.8 ft). Finer scale data would probably give a better indication of the areas visible. We also did not account for vegetation height in the viewshed analysis. While the GigaPan images supported the viewshed analysis, the consistency between the GigaPan images and the corresponding viewshed analysis was somewhat difficult to see in Figure 4.1.4-3 and would be best viewed digitally (e.g., using GIS) in order to determine the visibility of specific geographic features. The viewshed analysis should not be used for planning purposes until groundtruthed. Lastly, the USGS' GAP

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

Density Class	Area (km²)	Percent
Private Undeveloped	3844	53
< 1.5 units	2060	28
1.5 - 6 units	745	10
> 6 units	596	8
Commercial/Industrial	50	0.6
Urban-Regional Park	35	0.4
Total Area	7330	100

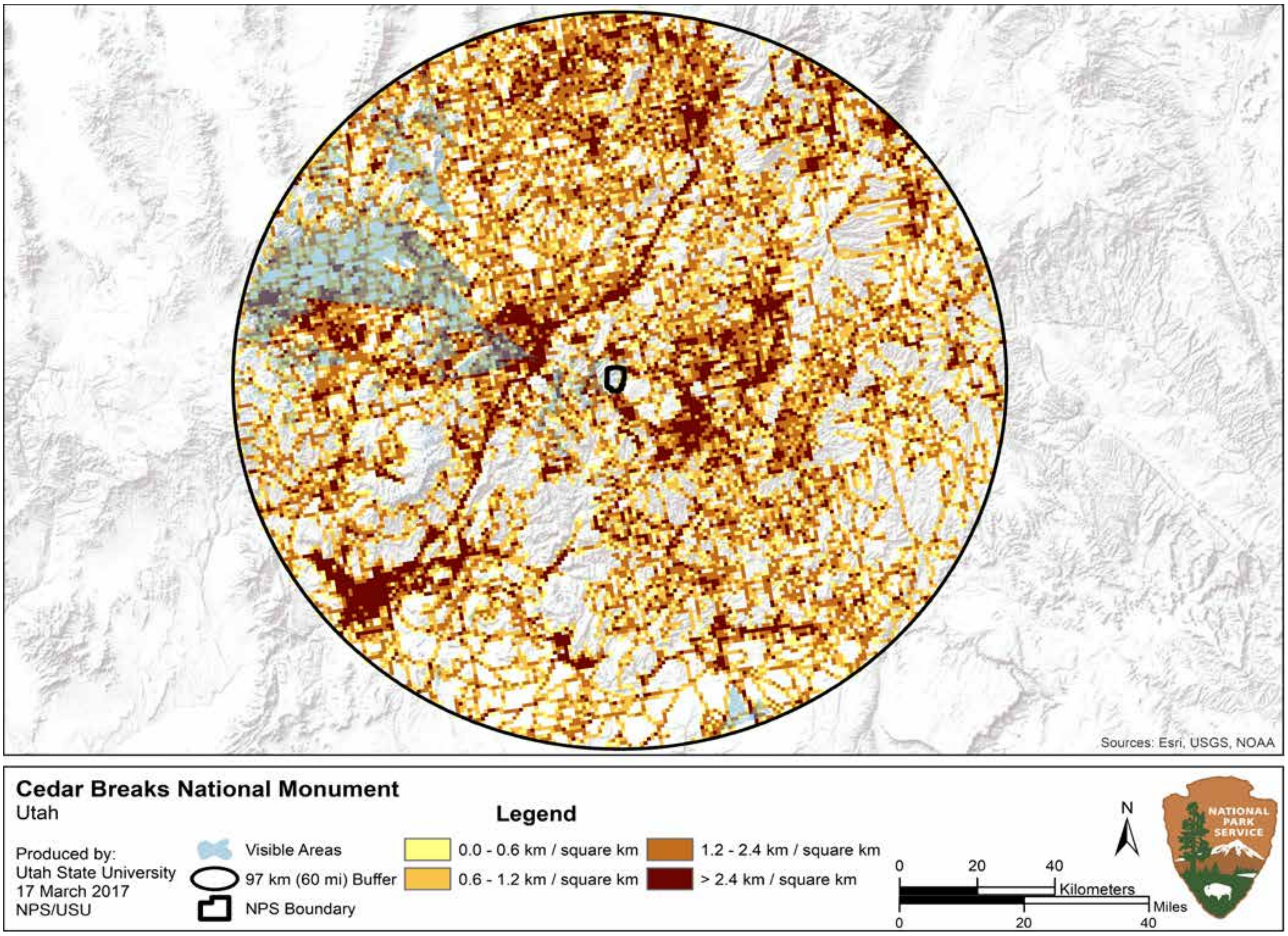


Figure 4.1.4-5. Road density and visible areas in and around Cedar Breaks NM.

Analysis Program's PAD contained many overlapping features (i.e., some land areas were counted more than once for multiple GAP Status categories and/or land management agencies). While most overlapping features were corrected prior to analysis, some features may have been missed due to the nature of the error (e.g., errors along boundaries or sliver errors).

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

Potential threats to Cedar Breaks NM's viewshed include development within the AOA; increased air, snowmobile, and vehicle traffic; increased visitation; and atmospheric dust and smog as a result of climate change. 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 was directly related to increased western settlement and livestock grazing during the 19th century (Neff et al. 2008). The air quality assessment revealed that this resource warrants moderate to significant concern at the monument. Of the seven measures used to assess air quality, four warranted moderate concern and three warranted significant concern. Factors that influence air quality may also influence the viewshed.

According to the housing density analysis, development within the monument's viewshed was expected to increase in only 15% of the AOA by 2100, but this was based on past development. The current U.S. Census Bureau data show that Utah is the fastest growing state in the nation (U.S. Census Bureau 2016a). However, current housing and road densities were relatively low, especially within the monument's viewshed. Although increased visitation could also impact viewshed to some extent, backcountry use is limited in the monument (NPS 2015a). The majority of visitors are concentrated along road corridors, at pullouts, visitor centers, and interpretive exhibits rather than dispersed across the backcountry. Overall, there are few potential threats to Cedar Breaks NM's viewshed.

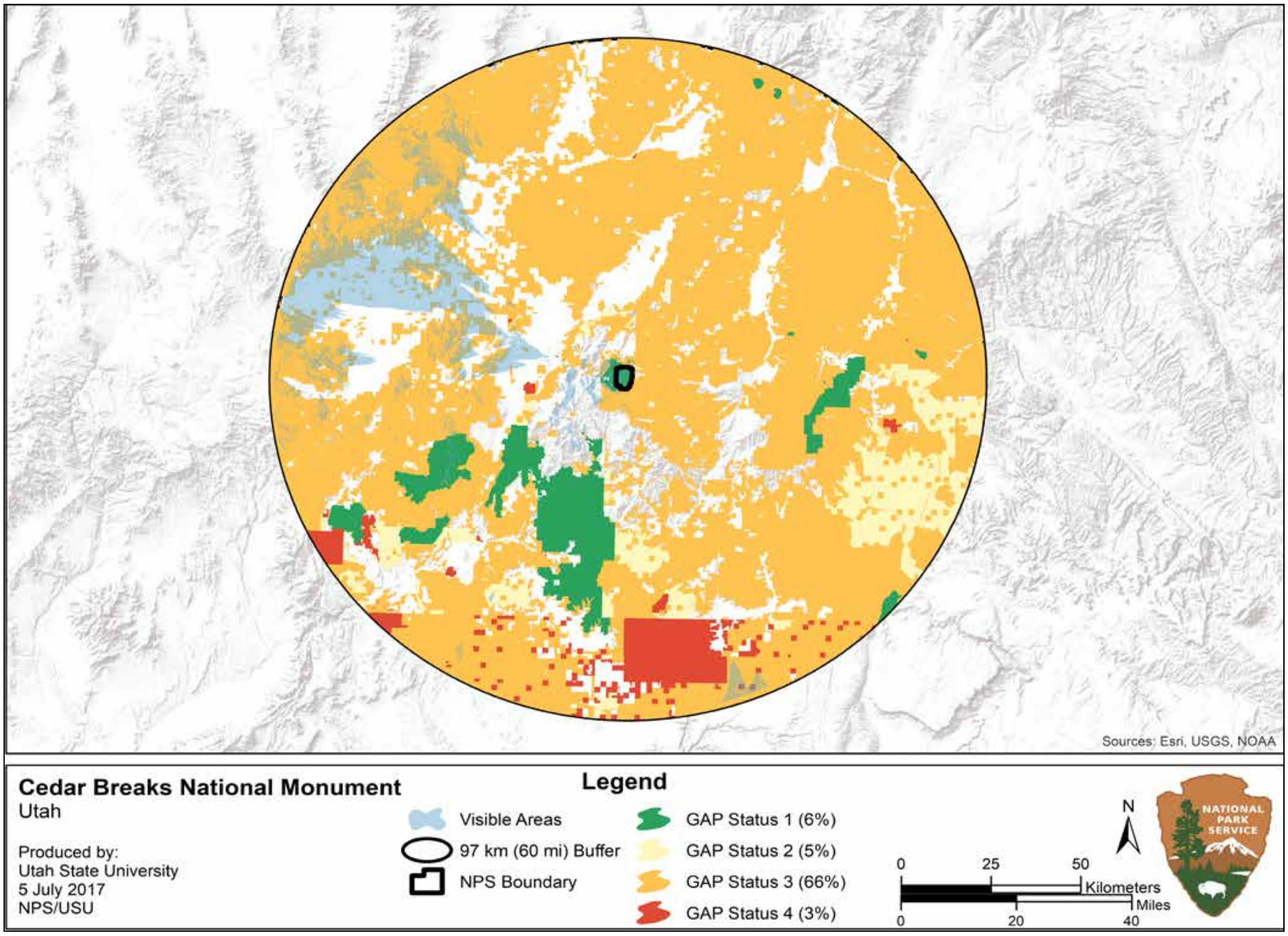


Figure 4.1.4-6. Land area within each of four GAP status classes in and around Cedar Breaks NM.

4.1.5. Sources of Expertise

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

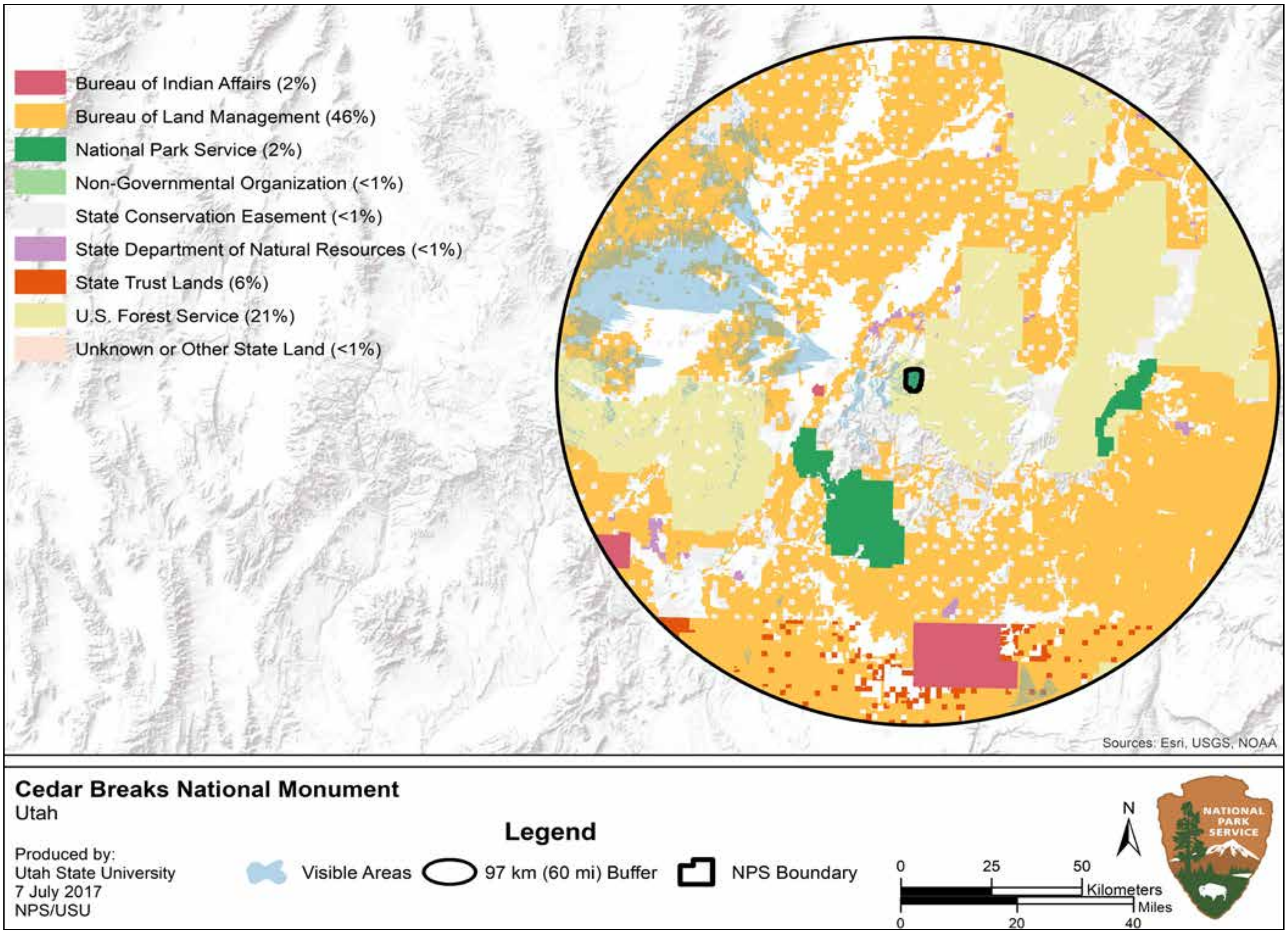
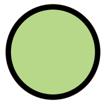
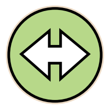
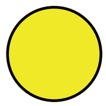
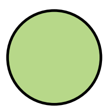


Figure 4.1.4-7. A map of lands managed by various agencies within and around Cedar Breaks NM.

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		There were few non-contributing features in the monument's viewshed as observed from the three key observation locations, and those that were present blended relatively well with the natural landscape or were too distant to be conspicuous. Non-contributing features included wood and stone fencing, a social trail, and roads. Cedar City, Utah was also visible in the background at the selected observation points. Trend is unknown and confidence is high.
	Extent of Development		The composite viewshed shows that areas to the west and north of the monument were most visible, while areas to the south and east were least visible. The majority of all housing consisted of private undeveloped lands (53%) and densities less than 1.5 units/km^2 (28%). Total road density (1.0 km/km^2) represented a rural landscape. Since 1970, 41% of the AOA increased in housing density while 58% remained unchanged. Based on these results, the condition for this measure is good. Trend is unchanging and confidence is medium.
	Conservation Status		While there were some areas where scenic conservation status was high, many of the land management agencies responsible for the lands that were visible from Cedar Breaks NM's observation points allow for extractive uses or were private lands, therefore, we consider conservation status for to be of moderate concern. Because these results were based on modeled data, confidence is medium. Trend is unknown.
Overall Condition			There were few non-contributing features in the monument's viewshed, and those that were visible were not conspicuous. The housing and road density analyses show that the region surrounding the park was mostly rural, but most of the landscape in the AOA was GAP Status 3 and open to future extractive uses that could alter the viewshed. Based on these results, the viewshed in Cedar Breaks NM is in good condition with an unknown trend. Confidence is medium.

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 2010b). Additionally, in an estimated 20 national parks, stargazing events are the most popular ranger-led program (NPS 2010b).

The value of night skies goes far beyond visitor experience and scenery (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.

The park is one of the best places in the region to experience dark night skies owing to its high elevation and relatively undeveloped regional setting (NPS 2015a). Throughout the year the monument hosts astronomy programs known as "star parties" in addition to other interpretive events that highlight the importance of dark night skies both within and around the monument (NPS 2016f). Monument staff also engage nearby communities and have formed partnerships with other agencies and organizations to protect and improve dark night skies surrounding the monument (NPS 2016f).

Figure 4.2.1-1. Milky Way during the summer from Point Supreme, Cedar Breaks NM. Photo Credit: NPS/Zach Schierl.

In 2017, the International Dark Sky Association (IDA) designated Cedar Breaks NM as a Dark Sky Park (IDA 2017). The IDA is a non-profit organization dedicated to protecting and preserving dark night skies throughout the world (IDA 2017). Criteria for becoming a Dark Sky Park are stringent and include a complete assessment of the night sky environment, retrofitting park lighting that is not in compliance with IDA standards, establishing or maintaining a night sky monitoring program, and working with nearby communities to protect the monument's nocturnal lightscape (IDA 2017).

4.2.2. Data and Methods

The NSNSD goals of measuring night sky brightness are to describe the quality of the lightscape, quantify how much it deviates from natural conditions, and how it changes with time due to changes in natural conditions, as well as artificial lighting in areas within and outside of national parks (Duriscoe et al. 2007). In this assessment, we characterize the night sky environment in Cedar Breaks 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. The Bortle Dark Sky Scale 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 Cedar Breaks NM's night sky condition at Brian Head Peak during 2003, 2004, and 2006 (Figure 4.2.2-1). Although Brian Head Peak is located outside the monument, the location's elevated viewshed allowed NSNSD staff an unobstructed view of the nocturnal lightscape that would otherwise have been blocked from within the monument. But it's important to note that Brian Head Peak is much closer to Brian Head Town, the closest source of skyglow (albeit small) to the monument, so conditions are going to be brighter than those within the monument proper.

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 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.

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. The zenith is generally considered the darkest part of pristine skies. 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 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.

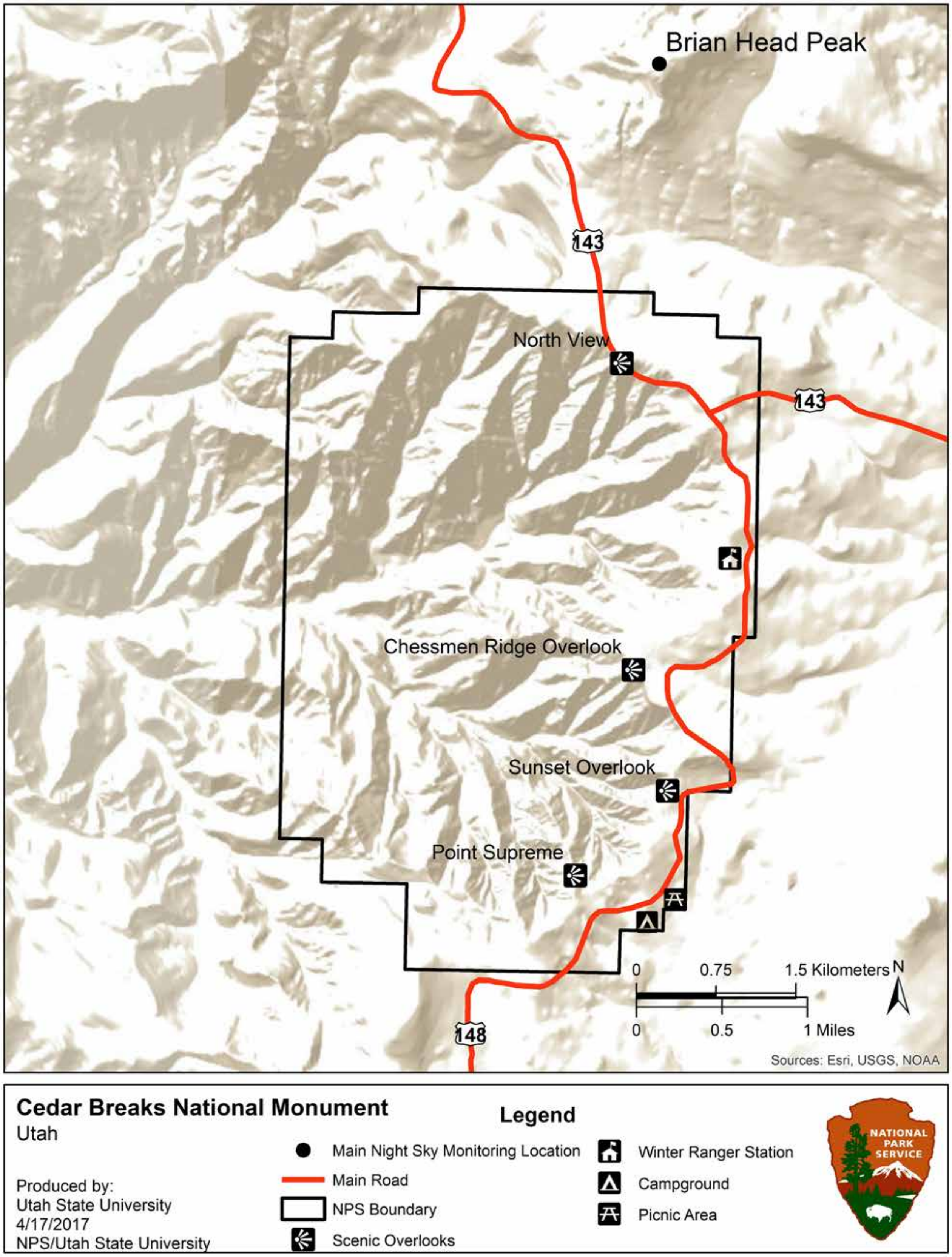


Figure 4.2.2-1. Location of the night sky monitoring site for Cedar Breaks NM.

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.

Maximum Vertical and Horizontal Illuminance

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

Zenith sky brightness describes the amount of light observed in the night sky overhead. 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 2016f). 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 (Figure 4.2.2-2). 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

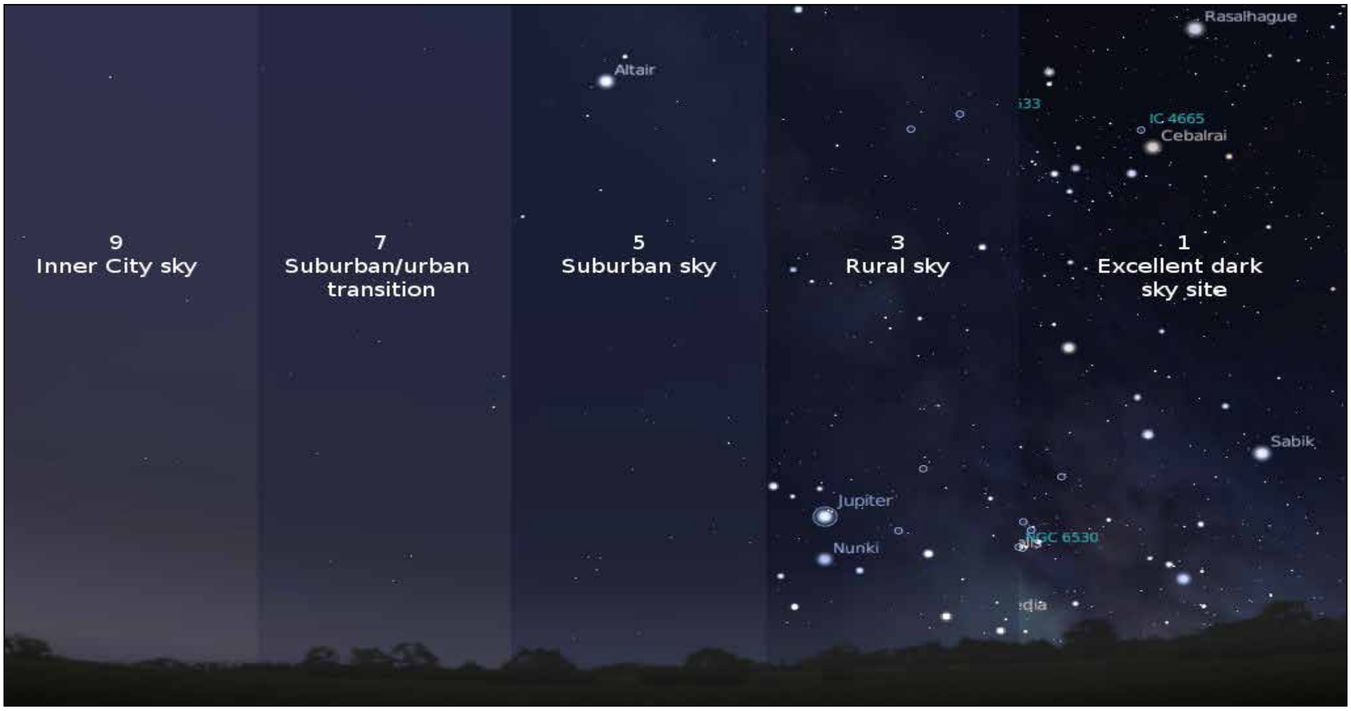


Figure 4.2.2-2. A graphic representation of the Bortle Dark Sky Scale (Bortle 2001). Figure Credit: NPS Natural Sounds and Night Skies Division.

suggest that a pristine night sky is very rare (NPS 2010b).

Cedar Breaks 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). The monument is also managed as wilderness. 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 wilderness and non-urban areas are generally more sensitive to the effects of light pollution.

<u>Anthropogenic Light Ratio (ALR)</u>

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).

<u>Maximum Vertical Illuminance</u>

Although no thresholds for maximum vertical illuminance have been set at this time, the NPS Night Skies Program recommends 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 expressed as a ratio to natural conditions, similar to ALR.

<u>Horizontal Illuminance</u>

As with maximum vertical illuminance, no thresholds for horizontal illuminance have been set at this time. The NPS Night Skies Program recommends 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.

<u>Zenith Sky Brightness</u>

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 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

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).

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).

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 10x; 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, Bortle Class 4 warrants moderate concern, and Bortle 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). Bortle 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 park-wide ALR of 0.32, a wilderness area ALR of 0.33, and a non-wilderness area ALR of 0.30 (Table 4.2.4-1). These values correspond to 30% to 33% brighter than average natural conditions. Figure 4.2.4-1 shows the modeled ALR for the region surrounding Cedar Breaks NM and the extent of the light domes cast by cities located in the region. The figure shows that the park is most influenced by lights from Cedar City, Utah 23 km (14 mi) to the west and Saint George, Utah 94 km (58 mi) to the southwest as well as the smaller communities of Brian Head Town 2 km north (1 mi), Enoch City 21 km (13 mi) northwest, and Parowan City 17 km (11 mi) north.

Ground-based ALRs varied from 0.24 to 0.47, which corresponds to a range of 24% to 47% brighter than average natural conditions (Table 4.2.4-1). Figures 4.2.4-2, -3, -4, and -5 show the anthropogenic light sources for each monitoring date. 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. Two of the four ground-based measurements, the modeled park-wide ALR, and the non-wilderness ALR are considered good; however, the modeled wilderness ALR and the remaining two ground-based measurements warrant moderate concern. Although these latter values were at the low end of the range warranting moderate concern, we consider this measure of night sky brightness to be divided between good condition and moderate concern. Confidence in this condition rating is medium since the most recent data were collected in 2006. Trend could not be determined based on these data.

Maximum Vertical Illuminance (milli-Lux)

Observed maximum vertical illuminance ranged from 0.85 to 1.04 milli-Lux (Table 4.2.4-1). After subtracting out the natural components specific to those measurements, the corresponding LPR is 77% and 100% brighter than average natural conditions,

Table 4.2.4-1. Night sky measurements collected at Brian Head Peak in Cedar Breaks 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
Park-wide	0.32	–	–	–	–
Wilderness	0.33	–	–	–	–
Non-Wilderness	0.30	–	–	–	–
26 September 2003	0.38	1.04	1.33	21.27	3
9 August 2004	0.24	0.67	0.85	21.47	–
12 September 2004	0.28	1.02	1.22	21.09	–
17 August 2006	0.47	0.85	0.93	21.42	–

Note: Park-wide, wilderness, and non-wilderness ALR values were modeled using the 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).

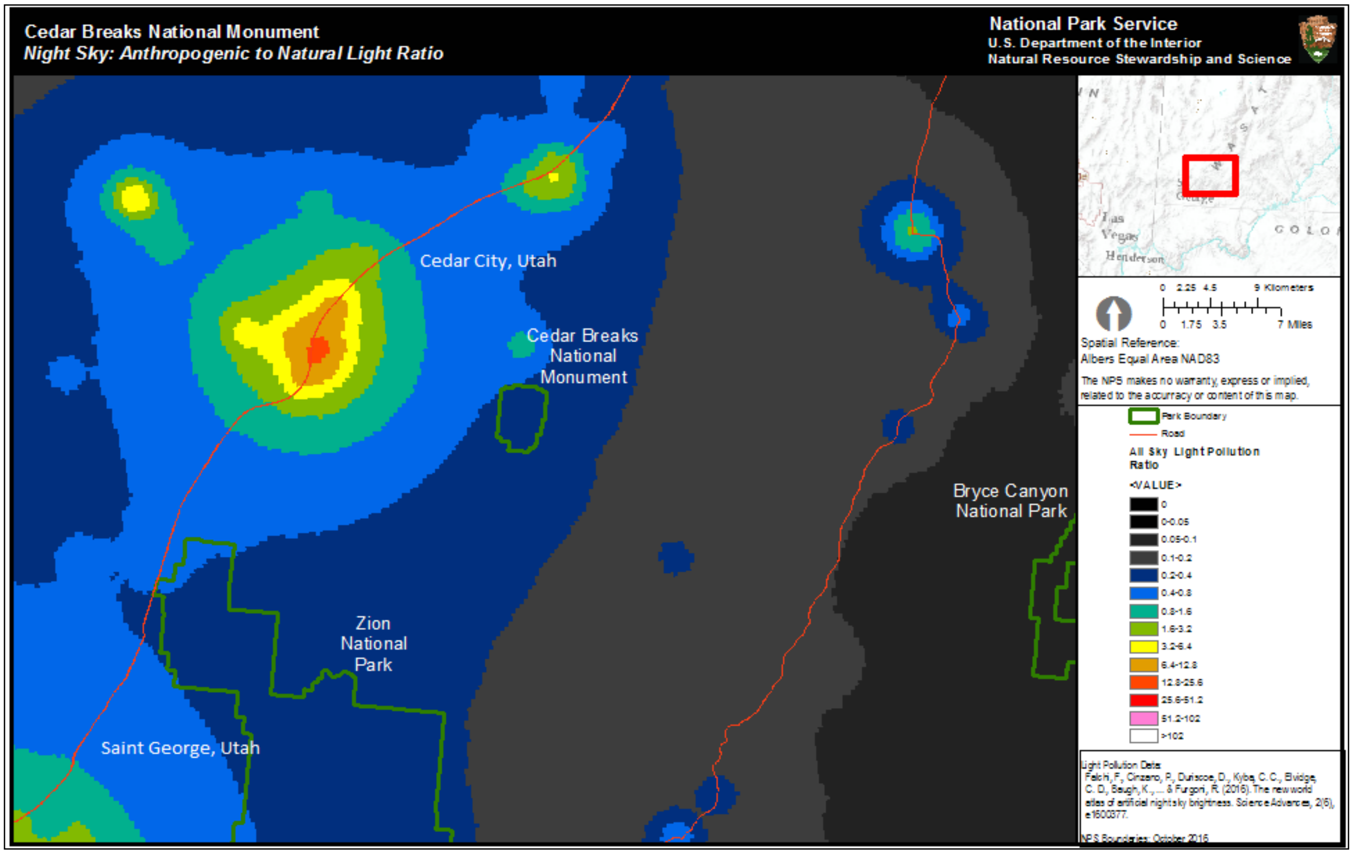


Figure 4.2.4-1. Modeled ALR map for Cedar Breaks NM. Figure Credit: NPS Natural Sounds and Night Skies Division.

respectively. All four measurements exceeded the NPS Night Skies Program 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 conditions. We could not determine trend based on these data, although Cedar City, UT and St. George, UT have grown a lot since 2006. Cedar Breaks NM is surrounded by some of the fastest growing cities/counties in the country.

<u>Horizontal Illuminance (milli-Lux)</u>

Observed horizontal illuminance ranged from 0.93 to 1.33 milli-Lux (Table 4.2.4-1). After subtracting out the natural components specific to those measurements, the corresponding LPR for these values is 22% and 29% brighter than average natural conditions. The NPS Night Skies Program recommends a threshold of

0.8 milli-Lux, which was exceeded on all 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. Confidence is low due to lack of reference conditions. We could not determine trend based on these data.

Zenith Sky Brightness (msa)

Zenith sky brightness varied from 21.09 to 21.47 msa. The corresponding LPRs for these values are 41% and 34% brighter than average natural conditions. Three values warrant moderate concern and one value warrants significant concern. The overall condition for this measure of sky brightness warrants moderate concern. We assigned medium confidence to this condition rating since data were collected more than 10 years ago; however since June 2016, park staff have also collected zenith sky brightness measurements using an IDA-approved Unihedron Sky Quality Meter (SQM) (Table 4.2.4-2). Using the same condition class thresholds displayed in Table 4.2.3-1, the SQM data indicate good condition to moderate concern for this measure of sky brightness. While these data seem to indicate improving conditions in zenith sky brightness, the data are not directly comparable to the values produced by the NSNSD. The NSNSD observed zenith sky brightness is computed based on the CCD image pixels that are within one degree-diameter circle centered on the zenith whereas a SQM has a wider field of view (NPS 2017b). Nevertheless, these data provide a useful way to monitor the night sky over time. We could not determine trend based on these data.

Bortle Dark Sky Class

NPS Night Skies Program observers estimated the night sky quality to Bortle Class 3 on 26 September 2003. Bortle Class 3 corresponds to a rural sky. The Bortle Class designation is somewhat subjective depending on the observer, and from Brian Head Peak, the town of Brian Head is in direct view. In particular, visual observations from this location were likely to be affected by glare from light sources within Brian Head. From Cedar Breaks NM proper, some skyglow from Brian Head Town is likely visible, but no direct glare/light is visible (Z. Schierl, Education Specialist & Dark Skies Coordinator, pers. comm.).

A Bortle Class 1-3 is considered good. We assigned medium confidence to this condition rating since this measure is subjective and observer-dependent. We could not determine trend based on one data point.

Overall Condition, Trend, Confidence, and Key Uncertainties

Overall, the night sky condition at Cedar Breaks NM is divided between good and warranting moderate concern. A summary of the condition and rationale is in Table 4.2.4-3. ALR values were split between good condition and warranting moderate concern, while the single Bortle Sky Class indicates good condition. However, three of the four zenith sky brightness values collected by the NSNSD warrant moderate concern as do a majority of the more recent SQM values. Confidence in the condition rating is medium since a majority of the data was collected more than five years ago. Overall trend could not be determined.

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,

Table 4.2.4-2. Unihedron sky quality meter measurements collected Cedar Breaks NM.

Date	Location	Observed Zenith Sky Brightness (SQM)
6/24/2016	Point Supreme	21.67
6/25/2016	Point Supreme	21.79
7/2/2016	Point Supreme	21.81
7/23/2016	Point Supreme	21.69
9/26/2016	Chessman Ridge	21.52
9/26/2016	North View	21.46
9/26/2016	Picnic Area/Campground	21.54
9/26/2016	Sunset Overlook	21.50
9/26/2016	UT 143, Monument East Boundary	21.49
9/26/2016	UT 143, Monument North Boundary/Brian Head Peak Turnoff	21.46
9/26/2016	UT 148, South Monument Boundary	21.51
9/26/2016	Visitor Center/Point Supreme	21.49
9/26/2016	Winter Ranger Station (Yurt)	21.47
11/2/2016	Point Supreme	21.32

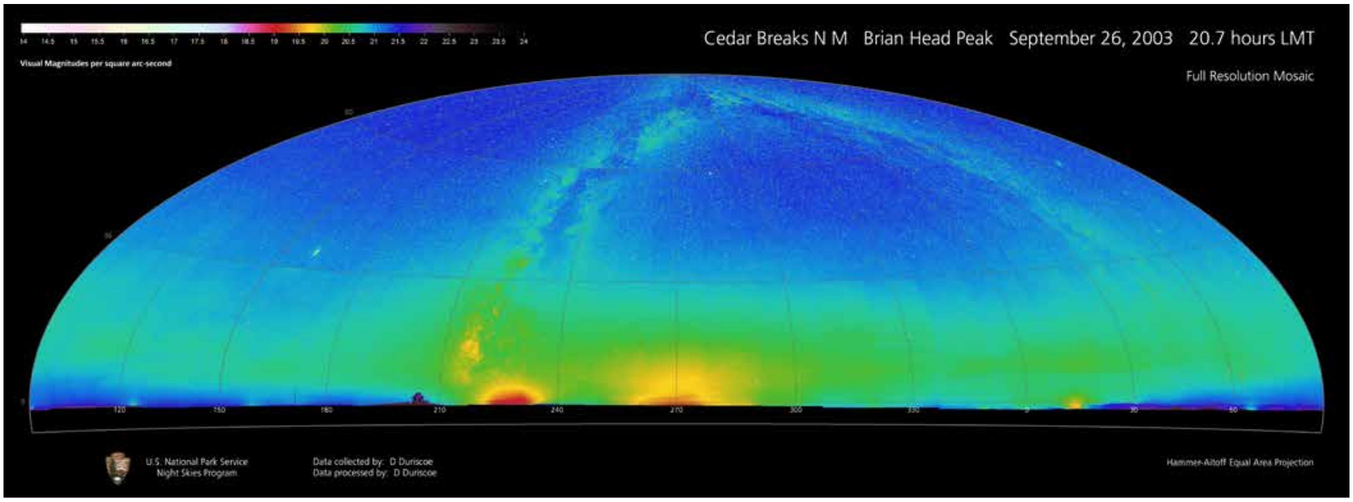


Figure 4.2.4-2. Panoramic all-sky mosaic of all light sources on 26 September 2003 at Brian Head Peak. Light sources include natural and anthropogenic. Figure Credit: NPS Natural Sounds and Night Skies Division.

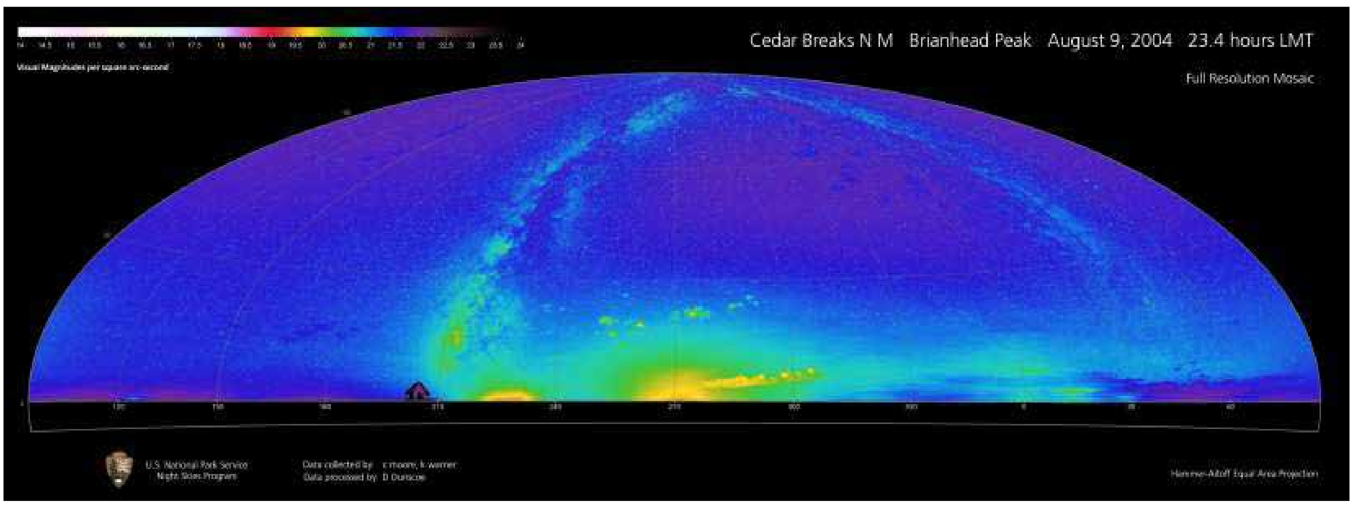


Figure 4.2.4-3. Panoramic all-sky mosaic of all light sources on 9 August 2004 at Brian Head Peak. Light sources include natural and anthropogenic. Figure Credit: NPS Natural Sounds and Night Skies Division.

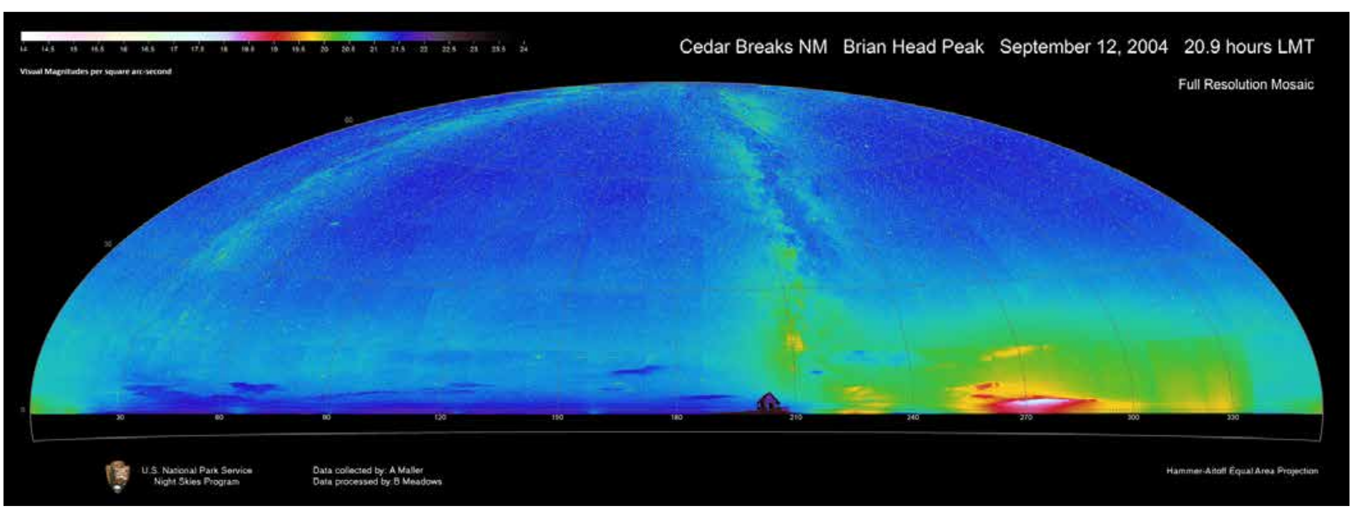


Figure 4.2.4-4. Panoramic all-sky mosaic of all light sources on 12 September 2004 at Brian Head Peak. Light sources include natural and anthropogenic. Figure Credit: NPS Natural Sounds and Night Skies Division.

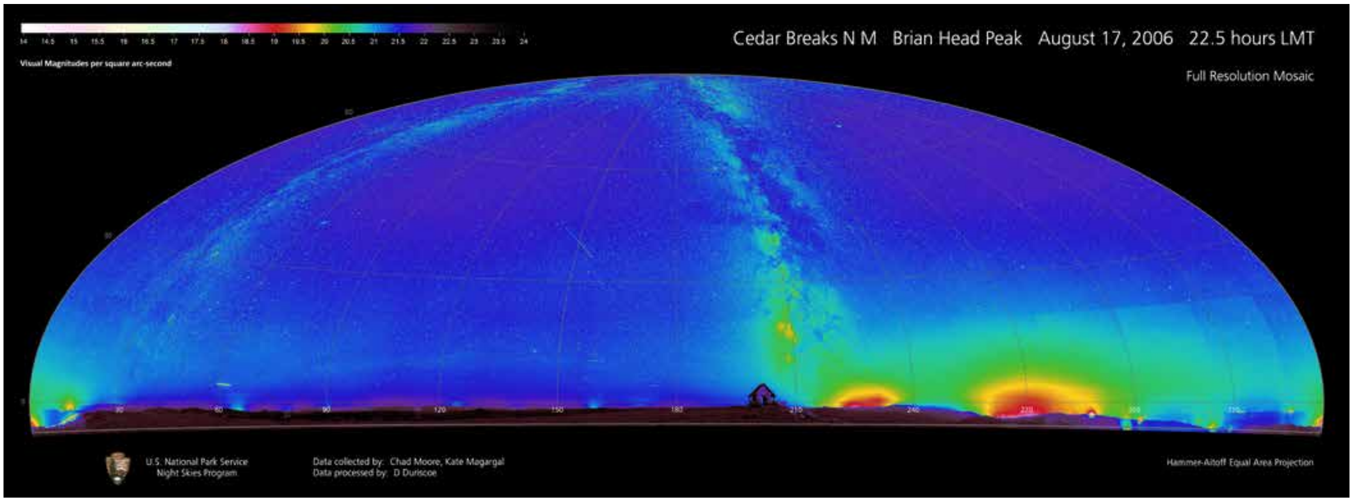


Figure 4.2.4-5. Panoramic all-sky mosaic of all light sources on 13 September 2004 at Brian Head Peak. Light sources include natural and anthropogenic. Figure Credit: NPS Natural Sounds and Night Skies Division.

field data vs. modeled data, and whether data can be extrapolated to other areas in the monument.

Regional and Local Context

Although some measures warrant moderate concern, Cedar Breaks NM still preserves a dark night sky rarely found elsewhere. Furthermore, park staff are committed to long-term monitoring of night skies, outreach (e.g., working with city council members and planners to promote night-sky friendly lighting), and education programs that highlight the monument's nocturnal landscape (NPS 2015a).

Cedar Breaks NM lies along the western edge of the Colorado Plateau and is within the Colorado Plateau Dark Sky Cooperative (CPDSC)— the first effort to protect dark night skies across a large region (CPDSC 2017). There are 17 national parks, state parks, and communities on the Colorado Plateau that have been designated as International Dark Sky Parks or Dark Sky Places, including Cedar Breaks NM (CPDSC 2017). The low population density of the region coupled with good air quality and large amount of public lands makes the Colorado Plateau an ideal place for promoting the importance of dark night skies.

Threats, Issues, and Data Gaps

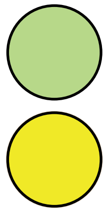
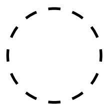
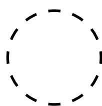
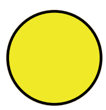
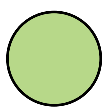
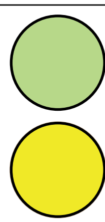
Although population density in Utah is relatively low, it is the fastest growing state in the U.S. (U.S. Census Bureau 2016a). As a result of increased population growth, there has been an overall increase in outdoor lighting in local communities and regional cities (NPS 2014). Additional threats include the transport of air pollutants and nighttime air traffic. Although the park has little control over regional air and light pollution, the park is committed to developing partnerships with nearby communities to implement energy conservation strategies that will minimize light pollution within the park (NPS 2016f).

4.2.5. Sources of Expertise

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

Sharolyn Anderson, Li-Wei Hung, and Bob Meadows, 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.

Table 4.2.4-3. 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)		Modeled park-wide ALR was 0.32, wilderness area ALR was 0.33, and non-wilderness area ALR was 0.30. Ground based ALRs varied from 0.24 to 0.47. Most values were considered good; however, the modeled wilderness ALR and two ground-based measurements warrant moderate concern. Confidence in this condition rating is moderate since the last monitoring date was more than ten years ago (i.e., 2006). Trend could not be determined.
	Vertical Maximum Illuminance (milli-Lux)		Observed maximum vertical illuminance ranged from 0.85 to 1.04 milli-Lux. The corresponding LPR was estimated as 77% to 100% brighter than average natural conditions for these two values. All four measurements exceeded the NPS Night Skies Program recommendation of 0.4 milli-Lux, however, since there are no established thresholds, we did not assign a condition for this measure. Confidence is low due to lack of reference conditions. We could not determine trend based on these data.
	Horizontal Illuminance (milli-Lux)		Observed horizontal illuminance ranged from 0.85 to 1.33 milli-Lux. The corresponding LPR ranged from 22% to 29% brighter than average natural conditions for these two values. The NPS Night Skies Program recommends a threshold of 0.8 milli-Lux, which was exceeded on all monitoring dates. However, there are no established thresholds. Confidence is low due to lack of reference conditions. We could not determine trend based on these data.
	Zenith Sky Brightness (msa)		Zenith sky brightness varied from 21.09 to 21.47 msa in 2004. The majority of more recent SQM measurements indicate moderate concern. Based on these data this measure of illuminance warrants moderate concern. We assigned medium confidence to this condition rating since data were collected more than ten years ago. We could not determine trend based on these data.
Sky Quality	Bortle Dark Sky Class		NPS Night Skies Program observers estimated the night sky quality to class 3 on 26 September 2003. Bortle Class 3 corresponds to a rural sky. The Bortle class designation is somewhat subjective depending on the observer. A Bortle Class 1-3 is considered good. We assigned medium confidence to this condition rating since this measure is subjective and observer-dependent. We could not determine trend based on one data point.
Overall Condition			Overall, the night sky at Cedar Breaks NM is divided between good condition and warranting moderate concern. ALR values were split between good condition and warranting moderate concern, while the single Bortle Sky Class indicates good condition. However, three of the four zenith sky brightness values collected by the NSNSD warrant moderate concern as do a majority of the more recent SQM values. Confidence in the condition rating is medium since a majority of the data were collected more than five years ago. Overall trend could not be determined.

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, the 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 are distinct in the same way that resource conditions and visitor experiences are distinct (NPS Management Policies 2006 § 2.2 and § 5.2). 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

Figure 4.3.1-1. The acoustic environment at Cedar Breaks NM is an important part of the visitor experience and ecosystem health. Photo Credit: NPS.

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 and Popper 2007, Kaseloo 2006). Researchers have also documented wildlife avoidance behaviors due to increased noise levels (McLaughlin and Kunc 2013, Shannon et al. 2015). 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).

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 Cedar Breaks NM were collected by the NPS Natural Sounds and Night Skies Division (NSNSD) in 2012. Acoustical monitoring systems were deployed two times (i.e., seasons) at two locations within the national monument, both within the front-country (Figure 4.3.2-1). The first sampling time period was in winter (February to March or April), and the second period was in summer (July to August; Table 4.3.2-1). Some characteristics of the Alpine Pond Trail monitoring site and the Ramparts Overlook monitoring site are summarized in Table 4.3.2-1. At least one back-country site was also planned for sampling, but the monitoring team was unable to safely access the site during the study period (Emma Brown, Acoustical Resource Specialist, NPS NSNSD, pers. comm.).

The Alpine Pond Trail site is along the Alpine Pond Trail, a two-mile, double-loop trail through forest and meadows on the eastern side of the monument; the lower trail offers views of the “breaks.” The Ramparts Overlook site is in the southern portion of the monument along Ramparts Trail. This trail is up to four miles round-trip and follows the rim. While similar types of sounds can be heard at these two locations, including people, traffic, wildlife, etc., it is generally windier along the rim, which helps mask anthropogenic noise (P. Roelandt and B. Larsen,

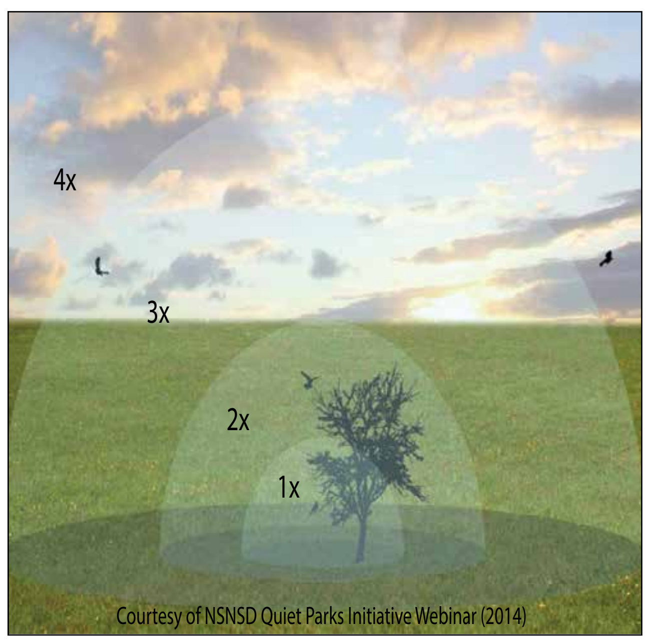


Figure 4.3.1-2. A 6 dB reduction in background noise level would produce a 4x increase in listening area. Figure Credit: © Ted E. Dunn.

Table 4.3.2-1. Location characteristics of acoustical monitoring sites at Cedar Breaks NM.

Location	Dates Deployed in 2012	Vegetation	Elevation
Site 1: Alpine Pond Trail	2-22 to 3/22; 7-10 to 8-7	Temperate Coniferous Forest	3,222 m (10,571 ft)
Site 2: Ramparts Overlook	2-3 to 4-8; 7-10 to 8-7	Temperate Coniferous Forest	3,010 m (9,875 ft)

Superintendent and Resource Manager, pers. comm. during NRCA workshop).

The purpose of the 2012 baseline soundscape inventory was to provide information during the development of a comprehensive approach to soundscape management planning, as well as during the development of other plans (e.g., Wilderness Management Plan) and noise impact assessments (NPS-NSNSD 2012). Results of the baseline monitoring were presented in an Acoustical Monitoring Snapshot for the monument (i.e., NPS-NSNSD 2012); a full report, containing sound source identification, an estimate of the natural ambient condition, and a summary of attended listening sessions, was not produced (Emma Brown, Acoustical Resource Specialist, NSNSD, pers. comm.). Information contained in the report was used to assess the first indicator in this assessment, sound level.

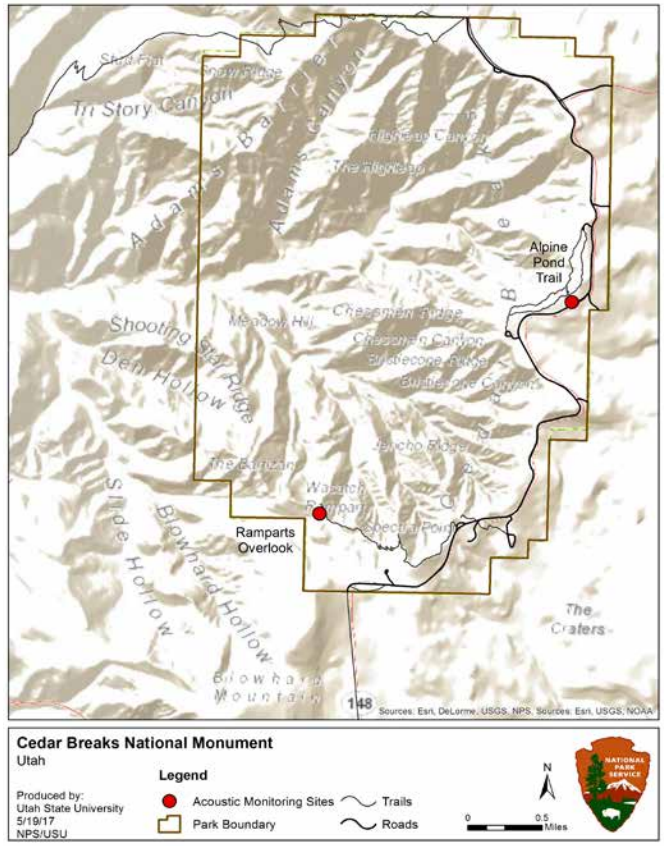


Figure 4.3.2-1. Locations of 2012 acoustical monitoring sites.

<u>% Time Above Reference Sound Levels</u>

The percent time above reference sound levels is a measure of the amount of time that the sound level exceeds specified decibel values (NPS -NSNSD 2012). Human responses to sound levels can serve as a proxy for potential impacts to 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 U.S. 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 monument would likely be conducting such conversations. The NSNSD determined the percent of time sound levels were above these four reference levels for both day (7:00 am to 7:00 pm) and night (7:00 pm to 7:00 am) during both winter and summer at the two sites within Cedar Breaks NM (NPS-NSNSD 2012).

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

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-NSNSD (2012).

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 other vertebrates because humans have more sensitive hearing at low frequencies than most species (Dooling and Popper 2007).

% 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.

For this measure, we set out to calculate the percent reduction in listening area from the natural ambient sound level for each monitoring location using data provided by NPS-NSNSD (2012). The natural ambient sound level refers to all naturally occurring sounds and excludes all anthropogenic noise; it is an estimate of the L_{50} that would occur in the absence of human caused noise (NPS-NSNSD 2014b). L_{50} refers to the level of sound exceeded fifty percent of the time at a given location. Note, however, that the natural ambient sound level was not available for the 2012 monitoring from NPS-NSNSD (2012). Therefore, we used the existing ambient L_{90} level as the natural ambient level, which is an acceptable practice (Acoustical Society of America [ASA] 2009, Ambrose and Florian 2006). The L_{90} value refers to the level of sound exceeded 90% of the time at a given location; it is an estimate of the background against which individual sounds are heard (NPS-NSNSD 2014b). We calculated reduction in listening area by determining the difference between the L_{50} and L_{90} values, and using a formula provided by NPS-NSNSD to calculate the reduction in listening area.

Existing ambient conditions include all sounds in a given area, natural and anthropogenic. NPS-NSNSD (2012) reported data for both day (7:00 am to 7:00 pm) and night (7:00 pm to 7:00 am) for two seasons, and we calculated reduction in listening area for both daytime and nighttime sound levels in both seasons (separately).

L_{50} Impact

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 m (886 ft) 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 4.3.3-1 (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. Of the organisms studied in Shannon et al. 2015, wildlife responses were observed at noise levels as low as 40 dBA. An additional 20% of studies documented impacts at sound levels below 50 dBA. If sound levels were above that which is expected to cause speech interference for interpretive programs (52 dBA), we considered the condition to warrant significant concern. According to the Shannon et al. (2015) literature review, a number of biological responses were observed in birds at sound levels greater than 52 dBA; these included changes in frequency components and timing of vocalizations, and an increase in the amplitude of vocalizations. With even higher sound levels, there have been reports of increases in vigilance and alert behavior, and reduced breeding success.

<u>% Reduction in Listening Area</u>

Cedar Breaks NM is considered a non-urban park, or a park with at least 90% of its land located outside an urban area. Parks outside of urban areas 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% or less would indicate good condition, while a more than 50% reduction in listening area would warrant significant concern (Turina et al. 2013; see Table 4.3.3-1). To arrive at these listening area reductions, we used the corresponding differences between the existing ambient L_{50} and L_{90} sound levels (with the L_{90} representing the natural ambient sound level). The

Table 4.3.3-1. Reference conditions used to assess the sound levels at Cedar Breaks 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 [1]	Listening area was reduced by ≤ 30% over natural ambient sound levels. (Difference between L_{50} & L_{nat} is ≤ 1.5) [2]	Listening area was reduced by 30-50% over natural ambient sound levels. (Difference between L_{50} & L_{nat} is >1.5 and ≤ 3.0) [2]	Listening area was reduced by >50% over natural ambient sound levels. (Difference between L_{50} & L_{nat} is >3.0) [2]
Geospatial Model	L_{50} Impact[1] (Mean L_{50} impact [dBA])	≤ 1.5 *Listening area reduced by ≤30%*	>1.5 and ≤ 3.0 *Listening area reduced by 30-50%*	>3.0 *Listening area reduced by > 50%*

[1] 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).

[2] When the L_{nat} sound level is not available, the L_{90} may be used in its place to represent the natural ambient sound level (ASA 2009).

difference is referred to as the impact, and the impact values were also based on Turina et al. (2013).

L_{50} Impact (Mennitt et al. 2013)
Reference conditions for this measure were developed by Turina et al. (2013) and are presented in Table 4.3.3-1. 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

% Time Above Reference Sound Levels
Figures 4.3.4-1 and 4.3.4-2 show the percent time sound levels were above the reference sound levels at the two monitoring locations during daytime (7 a.m. - 7 p.m.) and nighttime (7 p.m. - 7 a.m.) hours during summer and winter, respectively.

During the daytime in the summer, sound levels mainly exceeded the 35 dBA metric, with 15.4 to 42.7% of daytime hours above this level (at Ramparts Overlook and Alpine Pond Trail, respectively; Figure 4.3.4-1). Sound levels exceeded the 45 dBA metric 2.1 to 16.4% of the daytime hours, once again with the Alpine Pond Trail site experiencing the highest percent time above the reference level. Sound levels were relatively lower at night, with the 35 dBA metric exceeded 7.4 to 9.5% of the time. Sound levels exceeded the 45 dBA metric at night only 0.2 to 2.3% of the time. Sound levels at the sites rarely exceeded 52 or 60 dBA during day or night during the summer, with the greatest exceedance occurring at Alpine Pond Trail, with the 52 dBA level being exceeded 6.3% of the daytime. For the 35, 45, and 52 dBA levels, especially during the daytime, percent time above the levels was greater at Alpine Pond Trail than at Ramparts Overlook.

In summary, during both day and night, sound levels were below the 45 dBA metric (World Health Organization's recommendation for maximum noise level in bedrooms) the majority of the time in the summer at both monitoring sites. Therefore, based on our reference conditions, we considered this measure to be in good condition for the summer season. Confidence in this condition rating is high. No information on trends is available, so we consider trend for the summer season unknown.

The same measurements at Cedar Breaks NM during the winter showed some differences. Again, it was primarily the 35 dBA metric that was exceeded, both during the daytime (30.1-31.0% of the day) and nighttime (both at 40.2% of the night; Figure 4.3.4-2). As compared to the summer, however, in winter, the two sites had very similar % time above values, and values were somewhat higher at night than during the day.

In winter, sound levels exceeded the 45 dBA metric 4.1 to 6.0% of the daytime hours and 6.6 to 10.5% of the nighttime hours. Similar to the summer season, in the winter sound levels at the sites rarely exceeded 52 or 60 dBA during day or night, with the greatest percent time above the metrics occurring at Alpine Pond Trail during the night (with the 52 dBA level being exceeded 2.1% of the time).

During the winter, during both day and night, sound levels were below the 45 dBA metric the majority of the time at both monitoring sites. Therefore, based on our reference conditions, we considered this measure for the winter season to be in good condition. Confidence in this condition rating is high. No information on trends is available, so we consider trend for the winter season unknown.

Overall Summary for % Time Above Reference Sound Levels
As discussed in the preceding paragraphs, condition was good under this measure for each season individually; therefore, we consider the overall condition under this measure to be good. It should be noted, however, that the 45 dBA metric was exceeded to some extent, particularly at Alpine Pond Trail- 16.4% of the daytime during the summer, and 10.5% of the nighttime during the winter. The 52 dBA metric (speech interference threshold for speaking in a raised voice to an audience at 10 meters [32.8 feet; USEPA 1974]) was exceeded as much as 6.3% of summer daytime hours at Alpine Pond Trail. Again, we considered confidence as high for this measure, which was based on data collected by the NSNSD, but it is worth noting that the data are now approximately five years old. Overall trends for the measure are unknown.

It is also worth noting that the percent time above values provided here are for the full 12.5 - 20,000 Hz (frequency) range. The 20-1250 Hz subset of the frequency range is also available from NPS-NSNSD (2012). Transportation noises are often a major contributor of low frequency sounds (20-1250 Hz). The low-frequency range excludes higher-frequency

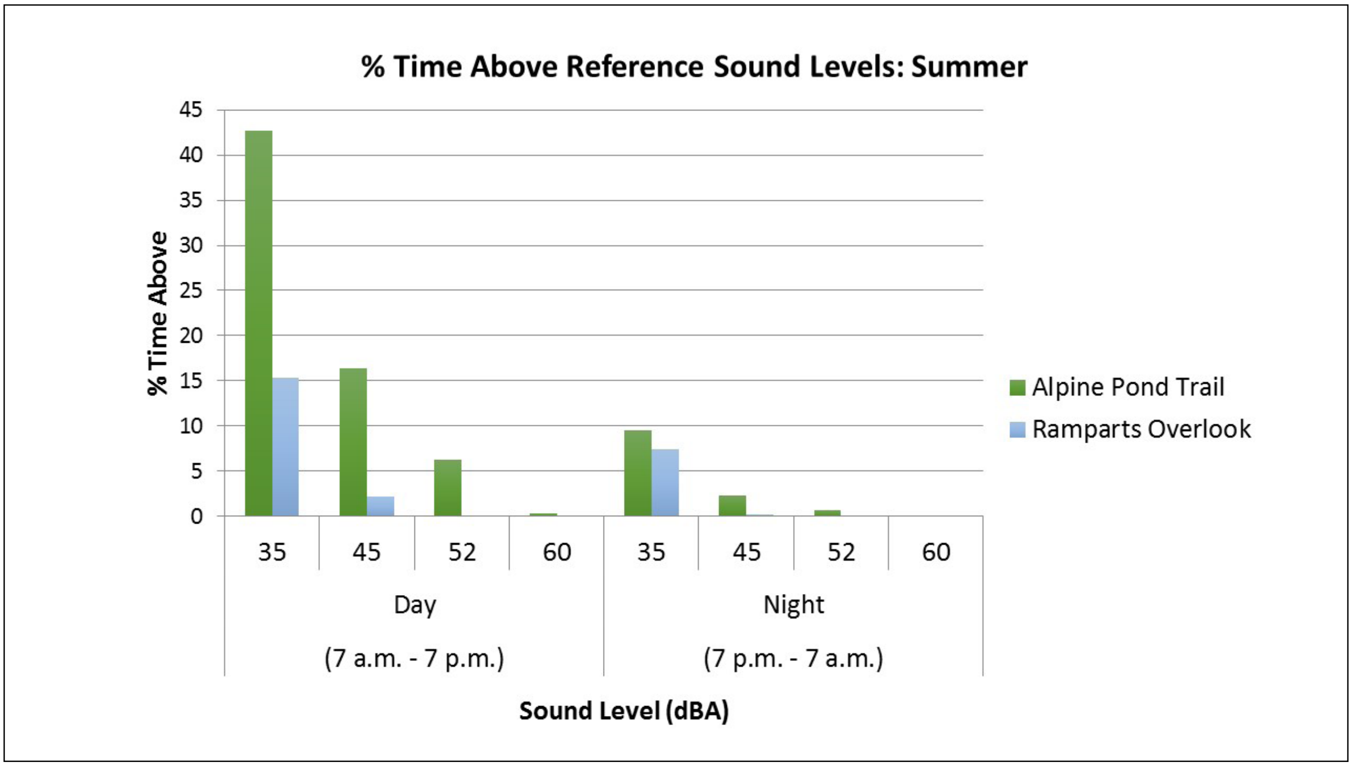


Figure 4.3.4-1. Percent time above reference sound levels at two sites in the summer.

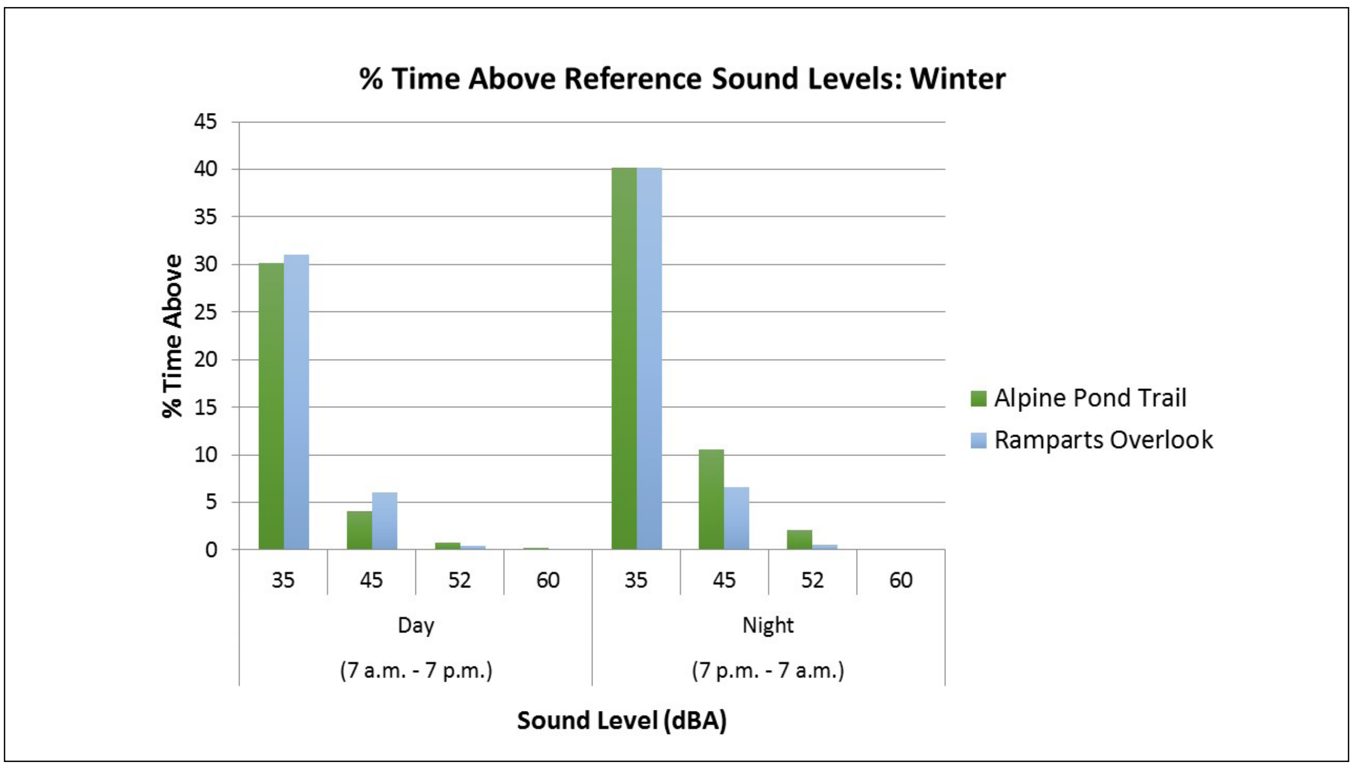


Figure 4.3.4-2. Percent time above reference sound levels at two sites in the winter.

bird and insect sounds (NPS-NSNSD 2012). In this section we reported that the greatest percent time above the 45 dBA metric (16.4%) occurred at the Alpine Pond Trail site during the day in the summer. If just the low frequency range is included, the percent time above value is 13.75%.

As noted elsewhere, because sound sources were not reported in NPS-NSNSD (2012), we cannot discuss sound sources that correspond to the sound level observations. However, according to monument staff, natural sounds such as birds and wind are prevalent, although vehicles, some aircraft, and people-related sounds can also be heard (P. Roelandt and B. Larsen, Superintendent and Resource Manager, pers. comm. during NRCA workshop). According to the monument's request for technical assistance from NSNSD for the baseline acoustical monitoring, sources of anthropogenic sounds within the monument include electronic equipment (e.g., cell phones, car security horns), visitor vehicles (snow mobiles), monument equipment (snow plows, helicopters, chain saws), and aircraft (commercial tours and commercial jets). Road traffic and visitor voices are two additional sound sources.

% Reduction in Listening Area

To assess this measure, we used data from NPS-NSNSD (2012). We calculated the percent reduction in listening area for each site/season/time period by determining the impact (in dB), or the difference between the L_{50} sound level and the L_{90} sound level. The L_{50} represents the level of sound exceeded 50% of the time during the given measurement period, and the L_{90} is the level of sound exceeded 90% of the time during the measurement period. In our analysis, we used the L_{90} sound level to represent natural sound levels. Although it would have been preferable to use the L_{nat} sound level rather than the L_{90}, this level was not available from the Snapshot report (NPS-NSNSD 2012).

The reduction in listening area analysis is shown in Table 4.3.4-1. The table shows the L_{50} and L_{90} sound levels for each site, for both daytime and nighttime hours, as well as the impact value (i.e., the difference), reduction in listening area, and condition. Based on the analysis, for each category, the reduction in listening area was somewhat less for the nighttime compared to the daytime. However, in most cases the condition for each site/season/time period was of significant concern. The lowest reduction in listening area occurred at the Ramparts Overlook site at night in the summer (45.0% reduction), and the highest reduction in listening area occurred the Alpine Pond Trail site during the day in the summer (82.6%). Among all of the sites/seasons/time periods, the two highest L_{50}s were recorded at Alpine Pond Trail during the summer during the day (32.8 dBA) and at the same site during the winter at night (32.1 dBA).

Overall, we consider condition under this measure to warrant significant concern. However, although we have high confidence in the acoustical monitoring effort and report, our use of the L_{90} values to represent natural sound levels lowers our confidence in the assessment. For example, in a similar assessment for another national park unit (Saguaro NP), we determined the impact level using both the L_{90} and L_{nat} sound levels; at least in this one case, using the L_{90} led to a condition of significant concern, while using the L_{nat} led to a condition of moderate concern. Therefore, we have only low confidence in our condition rating for Cedar Breaks NM under this measure. Trends are unknown.

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

Figure 4.3.4-3 shows the modeled mean impact sound level map for the national monument. The modeled mean impact was 0.8 dBA above natural conditions, but ranged from 0.0 in the least impacted areas to 6.6 dBA in the most impacted areas. The map depicts the areas most influenced by human-caused sounds as the 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 national 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.

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

Table 4.3.4-1. Existing ambient sound levels at two sites at Cedar Breaks NM and results of the % reduction in listening area analysis.

Time	Site Location	Season	L_{50} (dBA)	L_{90} (dBA)	Impact (dBA)	Reduction in Listening Area	Condition
Daytime Hours (7 am - 7 pm)	Alpine Pond Trail	Summer	32.8	25.2	7.6	82.6	Significant Concern
	Alpine Pond Trail	Winter	30.9	26.3	4.6	65.3	Significant Concern
	Ramparts Overlook	Summer	25.2	21.6	3.6	56.3	Significant Concern
	Ramparts Overlook	Winter	29.7	23.9	5.8	73.7	Significant Concern
Nighttime Hours (7 pm - 7 am)	Alpine Pond Trail	Summer	21.2	16.4	4.8	66.9	Significant Concern
	Alpine Pond Trail	Winter	32.1	27.6	4.5	64.5	Significant Concern
	Ramparts Overlook	Summer	21.7	19.1	2.6	45.0	Moderate Concern
	Ramparts Overlook	Winter	28.4	23.6	4.8	66.9	Significant Concern

expected to exceed 41 dBA (although acoustical conditions vary by area and depend on vegetation, landcover, elevation, climate, and other factors). The modeled estimates for Cedar Breaks NM were well below 41 dBA, with the average L_{50} being 30.5 dBA and the maximum being 36.5 dBA. 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 average impact result for the national monument was below 1.5 dBA (it was 0.8 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.

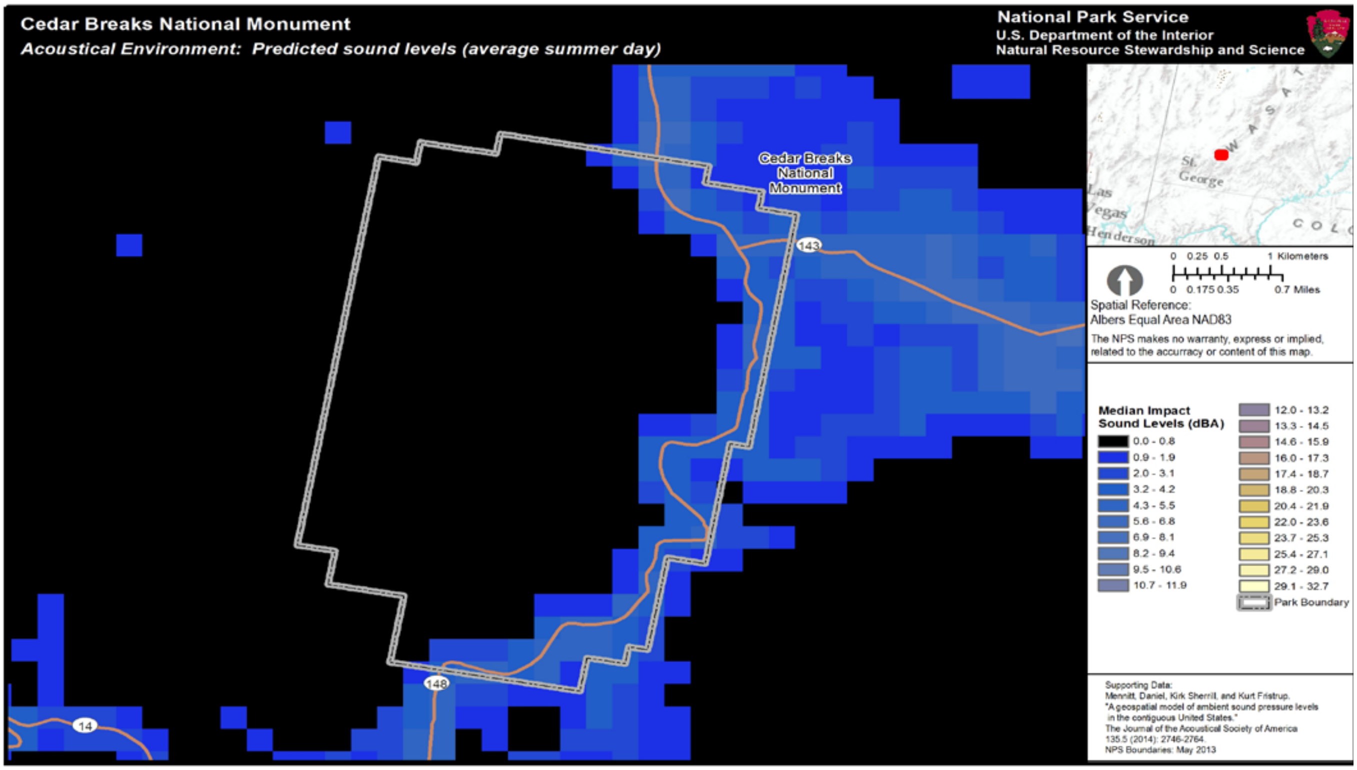
Overall Condition, Trend, Confidence Level, and Key Uncertainties

Overall, we consider the soundscape at Cedar Breaks NM to be in a condition of good to warranting moderate concern based on the sites monitored and the information available. This condition rating is based on two indicators with a total of three measures, which are summarized in Table 4.3.4-3. The overall trend is unknown.

Under the first measure (% time above reference sound levels), condition was considered good for each season individually and overall, because sound levels were below the 45 dBA metric (World Health Organization's recommendation for maximum noise level in bedrooms) the majority of the time. However, it should be noted that the 45 dBA metric was exceeded to some extent, particularly at Alpine Pond Trail-16.4% of the daytime during the summer, and 10.5% of the nighttime during the winter. The 52 dBA metric (speech interference threshold for speaking in a raised voice to an audience at 10 meters [32.8 feet; USEPA 1974]) was exceeded at most 6.3% of summer daytime hours at Alpine Pond Trail (but in all other cases to a lesser extent).

Under the first measure, comparisons between sites, seasons, and time period varied. For example, during the summer, the percent times above the reference sound levels were generally greater at Alpine Pond Trail than at Ramparts Overlook, but during the winter, the percent times above the metrics were more similar between the sites. Comparisons within sites for daytime versus nighttime sound levels revealed that in the summer, percent time above values were higher during the day than at night, but in the winter, percent time above values appeared somewhat higher at night than during the day. Unfortunately, sound sources were not reported by NPS-NSNSD (2012), so we cannot address the observed differences using monitoring data (on sound sources).

Condition under the second measure, % reduction in listening area, was considered to be of significant concern, but with an associated confidence level of "low." This is due to our use of L_{90} sound levels in place of L_{nat} levels, which were unavailable. Overall, reduction in listening area ranged from 45.0% (Ramparts Overlook at night in summer) to 82.6% (Alpine Pond Trail during day in summer). The existing ambient sound levels (see L_{50}s in Table 4.3.4-1) indicate that for Alpine Pond Trail, sound levels were highest during the day in the summer, followed by nighttime in winter. For Ramparts Overlook, sound levels were highest during the daytime in winter, followed by nighttime in winter.



NPS Natural Sounds & Night Skies Division and NPS Inventory and Monitoring Program MAS Group 20170308

Figure 4.3.4-3. The modeled L_{50} impact sound level at Cedar Breaks NM. Lighter colors represent higher impact areas. Figure Credit: Emma Brown, NPS NSNSD.

Finally, the geospatial model indicates good condition across the national monument. The modeled average impact result was predicted to be 0.8 dBA, below the level separating good and moderate concern conditions.

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 or low confidence. Factors that influence confidence in the condition rating include age of the data (<5 yrs is most desirable 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.

Confidence in the quality of the data from NPS-NSNSD (2012) is high. However, our overall confidence in the assessment is medium. Of our three measures, one was given a high confidence rating, one a medium confidence rating, and one a low confidence rating. The one with the low confidence rating was the measure warranting significant concern. Therefore, we consider the overall confidence in the assessment as medium. Although data were collected in two seasons, they were collected within only one year. Therefore, we could not determine trends in condition.

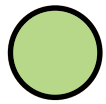
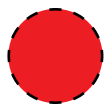
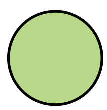
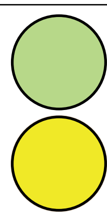
The main areas of uncertainty associated with the assessment include that sound sources were not identified in the acoustical monitoring report, natural ambient sound levels were not estimated in the acoustical monitoring report (and so we used the L_{90} as a proxy), and acoustical monitoring data are now approximately five years old. Regarding the third point, it would be most desirable to have monitoring data from the last few years to represent current condition. However, five-year-old data is still considered recent enough for us to have high confidence in it.

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

Acoustic Environment Condition	(dBA)		
	Min.	Max.	Avg.
Natural	29.6	31.4	30.4
Existing	28.2	36.5	30.5
Impact	0.00	6.6	0.8

Note: Data were provided by E. Brown, NPS NSNSD.

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

Indicators of Condition	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Sound Level	% Time Above Reference Sound Levels		Condition was good under this measure, because sound levels were under 45 dBA (the World Health Organization's recommendation for maximum noise level in bedrooms) most of the time. It should be noted, however, that the 45 dBA metric was exceeded to some extent, particularly at the Alpine Pond Trail site- 16.4% of the daytime during the summer, and 10.5% of the nighttime during the winter. The 52 dBA metric (speech interference threshold for speaking in a raised voice to an audience at 10 m [32.8 ft; USEPA 1974]) was exceeded at most 6.3% of summer daytime hours at the Alpine Pond Trail site. Confidence in the condition rating is high, but the data are now approximately five years old. Trends are unknown.
	% Reduction in Listening Area		For each category in the analysis, the reduction in listening area was somewhat less for the nightime compared to the daytime. However, in most cases the condition for each site/season/time period was of significant concern based on the reduction in listening area and reference conditions. The lowest reduction in listening area was at night in the summer at Ramparts Overlook (45.0% reduction), while the highest reduction in listening area occurred at Alpine Pond Trail during the day in the summer (82.6%). Overall, we consider condition under this measure to warrant significant concern. No data are available for trends. Although we have high confidence in the acoustical monitoring effort of NPS-NSNSD, our use of the L_{90} values to represent natural sound levels lowers our confidence to "low."
Geospatial Model	L_{50} Impact		The modeled average impact sound level for the national monument was 0.8 dBA above natural conditions, but ranged from 0 dBA in the least impacted areas to 6.6 dBA in the most impacted areas. Since the modeled average impact result for the monument was below 1.5, the L_{50} Impact was considered to be in good condition. This level of sound impact corresponds to a reduction in listening area of < 30%. Because these data were modeled, confidence is medium. Trend could not be determined based on the data.
Overall Condition			Overall, we consider the soundscape at the national monument to be in good condition to warranting moderate concern. Two of the measures were in good condition (and had a high and medium confidence level). One of the measures warrants significant concern, but it has an associated low confidence level. Trends are unknown. Overall confidence is medium.

Finally, it is also important to note that the acoustical monitoring data from the Alpine Pond Trail and Ramparts Overlook sites were along the east, more developed portion of the monument. Both trails are reached from Route 148, the road running down the east side of the monument. During the day in the summer, for example, sound levels were higher at the Alpine Pond Trail as compared to Ramparts Overlook. It is possible that data from a monitoring site more distant from Route 148 would have shown lower sound levels. Analysis with the geospatial model indicated that daytime impacts during midsummer were low, on average, for the monument.

The Cedar Breaks NM Wilderness Character Monitoring report (Booth-Binczik 2014) pointed out some anthropogenic sound sources that may affect the monument's soundscape; these sound sources are gunshot noise (e.g., during fall hunting seasons), and snowmobile noise during the winter and early spring.

Threats, Issues, and Data Gaps

The Cedar Breaks NM Foundation Document (NPS 2015a) reports that the monument's acoustic environment is becoming more impacted by noise from traffic increases. The document also addresses the potential for oil and gas-related development activities to occur to the west of the monument; such activities could involve new access roads and the operation of machinery. Potential impacts to the monument's soundscape from increased snowmobile activity and the increasing use of drones are unknown at this time. As/if development outside of the monument increases and/or visitation continues to increase, anthropogenic sounds, at least in some areas of the monument, would be expected to increase as well.

In addition to influencing the human experience of the landscape, anthropogenic sound (and its frequency) can influence the behavior and ability of wildlife to function naturally on the landscape. 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 mammals, 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 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).

A complete analysis of the 2012 acoustical monitoring conducted by NPS NSNSD is needed and is considered to be a data gap. Phyllis Bovin, NPS Intermountain Region NRCA Coordinator will be submitting a technical assistance request to NSNSD to request full analysis of the dataset, especially since visitation to the monument has greatly increased throughout the summer and winter months.

4.3.5. Sources of Expertise

NPS 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. Assessment author is Patty Valentine-Darby, Biologist and Science Writer, Utah State University.

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 2016). Cedar Breaks National Monument (NM) is designated as a Class II airshed. Although 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). The Northern Colorado Plateau Network's (NCPN) Vital Signs Monitoring Plan (O'Dell et al. 2005) recognized the importance of air quality monitoring within network parks, and the Cedar Breaks NM Wilderness Character Monitoring report (Booth-Binczik 2014) included four measures of air quality for monitoring the park's recommended wilderness area (i.e., ozone concentration, wet deposition of sulfur, wet deposition of nitrogen, and haze index).

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,

Figure 4.4.1-1. A view of Cedar Breaks NM. Photo Credit: NPS.

and wind-blown dust, or as secondary pollutants, which result from atmospheric chemical reactions. The CAA requires the U.S. Environmental Protection Agency (EPA) 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 (EPA 2016a). The two types of NAAQS are primary and secondary, with the primary standards establishing limits to protect human health, and the secondary standards establishing limits to protect public welfare from air pollution effects, including decreased visibility, and damage to animals, crops, vegetation, and buildings (EPA 2016a).

The NPS' ARD (NPS-ARD) air quality monitoring program uses EPA'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.

Figure 4.4.1-2. A scenic view from the rim of the Cedar Breaks amphitheater. Photo Credit: NPS.

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 2016). 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, Schwinning et al. 2005, Allen et al. 2009). Increased grasses can increase fire risk (Rao et al. 2010), with profound implications for biodiversity in non-fire adapted ecosystems. Nitrogen may also increase water use in plants like big sagebrush (*Artemisia tridentata*) (Inouye 2006).

According to the EPA (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 (EPA 2016b), including at Cedar Breaks 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 2016).

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 Cedar Breaks 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, EPA, 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 from the closest stations "outweigh" the rest. 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.

Haze Index

The haze index measures visibility, which is monitored by the Interagency Monitoring of Protected Visual Environments (IMPROVE) Program (NPS-ARD 2010).

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; EPA-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 park 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. Monitoring data from the IMPROVE BRCA1 site (operating since 1988) were used to determine the visibility trend at Cedar Breaks NM.

The level of ozone indicator includes two measures, human health: annual 4th-highest 8-hr concentration and vegetation health: 3-month maximum 12-hr W126). Ozone is monitored across the U.S. through air quality monitoring networks operated by the NPS, EPA, states, and others. Aggregated ozone data are acquired from the EPA Air Quality System (AQS) database. Note that prior to 2012, monitoring data were also obtained from the EPA Clean Air Status and Trends Network (CASTNet) database. There are no on-site or nearby representative monitors to assess human or vegetation health ozone trends.

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

The primary NAAQS for ground-level ozone is set by the EPA, 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 EPA strengthened the national ozone standard by setting the new level at 70 ppb (EPA 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 from March to September is reported in “parts per million-hours” (ppm-hrs), and is used for vegetation health risk from ozone condition assessments. Annual maximum 3-month 12-hour W126 values are averaged over a 5-year period at all monitoring sites with at least three years of complete annual data. Five-year averages are interpolated for all ozone monitoring locations to estimate 5-year average values for the contiguous U.S. The estimated current ozone condition for vegetation health risk at the park is the maximum value within park boundaries derived from this national analysis.

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 Sulfur

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. There are no on-site or nearby representative monitors to assess wet nitrogen and sulfur deposition trends.

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. There are no on-site or nearby representative monitors to assess mercury deposition trends.

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.

Visibility (Haze Index)

A visibility condition estimate of less than 2 deciviews (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 EPA (EPA

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
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).

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 EPA's Policy Assessment for the Review of the Ozone NAAQS (EPA 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 4.4.3-2 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).

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.

Haze Index
The estimated 5-year (2011-2015) value (2.9 dv) for the monument'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 2006-2015, the trend in visibility at Cedar Breaks NM improved on the 20% clearest days (Figure 4.4.4-1) and on the 20% haziest days (Figure 4.4.4-2) (IMPROVE Monitor ID: BRCA1, UT). The CAA visibility goal requires visibility improvement on the 20% haziest days, with no degradation on the 20%

Table 4.4.3-2. 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)

Table 4.4.4-1. Condition and trend results for air quality indicators at Cedar Breaks NM.

Data Span	Visibility (dv)	Ozone: Human Health (ppb)	Ozone: Vegetation Health (ppm-hrs)	N (kg/ha/yr)	S (kg/ha/yr)	Mercury (µg/m²/yr)	Predicted Mercury (ng/L)
Condition	Moderate Concern (2.9) 2011-2015	Moderate Concern (69.4) (2011-2015)	Significant Concern (14.5) (2011-2015)	Moderate Concern (2.9) 2011-2015	Moderate Concern (1.1) 2011-2015	Significant Concern (12.2-15.6) 2013-2015	Significant Concern (0.13) 2013-2015
Trend: 2006-2015	The trend in visibility improved on the 20% clearest days and improved on the 20% haziest days (IMPROVE Monitor ID: BRCA1, UT) (text excerpted from NPS 2017b).						

Sources: NPS-ARD (2017b,c).

clearest days (excerpted from NPS-ARD 2017b). The visibility goal was met (exceeded) for the 20% clearest days and met for the 20% haziest 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 contributions made by different classes of particles to haze on the clearest days and on the haziest days are shown in Figures 4.4.4-3 and -4, respectively, using data collected at the IMPROVE monitoring location, BRCA1, UT. The primary visibility-impairing pollutants on the clearest days from 2006-2015 were ammonium sulfate, organic carbon, and ammonium nitrate, respectively. On the haziest days, organic carbon, ammonium sulfate, and coarse mass, respectively, were the primary visibility-impairing pollutants. Ammonium sulfate originates mainly from coal-fired power plants and smelters, and organic carbon originates primarily from combustion of fossil fuels and vegetation. Sources of coarse mass include road dust, agriculture dust, construction sites, mining operations, and other similar activities.

In 2015, the clearest days occurred during January, followed by December, then November (Figure 4.4.4-5). The haziest days occurred during August, followed by April, June, and July (Figure 4.4.4-6).

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

Ozone data used for this measure were derived from estimated five-year (2011-2015) values of 69.4 parts per billion for the 4th highest 8-hour concentration, which resulted in a condition rating warranting moderate concern for human health (NPS-ARD 2017b). Trend could not be determined because there are not sufficient on-site or nearby ozone monitoring data. Our level of confidence in this measure is medium, because estimates are based on interpolated data from more distant ozone monitors.

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 14.5 parts per million-hours (ppm-hrs) for the W126 Index. Using these numbers, vegetation health risk from ground-level ozone warrants significant concern at Cedar Breaks NM (NPS-ARD 2017b). Trend could not be determined because there are not sufficient on-site or nearby ozone monitoring data. Our level of confidence in this measure is medium because estimates are based on interpolated data from more distant ozone monitors.

An ozone risk assessment conducted by Kohut (2004, 2007) for NCPN parks concluded that plants in the national monument were at low risk of foliar ozone injury. Three plant species identified as ozone sensitive at the park during the Kohut (2004) effort are listed in Table 4.4.4-2. All three of the species are bioindicators for ozone (Kohut 2004), meaning that they can reveal ozone stress in ecosystems by producing distinct visible and identifiable injuries to plant leaves. A list of ozone sensitive species is also available from Bell (in review), which includes additional species not noted by Kohut (2004; Table 4.4.4-2). Finally, it should also be noted that a qualitative survey of ozone injury in plants was conducted in Cedar Breaks NM and two nearby national park units in 1999 by NPS (Scruggs 2000). The survey was conducted in readily-accessible sites that had species known to be sensitive to ozone.

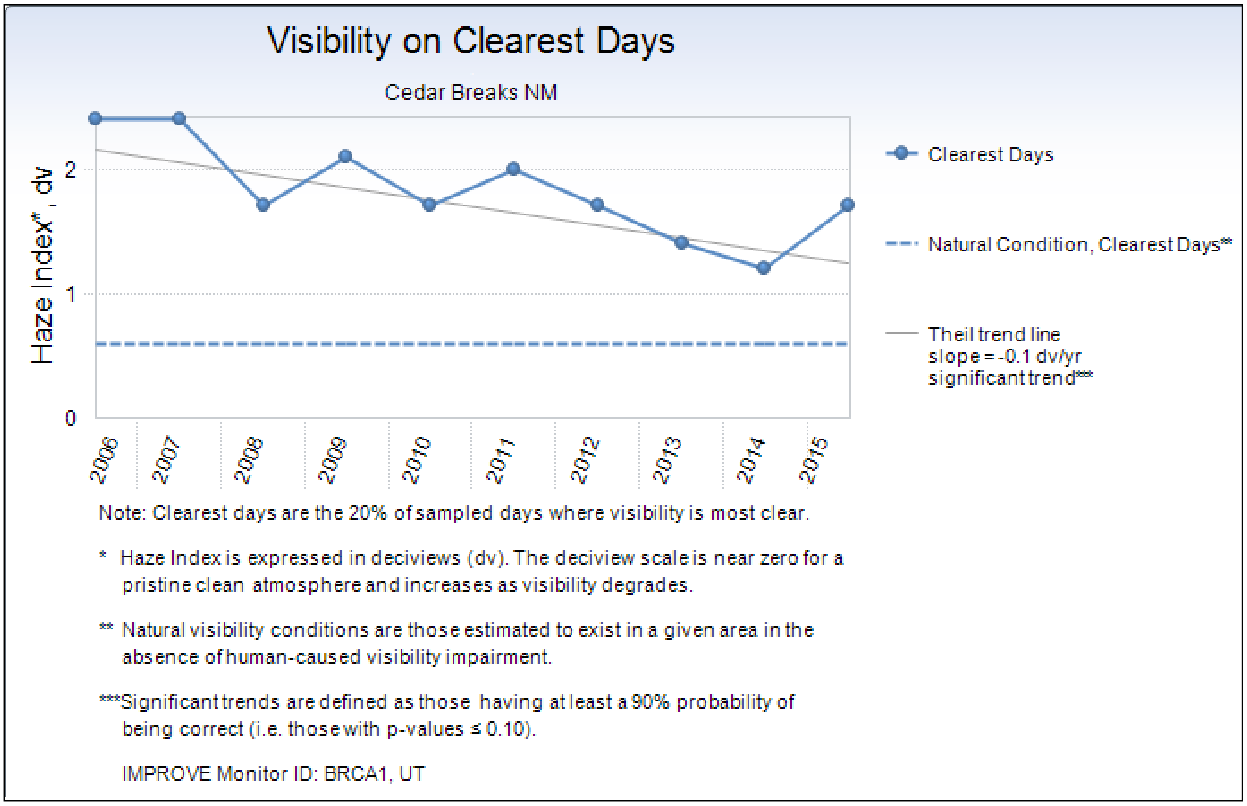


Figure 4.4.4-1. For 2006-2015, the trend in visibility at Cedar Breaks NM improved on the 20% clearest days. Figure Credit: NPS-ARD 2017b.

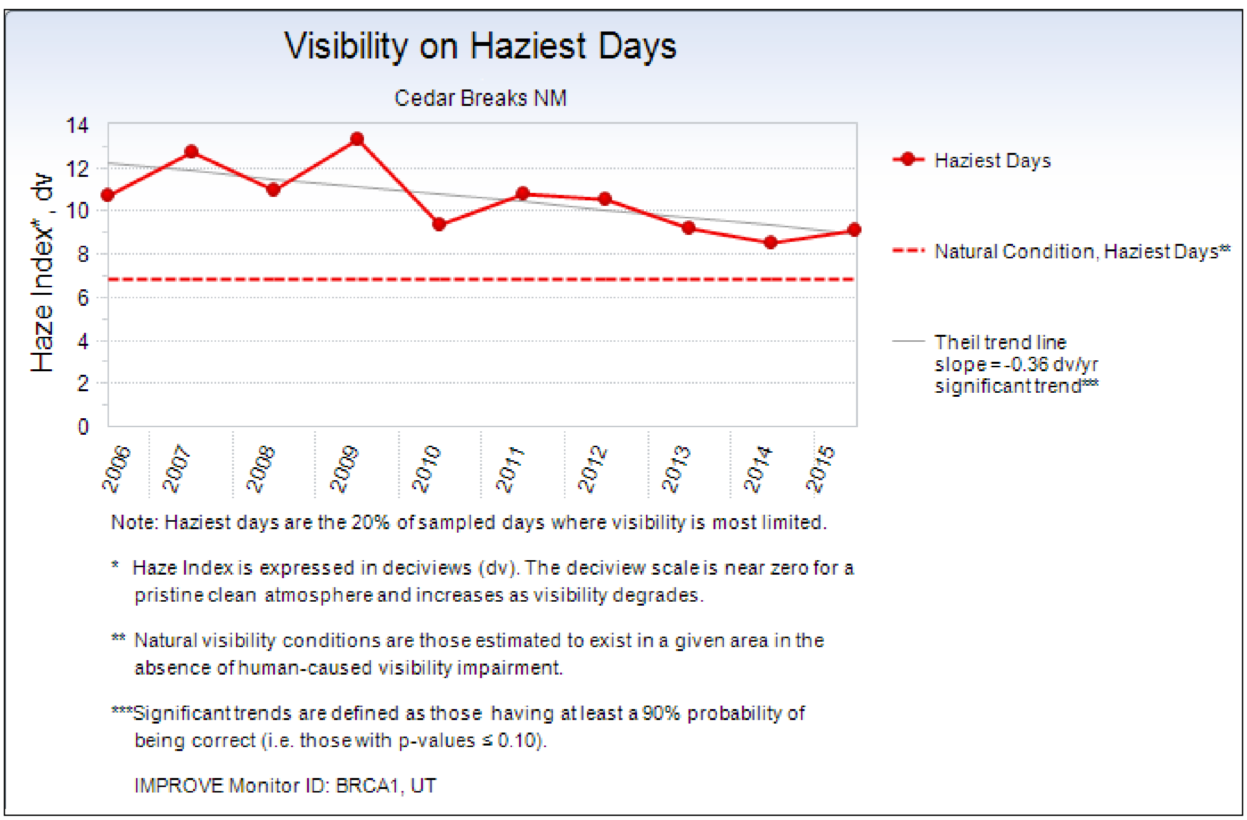


Figure 4.4.4-2. For 2006-2015, the trend in visibility at Cedar Breaks NM improved on the 20% haziest days. Figure Credit: NPS-ARD 2017b.

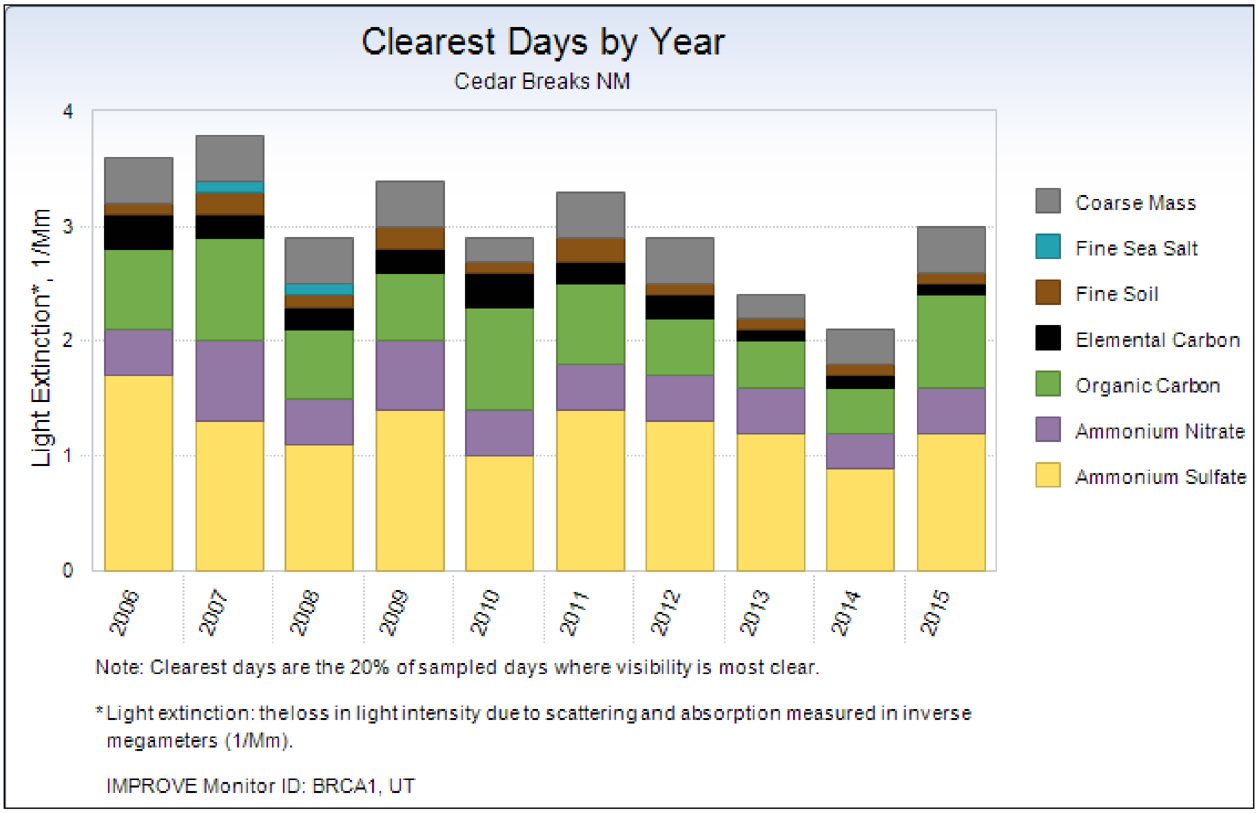


Figure 4.4.4-3. Visibility data collected at BRCA1, UT IMPROVE station showing the composition of particle sources contributing to haze during the clearest days by year (2006-2015). Figure Credit: NPS-ARD 2017b.

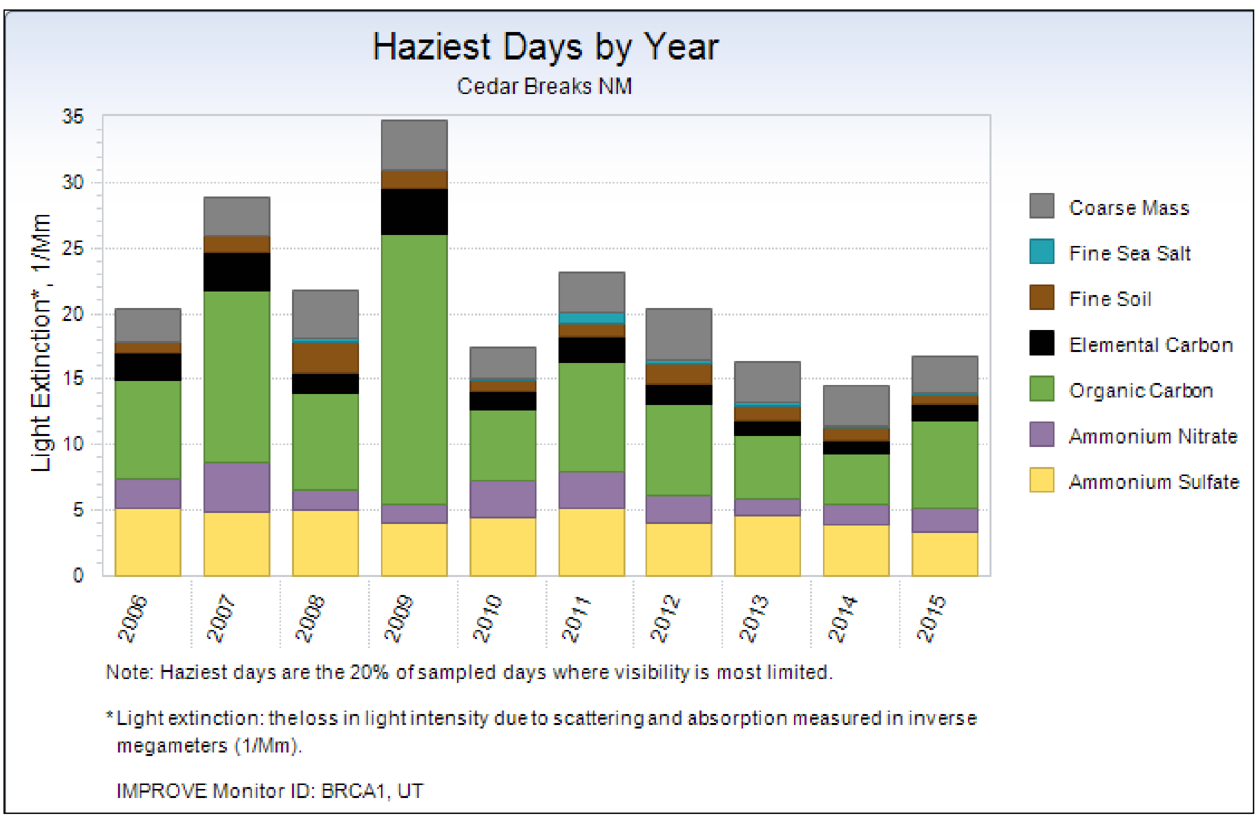


Figure 4.4.4-4. Visibility data collected at BRCA1, UT IMPROVE station showing the composition of particle sources contributing to haze during the haziest days by year (2006-2015). Figure Credit: NPS-ARD 2017b.

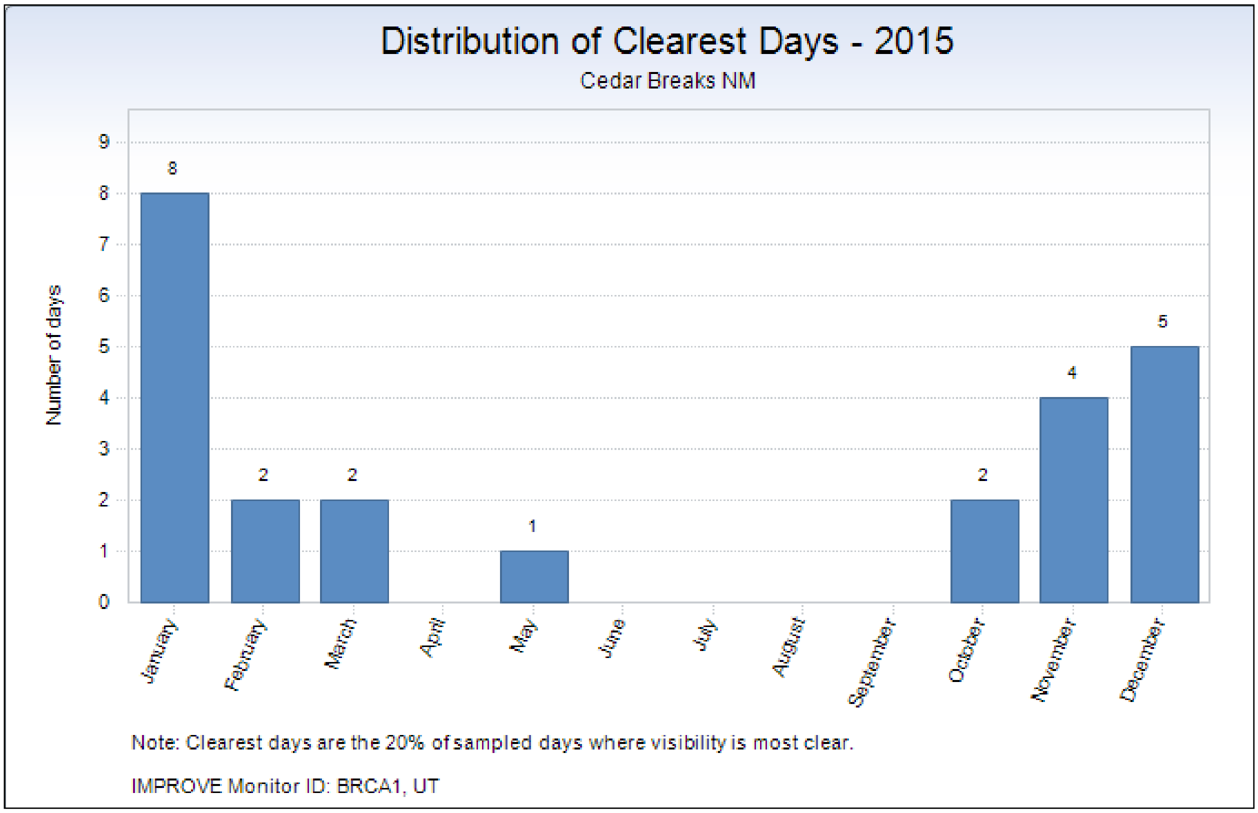


Figure 4.4.4-5. Visibility data collected at BRCA1, UT IMPROVE station showing the distribution of clearest days by month for 2015. Figure Credit: NPS-ARD 2017b.

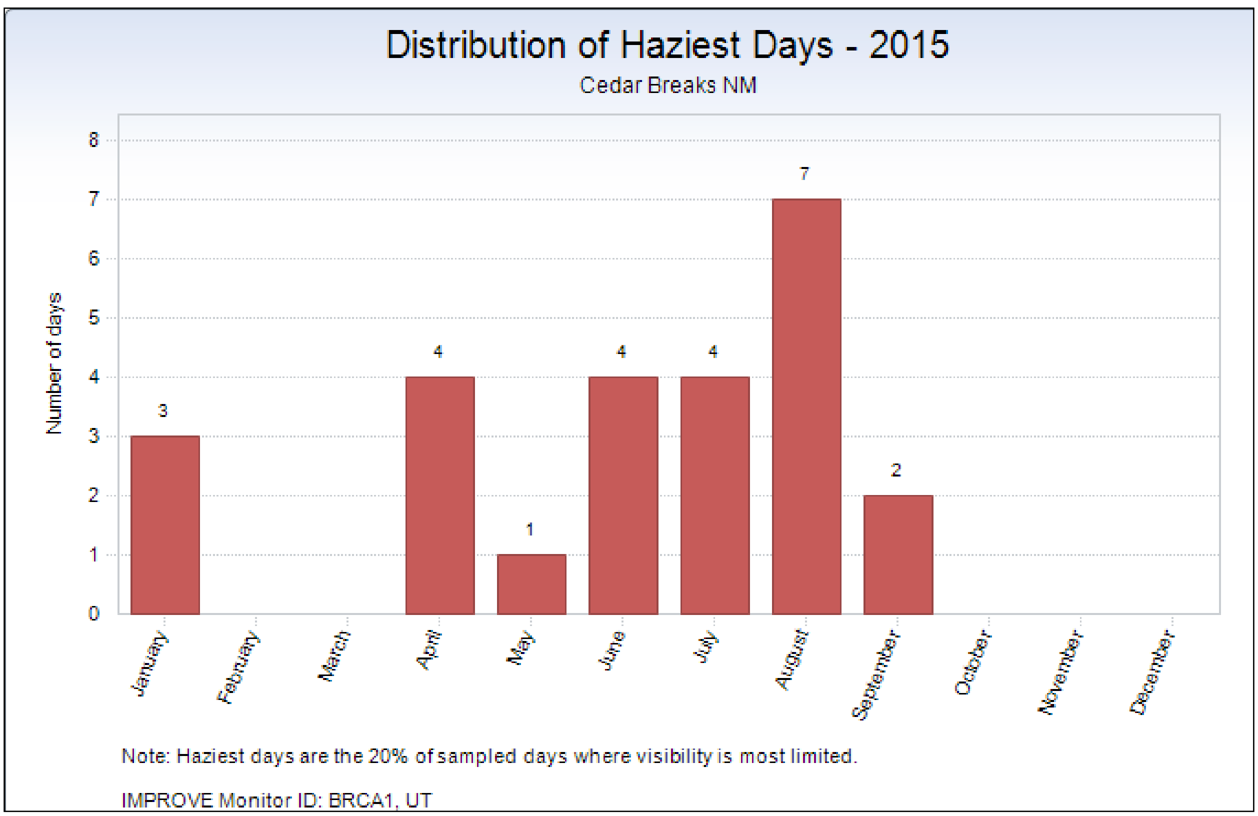


Figure 4.4.4-6. Visibility data collected at BRCA1, UT IMPROVE station showing the distribution of haziest days by month for 2015. Figure Credit: NPS-ARD 2017b.

Table 4.4.4-2. Ozone sensitive plants found at Cedar Breaks NM.

Scientific Name	Common Name	Bell (in review)	Kohut (2004)	Bioindicator?
Amelanchier alnifolia *	Saskatoon serviceberry	X	–	No
Amelanchier utahensis	Utah serviceberry	X	–	No
Apocynum cannabinum *	Common dogbane	X	–	No
Lonicera involucrata	Black twinberry	X	–	Yes
Pinus ponderosa	Ponderosa pine	–	X	Yes
Populus tremuloides	Quaking aspen	X	X	Yes
Salix scouleriana	Scouler's willow	X	X	Yes

* Species is listed as "probably present" in the park on the Bell (in review) list.

One species, red elderberry (Sambucus racemosa), at Cedar Breaks NM was reported to have probable ozone injury (Scruggs 2000).

Nitrogen

Wet N deposition data used for the condition assessment were derived from estimated five-year average values (2011-2015) of 2.9 kg/ha/yr. This resulted in a condition rating of moderate concern (NPS-ARD 2017b). No trend information is available because there are not sufficient on-site or nearby deposition monitoring data. 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 (2011-2015) average values of 1.1 kg/ha/yr, which resulted in a condition rating of moderate concern for Cedar Breaks NM (NPS-ARD 2017b). No trend information is available because there are not sufficient on-site or nearby deposition monitoring data. 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 NCPN parks, which included Cedar Breaks NM. Pollutant exposure included the type of deposition (i.e., wet, dry, cloud, fog), the oxidized and reduced forms of the chemical, if applicable, and the total quantity deposited. The ecosystem sensitivity considered the type of terrestrial and aquatic ecosystems present at the parks and their inherent sensitivity to the atmospherically deposited chemicals.

These risk rankings for the park were considered very low for acid pollutant exposure, high for ecosystem sensitivity, and high for park protection, 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 very low for pollutant exposure, low for ecosystem sensitivity, and high for park protection, with an overall summary risk of low for the national monument. Potential effects of nitrogen deposition include the disruption of soil nutrient cycling and impacts to the biodiversity of some plant communities, including alpine communities, grasslands and meadows, arid and semi-arid communities, and wetlands. These nitrogen sensitive communities cover a relatively small portion of the national monument, occurring mostly in the eastern, northeastern, and southeastern portions of the park (Figure 4.4.4-7). Again, the overall summary risk from atmospheric nutrient N enrichment was low for the park relative to the other Inventory and Monitoring parks (Sullivan et al. 2011b).

In general, nitrate, sulfate, and ammonium deposition levels have changed over the past 20 years throughout the United States (Figure 4.4.4-8). 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

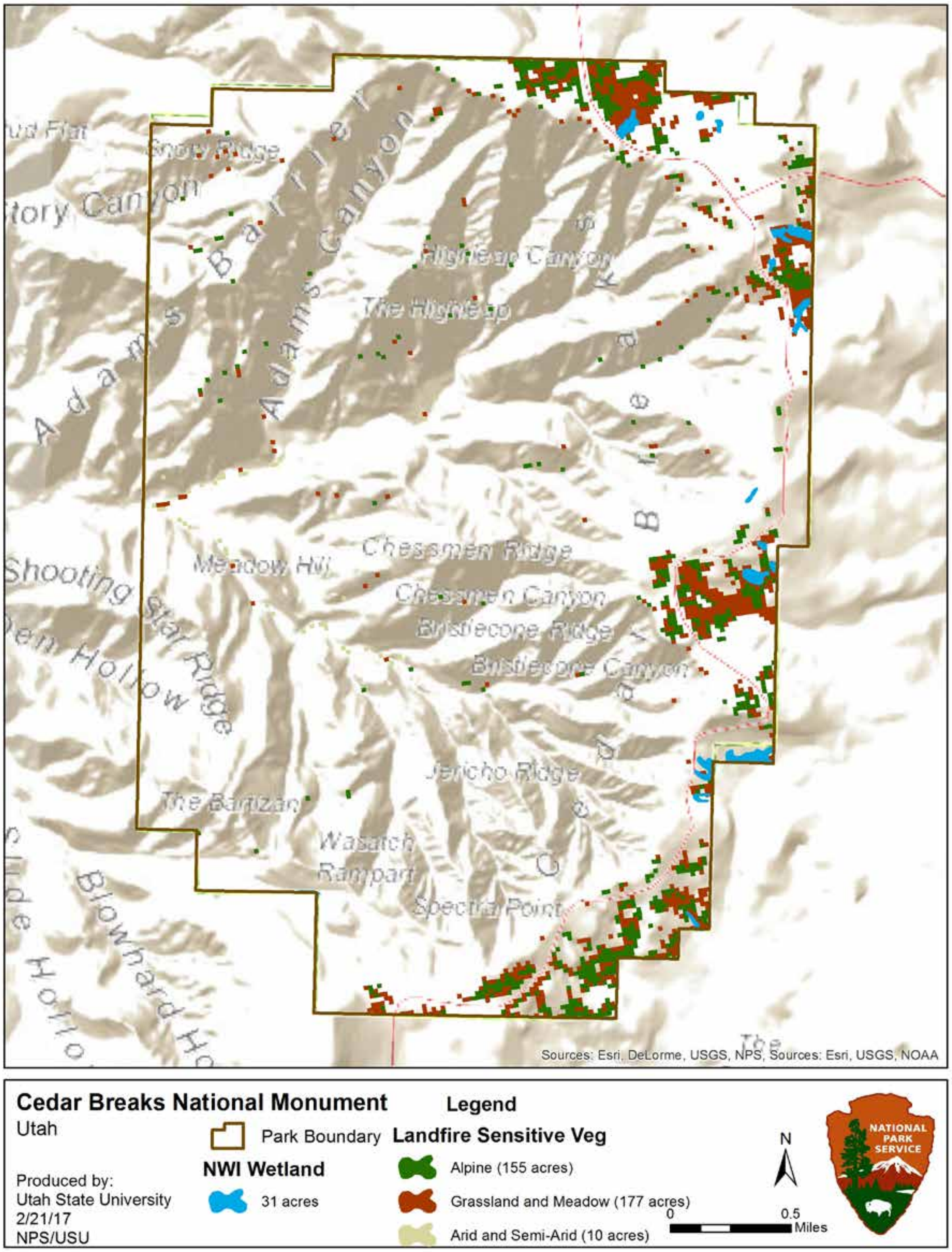


Figure 4.4.4-7. Locations of nitrogen sensitive communities at Cedar Breaks NM using the NPS/USGS vegetation mapping dataset. Secondary Data Source: E&S Environmental Chemistry, Inc. (2009).

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 Cedar Breaks NM, but no statistically significant change in nitrate concentrations. According to the Lehmann and Gay (2011) study, for

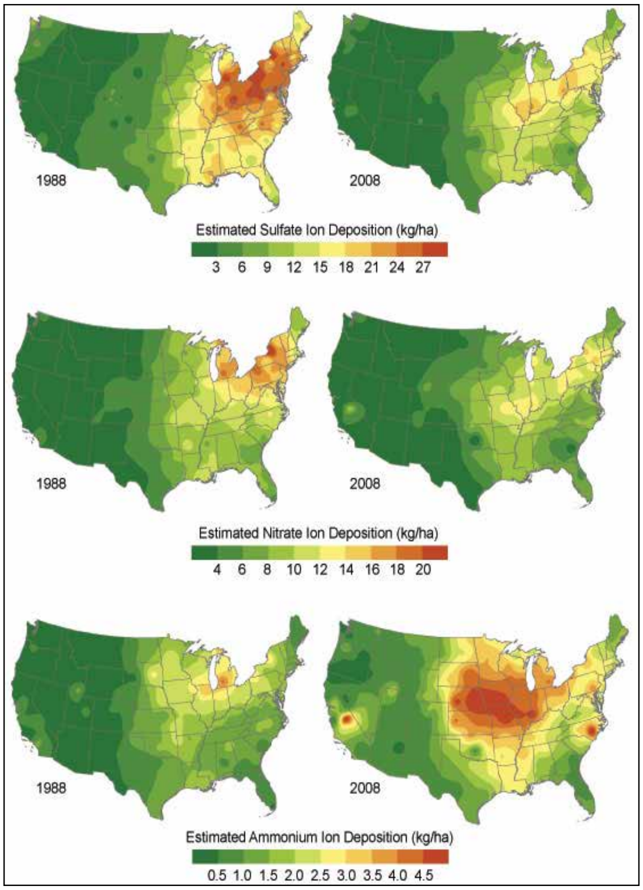


Figure 4.4.4-8. Change in wet deposition levels from 1988-2008 throughout the United States. Figure Source: http://www.nature.nps.gov/air/Monitoring/wetmon.cfm.

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 EPA, and may therefore continue to rise (NPS-ARD 2010).

Mercury and Predicted Methylmercury

The 2013-2015 wet mercury deposition was very high at the park and ranged from 12.2 to 15.6 micrograms per square meter per year (NPS-ARD 2017c). The predicted methylmercury concentration in park surface waters was estimated to be 0.13 ng/L (USGS 2015), a very high concentration (NPS-ARD 2017c). When both measures are available (i.e., wet mercury deposition and predicted methylmercury concentration), the mercury status assessment matrix shown in Table 4.4.3-2 can be used to determine overall mercury/toxics status (NPS-ARD 2015a). The matrix indicates a condition of significant concern for the combined effects of wet mercury deposition and predicted methylmercury at Cedar Breaks NM. However, the level of confidence in this measure is low, because the estimates are based on interpolated or modeled data rather than in-park studies, since there are no park-specific studies examining contaminant levels in taxa from park ecosystems. Trend could not be determined.

Overall Condition and Trend, Confidence Level, and Key Uncertainties

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

Based on the indicators and measures, we consider the overall condition of air quality at Cedar Breaks NM to be of moderate to significant concern. Among the six measures, four were considered to be of moderate concern, and two were considered to be of significant concern.

We consider the confidence level as high for visibility (haze index) based on the IMPROVE monitoring station, BRCA1, UT. The confidence levels for wet deposition of N and S and the ozone measures are medium, because the estimates are based on interpolated data from more distant monitors. Finally, as mentioned above, the confidence levels for wet mercury deposition and predicted methylmercury concentration are low because the estimates are based on interpolated or modeled data rather than in-park studies. Based on these confidence levels, we assigned an overall confidence level of medium for 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 park.

Because trend information for most of the seven measures was not available, we did not assign an overall

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 Cedar Breaks NM. This is based on NPS ARD benchmarks and the 2011-2015 estimated visibility on mid-range days of 2.9 deciviews (dv) above estimated natural conditions. For 2006-2015, the trend in visibility at the park improved on the 20% clearest days and improved on the 20% haziest days (IMPROVE Monitor ID: BRCA1, UT). The Clean Air Act visibility goal requires visibility improvement on the 20% haziest days, with no degradation on the 20% clearest days. The level of confidence is high because there is an on-site or nearby visibility monitor.
Level of Ozone	Human Health: Annual 4th-Highest 8-hour Concentration		Human health risk from ground-level ozone warrants moderate concern. This status is based on NPS ARD benchmarks and the 2011-2015 estimated ozone of 69.4 parts per billion (ppb). Trend could not be determined because there are not sufficient on-site or nearby monitoring data. 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 14.5 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 low risk for ozone damage (Kohut 2007, Kohut 2004). Trend could not be determined because there are not sufficient on-site or nearby monitoring data. 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 2.8 kilograms per hectare per year (kg/ha/yr). Ecosystems in the park were rated as having low sensitivity to nutrient enrichment effects relative to all Inventory & Monitoring parks (Sullivan et al. 2011a; Sullivan et al. 2011b). Trend could not be determined because there are not sufficient on-site or nearby monitoring data. The confidence level is medium because estimates are based on interpolated data from more distant deposition monitors.
	S in kg/ha/yr		Wet sulfur deposition warrants moderate concern. This status is based on NPS ARD benchmarks and the 2011-2015 estimated wet sulfur deposition of 1.1 kilograms per hectare per year (kg/ha/yr). Ecosystems in the park were rated as having high sensitivity to acidification effects relative to all Inventory & Monitoring parks (Sullivan et al. 2011a, Sullivan et al. 2011b). Trend could not be determined because there are not sufficient on-site or nearby monitoring data. The confidence level is medium because estimates are based on interpolated data from more distant deposition monitors.
	Mercury		The 2013-2015 estimated wet mercury deposition was very high at the park and ranged from 12.2 to 15.6 micrograms per square meter per year. This measure is used in conjunction with the predicted methylmercury concentration to determine the overall condition of mercury/toxics.
	Predicted Methylmercury Concentration		For 2013-2015, the predicted methylmercury concentration in park surface waters was very high (0.13 nanograms per liter). Trends could not be determined. Confidence in the measure is low because estimates are based on interpolated or modeled data rather than in-park studies; there are no park-specific studies examining contaminant levels in taxa from park ecosystems. This measure is used in conjunction with wet mercury deposition to determine the overall condition of significant concern at the national monument.

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 Cedar Breaks NM to warrant moderate to significant concern. The only measure with a high confidence level (haze index) was of moderate concern. Of the four measures with a medium confidence level, three were of moderate concern and one was of significant concern. The measure with a low confidence level (for mercury/toxics) warrant significant concern. Trends were reported for only one measure (haze index), and are improving. As described, confidence in the various measures was varied, but we consider overall confidence to be medium. Overall trends are unknown.

Note: Condition summary text was primarily excerpted from NPS-ARD (2017b,c).

trend for air quality. However, trend information was available for one of the measures (haze index). For 2006-2015, the trend in visibility improved at the park on the 20% clearest days and on the 20% haziest days (IMPROVE Monitor ID: BRCA1, UT).

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

Threats, Issues, and Data Gaps

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). For example, air quality in Cedar Breaks NM plays an important role in maintaining the high-quality scenic vistas and clear night skies of the national monument (NPS 2015a). Good visibility allows visitors to appreciate the amphitheater's colors, the dramatic rock formations, and impressive vistas of Brian Head Peak and more distant ranges (NPS 2015a).

Impacts to air quality can result from pollution from urban centers and development and wildfires near and more distant from the national monument (NPS 2015a). In general, sources of air quality threats may include forest fires (natural or prescribed), dust created from mines and quarries, and carbon emissions. For example, NPS (2013) described concerns over impacts to existing air quality within the region from regional development projects (e.g., coal mining activities located near the town of Alton, about 19.3 km (12 mi) to the west/southwest of Cedar Breaks NM).

Monahan and Fisichelli (2014) studied how recent climate conditions compared to historical conditions for Cedar Breaks NM and areas within 30 km (18.6 mi) of the park's boundary. They determined which climate variables recently (past 10-30 years) experienced "extreme" values ("extreme" being those exceeding 95% of the historical range of conditions) compared to the 1901-2012 historical range of variability. The researchers found that five temperature variables were "extreme warm" (annual mean temperature, maximum temperature of the warmest month, minimum temperature of the coldest month, mean temperature of the warmest quarter, and mean temperature of the coldest quarter). None of the temperature variables were "extreme cold," and none of the precipitation variables were "extreme dry" or "extreme wet" (Monahan and Fisichelli 2014).

One effect of climate change is an increase in wildfire activity (Abatzoglou and Williams 2016). Fires contribute a significant amount of trace gases and particles into the atmosphere that affect local and regional visibility and air quality (Kinney 2008). Wildfires have increased across the western U.S., and there is a high potential for the number of wildfires to grow as climate in the Southwest becomes warmer and drier (Abatzoglou and Williams 2016). Warmer conditions also increase the rate at which ozone and secondary particles form (Kinney 2008). Declines in precipitation may also lead to an increase in wind-blown dust (Kinney 2008). Weather patterns influence the dispersal of these atmospheric particulates. Because of their small particle size, airborne particulates from fires, motor vehicles, power plants, and wind-blown dust may remain in the atmosphere for days, traveling potentially hundreds of miles before settling out of the atmosphere (Kinney 2008).

As described in this assessment, the level of confidence was medium for most of the measures used. This was because the measures used estimates based on interpolated data from more distant monitors. The Foundation Document for Cedar Breaks NM (NPS 2015a) suggested that increased collaboration with neighboring parks to monitor ozone, and collaboration with a university to establish a long-term air quality monitoring station at the monument, would enable the collection of data and information on air quality that would lead to greater confidence in the assessment of air quality condition.

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 Patty Valentine-Darby, science writer at Utah State University.

4.5. Geology

4.5.1. Background and Importance

Cedar Breaks National Monument (NM) protects 2,635 ha (6,155 ac) of sparsely vegetated “breaks”, alpine meadows, and dense coniferous forests (Tendick et al. 2011). Elevations in the monument vary dramatically from 3,250 m (10,662 ft) above the breaks to 2,469 m (8,100 ft) on Ashdown Creek below the rim (Tendick et al. 2011). The monument was established in 1933 to preserve the distinctive geologic formations found in the breaks (NPS 2015a). Over millions of years, colorful spires, fins, pinnacles, canyons, and hoodoos have eroded from ancient limestones found in the Pink Cliffs of the Claron Formation (Figure 4.5.1-1). The same processes that created the breaks are at work today as unstable hoodoos crumble and new ones form.

The creation of these striking geologic features began more than 60 million years ago (Thornberry-Ehrlich 2006). During this time, much of southwestern Utah was covered by a large freshwater lake (Lake Claron), but over 20 to 25 million years, the lake basin experienced several dry and wet periods (NPS n.d., a). During wet periods sand, silt, and mud from highland streams flowing from the south and west washed into the lake. Iron and manganese from these eroded highland rocks are responsible for the pinks, reds, and purples observed in the Claron Formation (Thornberry-Ehrlich 2006). By about 35 million years ago, Lake Claron had permanently disappeared, and sediments in the dry lake bed solidified into rock (NPS n.d., a). About 15 million years ago, the underlying bedrock uplifted, creating the Colorado Plateau. As the plateau rose, deep faults split it into smaller plateaus trending north and south, including the Markagunt Plateau. The colorful breaks of Cedar Breaks are carved into the western edge of the plateau where it is uplifted 1,219 m (4,000 ft) by the Hurricane Fault. It is along this fault that the famous hoodoos, fins, and spires were, and continue to be, created.

Water is the primary erosive force in Cedar Breaks NM. With more than 250 days of frost per year, water seeping into cracks in the rock freezes and expands, exerting extreme pressure that splits rock apart (NPS 2016a). Chemical weathering from acidic rain and slope failures caused by intense rainstorms also sculpt the landscape (Thornberry-Ehrlich 2006). These natural forces occur on a time scale that is visible to the average human observer. Rockfall, slope failures, and crumbling hoodoos are sometimes observed by monument visitors. While natural erosional processes dominate in Cedar Breaks NM, anthropogenic impacts can accelerate erosion and damage or destroy sensitive geologic features (NPS 2015a), as well as park facilities.

Figure 4.5.1-1. The amphitheater in Cedar Breaks NM. Photo Credit: NPS.

4.5.2. Data and Methods

This assessment focuses on the anthropogenic impacts to geologic features in the monument. The first indicator, known deterioration of geological and paleontological features, and two measures described below are based on those used to monitor the wilderness character of geological features in other NPS units, including Cedar Break NM (Booth-Binczik 2014, NPS 2014d). Since the monument is located in a seismically active zone, we also included one measure of earthquake activity and a discussion related to risk due to the monument's proximity to Hurricane Fault.

Anthropogenic Incidents

Resource management and law enforcement staff record instances of damage to monument resources using the Incident Management Analysis and Reporting System (IMARS). Examples of potential incidents include illegal collection of rocks and fossils, off-trail travel, and vandalism or graffiti (Booth-Binczik 2014). Law enforcement and telecommunications staff at Zion National Park, which share law enforcement responsibilities with Cedar Breaks NM, searched the IMARS database for these types of incidences that occurred from 2012 to April 2017. We reported the number and type of incident.

Rockfall or Slope Failures

We searched archived NPS press releases for Cedar Breaks NM for slope failures or rockfalls that affected NPS structures or interfered with visitor use (NPS 2017). We also relied on personal communication with Cedar Breaks NM staff for known occurrences of rockfall or slope failures that affected overlooks, structures, or other NPS facilities.

Presence/Absence of Earthquakes

Using the U.S. Geological Survey's Earthquake Catalog, we downloaded the locations of ≥ 2.5 magnitude (micro) earthquakes that occurred within an 80-km (50-mile) radius of the monument from 1997 to 2017 (USGS 2017). We downloaded data for natural earthquakes as well as seismic events that were human-caused by selecting the following search terms: anthropogenic, blasting, explosion, acoustic noise, and sonic booms. Table 4.5.2-1 shows the various earthquake magnitudes and class descriptions identified by the Incorporated Research Institutions for Seismology (IRIS 2017). Damage from earthquakes does not usually occur at a magnitude less than 4 or 5, but factors such as soil type and distance from the earthquake also determine whether damage occurs (USGS 2017).

We also consulted literature evaluating the movement along the Hurricane Fault, a major active fault with segments 9.7 to 19.4 km (6 to 12 mi) west of the monument. While the examination of the historic record is useful, major events on the Hurricane Fault are too widely spaced in time to be included in that record (Lund and others, 2007) An effort to evaluate seismic risk in Zion National Park was conducted in 2010 (i.e., Lund et al. 2010), and because that park is a similar distance from the Hurricane Fault, its conclusions can be applied to Cedar Breaks and are discussed in the Threats section.

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 two indicators and three measures. Since the monument is a seismically active region, we couched the reference conditions in terms of human impacts that may adversely affect geological or paleontological resources in the monument.

4.5.4. Condition and Trend

Anthropogenic Incidents

There were no IMARS related to human impacts to geological or paleontological features at Cedar Breaks NM (NPS, E. DeGroat, telecommunications manager, e-mail communication, 9 May 2017). This does not necessarily mean there were no incidents: only that none were reported. As noted in the wilderness character monitoring report, the remote backcountry areas of the breaks are rarely visited, so damage may go undetected (Booth-Binczik 2014). Conversely, visitors rarely visit these areas, so damage is also probably rare

Table 4.5.2-1. Earthquake magnitude descriptions.

Class	Magnitude
Great	≥ 8
Major	7 - 7.9
Strong	6 - 6.9
Moderate	5 - 5.9
Light	4 - 4.9
Minor	3 - 3.9
Micro	< 3

Source: IRIS (2017).

Table 4.5.3-1. Reference conditions used to assess geology.

Indicators	Measures	Good	Moderate Concern	Significant Concern
Known Deterioration of Geological or Paleontological Resources	Anthropogenic Incidents	There are no known anthropogenic incidents that affect geological or paleontological resources.	There have been a small number of known anthropogenic incidents that affect geological or paleontological resources.	There have been a medium to high number of known anthropogenic incidents that affect geological or paleontological resources.
	Rockfall or Slope Failures	There have been no incidents of rockfall or slope failure along trails, roads, or overlooks, or in close proximity to geologic features (e.g., hoodoos) within the monument. There also appear to be no areas of concern for such occurrences.	There have been a small number or low level of incidents of rockfall or slope failure along trails, roads, or overlooks, or in close proximity to geologic features (e.g., hoodoos) within the monument.	There have been a medium to high number or level of incidents of rockfall or slope failure along trails, roads, or overlooks, or in close proximity to geologic features (e.g., hoodoos) within the monument.
Seismic Activity	Presence/ Absence of Earthquakes	No anthropogenic seismic events have occurred in the vicinity of the monument.	Anthropogenic seismic events have occurred in the vicinity of the monument, but they occur at a low to moderate level (in either frequency or magnitude).	Anthropogenic seismic events have occurred in the vicinity of the monument, and they occur at a medium to high level (in either frequency or magnitude).

(Booth-Binczik 2014). However, off-trail travel occurs fairly regularly along the rim, especially at overlooks (NPS, B. Larsen, interview, 10 April 2017). Since no incidents were reported and NPS staff indicate these incidents in the sensitive breaks habitat are probably low due to inaccessibility, the condition is good. Trend is unknown and confidence is low due to the absence of a focused inventory of anthropogenic damage to geological and paleontological resources.

<u>Rockfall or Slope Failure</u>

Most park facilities are located above the breaks in areas of relatively gentle terrain. They are therefore at a very low risk of rockfall tumbling down onto the facility, and at a somewhat higher risk of rockfall undermining a structure near the rim. Few instances of rockfall or slope failures have been documented in the monument, although it is a potential hazard along all roads and trails (Thornberry-Ehrlich 2006). However, only four trails originate from within the monument and only one of them is located along the rim of the amphitheater and out to Ramparts Overlook. Because part of this trail is located in the breaks, it is occasionally washed out. In 2012 there were slope failures at the popular Chessmen Ridge and North View overlooks and in 2007, slope failure occurred at Point Supreme (Sharrow 2007). The Chessmen Ridge and North View areas were reinforced as a result of these events (NPS, P. Roelandt, superintendent, NRCA scoping meeting, 11 April 2017), and the railing at Point Supreme was rebuilt in 2008 about 3 m (10 ft) farther from its original location, "providing a margin for future cliff retreat" (Sharrow 2007). In total, there are five designated overlooks in the monument and off-trail travel is common at many of them (NPS, B. Larsen, biologist, NRCA scoping meeting, 10 April 2017). For these reasons, this measure is split between good and moderate concern condition. Confidence is medium since it's unlikely that all known rockfall and slope failures that affect trails, buildings, and other administrative areas have been documented. There are not enough data to determine trend.

<u>Presence/Absence of Earthquakes</u>

There were 179 earthquakes recorded from 1997 to 2017 (Figure 4.5.4-1). Of the 179 earthquakes, 109 were considered micro (< 3 magnitude), 66 were considered minor (3 - 3.9 magnitude), and four earthquakes were considered light (4 - 4.9 magnitude). There was no trend in earthquake activity from 1997 to 2017 (Figure 4.5.4-2) and none of the seismic events were related to anthropogenic activities (e.g., blasting, aircraft, sonic booms). Since all earthquakes were relatively small and none were related to human activities, this measure indicates good condition. Confidence is high and the trend is unknown.

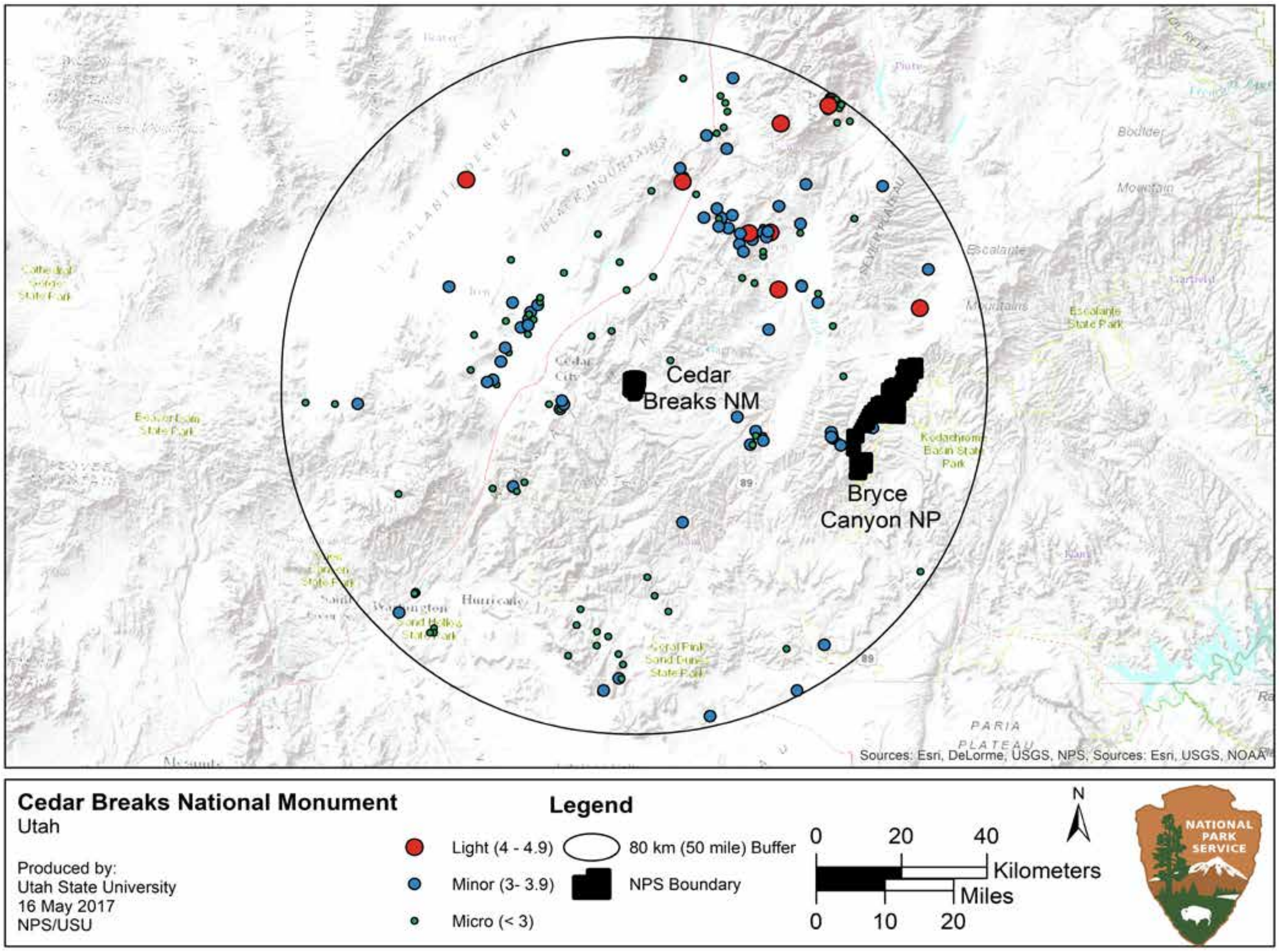


Figure 4.5.4-1. Map of earthquakes and anthropogenic seismic events during 1997-2017.

Overall Condition, Trend, Confidence Level, and Key Uncertainties

Table 4.5.4-1 summarizes the condition rating and rationale used for each indicator and measure. The overall condition rating for geologic resources in Cedar Breaks NM was split between good and moderate concern; however, it is important to note that data are limited. The condition rating was based largely on the two measures of known deterioration of geological or paleontological resources since these measures have the most immediate impact on geological features in the monument. While a single earthquake in close proximity to the monument, or an earthquake of high magnitude can cause substantial damage, it is the day-to-day stressors of rockfalls, slope failures, and vandalism (inadvertent or purposeful) that are the most immediate threats.

The first measure, anthropogenic incidents, was assigned low confidence since it is likely that at least some resource damage incidents were not recorded in the IMAR system. Fortunately, theft and damage to these resources is probably low due to the remote location of most geologic features. Low confidence was assigned to the measure of rockfall and slope failure because these events may also be underreported, although visitors are at low risk of injury as a result of these events. The limited access into the breaks significantly reduces the risk posed to visitors, which is the primary threat from this natural process. The greatest risk to visitors from slope failures is off-trail travel along the rim.

In contrast, the presence/absence of earthquakes measure was assigned high confidence because the USGS uses a network of seismograph stations that record earthquakes on a real-time basis over the long-term (USGS 2017). This measure was considered to be in good condition because none of the 179 earthquakes appeared to be related to anthropogenic

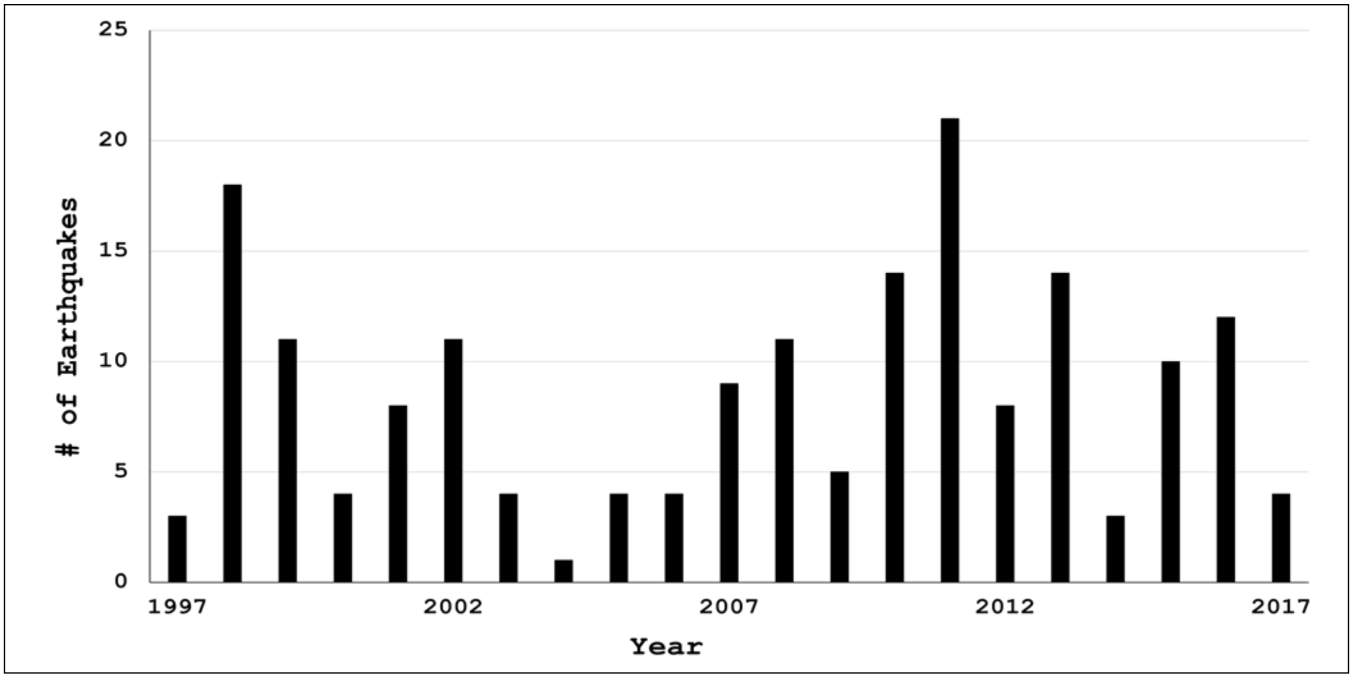


Figure 4.5.4-2. Number of earthquakes during 1997-2017.

activities. Although natural earthquakes have the potential to alter the geology of the monument, these are natural occurrences that are partly responsible for shaping this dynamic landscape.

Factors that influence confidence in the condition rating include age of the data (< 5 years 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.

Threats, Issues, and Data Gaps

There are a number of threats, issues, and data gaps related to geologic resources at Cedar Breaks NM. Rockfall and slope failures are a potential hazard along all roads and trails (Thornberry-Ehrlich 2006). This is a major concern in the weaker rock Red member and the highly fractured White member of the Claron formation, as well as the Straight Cliffs Sandstone (Thornberry-Ehrlich 2006). While there is no comprehensive study of the erosion processes at the monument with respect to the different rock formations associated with administrative features, including buildings, roads, and trails (Thornberry-Ehrlich 2006)), observation that the slopes below the rim are steep, loose and subject to frequent freeze-thaw cycles indicates that the rate is high. The potential loss of paleontological resources is high because of the high rate of erosion, but erosion also exposes new fossils. Although some work has been done to describe paleontological resources in the monument, a comprehensive survey has not been conducted (Tweet et al. 2012). The rapid erosion at the viewpoints throughout the monument is of concern due to the resultant impacts on facilities (Sharrow 2007).

The Hurricane Fault is a major fault stretching 249.4 km (155 mi) with its northern terminus a short distance north of Cedar City. Land west of the fault in Cedar Valley is falling relative to the plateau capped by Cedar Breaks. Based on studies of slip rates where the fault crosses and is offsetting basalt flows, and of surface ruptures along the fault scarp, Lund et al. (2007) estimated the slip rate on the Cedar City segment of 0.53 mm/year, an average frequency of large earthquakes of 2,800 years and the most recent surface rupturing quake 1,530 years ago. Their estimated largest possible earthquake is moment magnitude 6.6, which indicates that large earthquakes are possible but rare events. Substantial shaking lasting more than a minute would cause rockfall and slope failures. Liquefaction is unlikely due to the shallow bedrock.

While erosion is a natural and important geologic process reflective of the region's dynamic landscape (Figure 4.5.4-3), erosion due to anthropogenic causes

Table 4.5.4-1. **Summary of geology indicators, measures, and condition rationale.**

Indicators of Condition	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Known Deterioration of Geological or Paleontological Resources	Anthropogenic Incidents		Since no incidents were reported and NPS staff indicate these incidents in the sensitive breaks habitat are probably low due to inaccessibility, the condition is good. Trend is unknown and confidence is low due to the absence of a focused inventory of anthropogenic damage to geologic resources.
	Rockfall or Slope Failures		This measure is split between good and moderate concern condition since access into the breaks is limited except for a portion of one trail, but slides have occurred at three of the five overlooks and off-trail travel is common at many of them. Confidence is medium since it's unlikely that all known rockfall and slope failures that affect trails, buildings, and other administrative areas have been documented. There are not enough data to determine trend.
Seismic Activity	Presence/ Absence of Earthquakes		Since all earthquakes were relatively small and none were related to human activities, this measure indicates good condition. Confidence is high and the trend is unknown.
Overall Condition			The overall condition rating for geologic resources in Cedar Breaks NM was split between good and moderate concern; however, it is important to note that data are limited. The condition rating was based largely on the two measures of known deterioration of geological or paleontological resources since these measures have the most immediate impact on geological features in the monument. Confidence is low and trend is unknown.

may alter the monument's geology beyond what is natural. Social trails contribute to erosion, soil compaction, and the destruction of native vegetation, but there are no data on the effects of social trails in the monument (NPS 2015a). Social trails also pose a threat to visitor safety in the advent of a slope failure. Some visitors may not be aware that off-trail travel along the rim is illegal, and even a small number of visitors can have a significant impact on sensitive soils and vegetation (NPS 2015a). Once social trails have become established they are difficult to rehabilitate (NPS 2015a). This is of particular concern since many of the monument's rare plant species occur in the breaks (Fertig and Reynolds 2009). Finally, fire also increases erosion at least in the short-term, but this disturbance is a largely natural and necessary process for the fire-adapted forests on the plateau (NPS 2015a), although the presence of invasive species combined with climate change has increased the fire frequency.

Although less obvious than direct human impacts, climate change could also alter patterns and rates of erosion since water is the primary driver that shapes the landscape. Monahan and Fisichelli (2014) evaluated which of 240 NPS units have experienced extreme climate changes during the last 10-30 years. Extreme climate changes were defined as temperature and precipitation conditions exceeding 95% of the historical range of variability. These results indicate a trend toward warmer but not necessarily drier conditions within the monument (Monahan and Fisichelli 2014). While there were no apparent changes in total precipitation, warmer temperatures influence whether precipitation falls as snow or rain, which in

Figure 4.5.4-3. A bristlecone pine on the edge of the breaks. Photo Credit: NPS/Bryan Larsen.

turn may affect the timing, rate, and degree of erosion (Thornberry-Ehrlich 2006).

Cedar Breaks NM is located in a seismically active zone, but most earthquakes are of low magnitude. However, the monument is located to the east of the Hurricane Fault, which "is capable of producing rare earthquakes up to a magnitude 7" (NPS 2015a)._Although several mines that use blasting are located near the monument (Thornberry-Ehrlich 2006), no anthropogenic seismic events have been recorded during the last 20 years. However, a more focused study on the effects of nearby mines and active faults near or in Cedar Breaks NM is needed (Thornberry-Ehrlich 2006). There are no abandoned mineral land features in the monument (Burghardt et al. 2014).

The geologic features of Cedar Breaks NM are the defining resource of the monument. The exposed Claron Formation provides an excellent opportunity for visitors to visualize the past geologic environment and to even witness the forces that shape the landscape. While many areas of the monument are protected because they are difficult to access, trails and overlooks receive heavy use, including off-trail travel, which may be the most significant threat to the monument's geological and paleontological resources.

4.5.5. Sources of Expertise

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

4.6. Springs and Seeps

4.6.1. Background and Importance

Springs and seeps are perennial or intermittent pools of water that flow to the ground surface from bedrock or soil (Kreamer and Springer 2008). Seeps are often represented by small pools or damp soils at the earth's surface, while springs usually exhibit measurable discharge (Kreamer and Springer 2008, Springer and Stevens 2008). In Cedar Breaks National Monument (NM) springs and seeps are an uncommon but important resource for wildlife and plants (Figure 4.6.1-1; Springer et al. 2006). These unique wetland habitats attract aquatic invertebrates, amphibians, birds, and other wildlife not found elsewhere (Cantonati et al. 2012). Historically, humans have also been attracted to these areas, and springs and seeps emerging from caves may yield evidence of past human occupation (Thornberry-Ehrlich 2006). Aside from Ashdown Creek, springs and seeps represent the only perennial source of water in the monument (Tendick et al. 2011).

Although water is limited in Cedar Breaks NM, it is the primary driving force responsible for the unusual geologic formations (i.e., the breaks) that the monument is known for (Thornberry-Ehrlich 2006). The breaks are a unique collection of rock spires, fins, pinnacles, and canyons formed by the erosion of the colorful sandstones, mudstones, and limestones of the Claron Formation (Thornberry-Ehrlich 2006). The majority of the monument's springs and seeps occur near the base of the breaks where the "ground surface intersects an aquifer or groundwater conduit" (Thornberry-Ehrlich 2006). Although less numerous, springs also occur above the breaks in the eastern part of the monument, which is located on the Markagunt Plateau (Thornberry-Ehrlich 2006).

The Markagunt Plateau contains the highest elevation areas in southwestern Utah with an average elevation of 2,896 m (9,500 ft) (Thornberry-Ehrlich 2006, Spangler 2012). Brian Head Peak, located just north of the monument, is the highest point on the plateau at an elevation of 3,446 m (11,307 ft) (Spangler 2012). Owing to the monument's high elevation relative to the surrounding region, springs and seeps originating on the plateau form the headwaters of tributaries to principal drainages within and outside the monument (Spangler 2012). Ashdown Creek, which merges with Coal Creek downstream, forms the principal drainage in the western half of the monument below the breaks, while Mammoth Creek and its associated tributaries form the principal drainage to the east of the breaks (Spangler 2012).

Since Cedar Breaks NM was established in 1933, there has been little development of water resources within the monument (NPS 2015a). In 1925 however,

Figure 4.6.1-1. Alpine Pond Spring in Cedar Breaks NM. Photo Credit: NPS.

Blowhard Spring was developed for human use, and between 1933 and about 2000, Twin Spring, just southwest of Spectra Point, was also diverted into the water supply system (Utah Division of Water Rights 2000). Currently, the monument's only water supply is extracted from Blowhard Spring (NPS, P. Roelandt, Superintendent, NRCA scoping meeting, 11 April 2017).

4.6.2. Data and Methods

To assess the current condition of springs and seeps in Cedar Breaks NM, we used four indicators with between two and five measures each for a total of 12 measures. Springs and seeps were identified as an important resource for monitoring at select Northern Colorado Plateau Network (NCPN) parks (Weissinger and Moran 2013). Although Cedar Breaks NM was not selected for monitoring water resources in the network, park staff have identified springs and seeps as important for their own monitoring purposes. The three indicators that were selected by the NCPN for monitoring springs and seeps were: water quantity, water chemistry, and vegetation species composition (Weissinger and Moran 2013). We also included additional indicators and measures (described below) that Natural Resource Condition Assessment (NRCA) staff and Cedar Breaks NM natural resources staff determined as important for assessing springs and seeps in the monument. Figure 4.6.2-1 shows the location of known springs and seeps in Cedar Breaks NM.

Spring Discharge (L/s)

In 2005, 75 springs and seeps were inventoried in 26 National Park Service (NPS) units across the Northern and Southern Colorado Plateau Inventory and Monitoring Networks (I&M), two of which were located in Cedar Breaks NM: Sunset View Spring

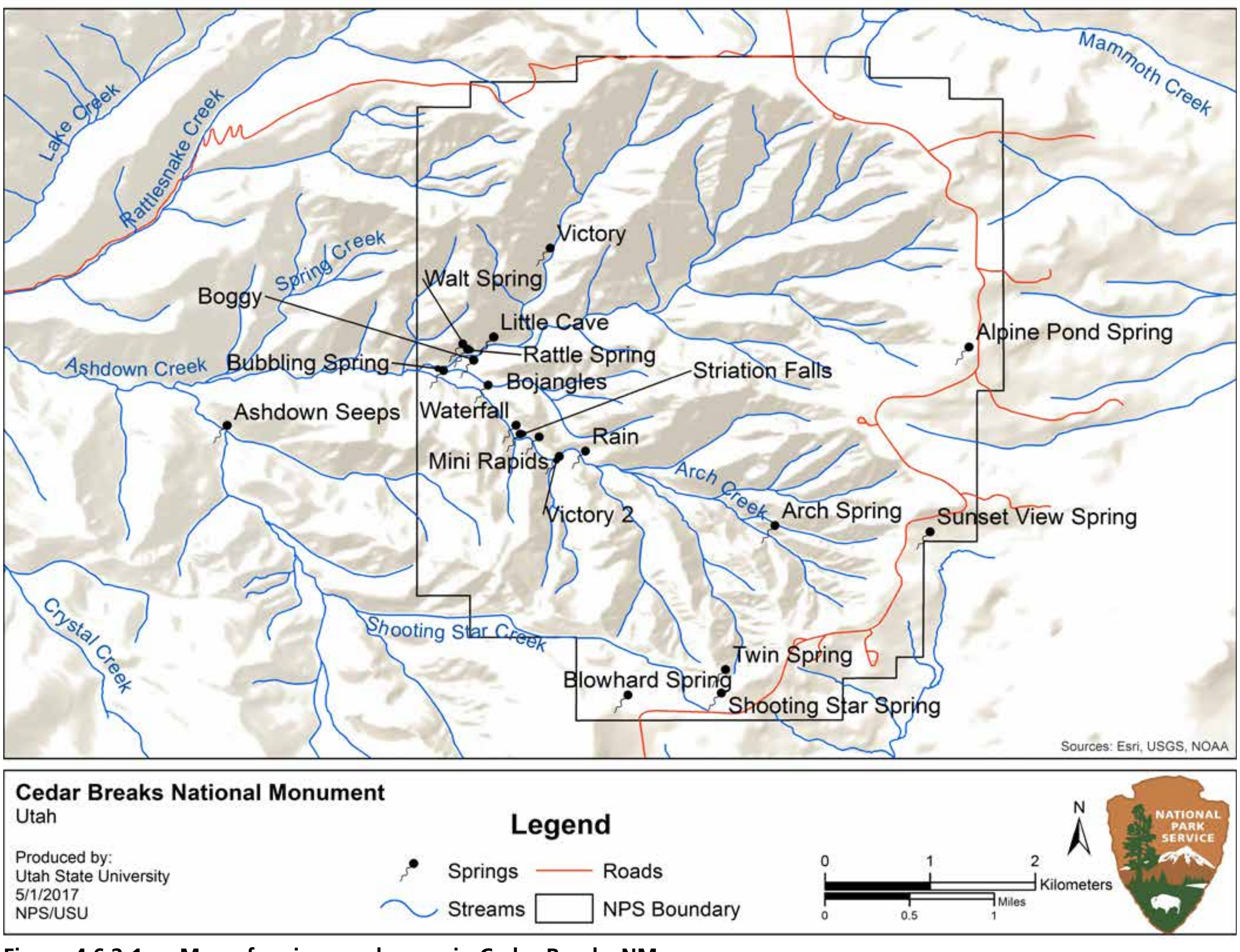


Figure 4.6.2-1. Map of springs and seeps in Cedar Breaks NM.

and Alpine Pond Spring (Springer et al. 2006). Data on spring discharge were collected on 22 August and 23 August, respectively. Spring discharge data were also downloaded from the National Water Quality Monitoring Council's (NWQMC) water quality portal (NWQMC 2017) on 4 April 2017. The NWQMC water quality portal integrates water quality data from the U.S. Geological Survey's National Water Information System (NWIS), the U.S. Environmental Protection Agency's STOrage and RETrieval (STORET) data warehouse, and the U.S. Department of Agriculture's Sustaining The Earth's Watersheds - Agricultural Research Database System (STEWARDS). Spring discharge data were available for four springs. The springs were: Alpine Pond Spring, Blowhard Spring, Twin Spring, and Sunset View Spring. Data were reported intermittently from May through October 1957 to 1984.

Water Rights

Since data on spring discharge were limited and dated, we also reviewed water rights for the monument. In 2000, Cedar Breaks NM entered into a Water Rights Settlement Agreement with the State of Utah (Utah-DWR 2000). We describe the current status of water rights for water resources occurring within the monument as a proxy for water quantity but acknowledge that this only accounts for human use of water resources and does not take into account the effects of climate change or other variables on water quantity. We downloaded geographic information system (GIS) data for water rights areas from Utah's Division of Water Rights website (Utah-DWR 2015).

Water Quality: Specific Conductance, pH, Dissolved Oxygen, Temperature, and Nitrates

We drew from several sources to describe water quality measures for springs and seeps in the monument, including Govedich and Bain (2012), Springer et al. (2006), and NWQMC (2017). Each report and data storage system provided different types of data for different water resources within the monument. Each source is described in the following text.

Water quality data (pH, dissolved oxygen, and nitrates) were collected at 14 springs located in the breaks during 2008 to 2011 (Govedich and Bain 2012). Although numerous additional water quality measures were also collected as part of this study, we only included those used by the NCPN in their monitoring efforts with the exception of nitrates.

On 22-23 August 2005, Springer et al. (2006) sampled Sunset View Spring and Alpine Pond Spring for specific conductance, pH, temperature, and dissolved oxygen (see the report for other water quality measures). 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).

Water quality data were downloaded from the NWQMC website on 4 April 2017 as described for water quantity (NWQMC 2017). Data for specific conductance, pH, dissolved oxygen, and temperature were reported intermittently for six springs from May through October 1957 to 1984. The significance of each water quality measure is described below.

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 2016b). To place the values for conductance for waters in the park in perspective, the recommended level for total dissolved solids in drinking water is 500 mg/l which is approximately equal to 940 ųS/cm of conductance (USEPA 2016c).

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 2016b).

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 2016b). Dissolved oxygen affects the ability of organisms and plants to live and grow in water bodies.

Temperature (° C)

All core water quality parameters are influenced by temperature. For example, groundwater with higher temperatures typically has a lower pH, which in turn dissolves more minerals from the surrounding rock than cooler water. This, in turn, influences specific conductivity (USGS 2016b). However, water temperature from springs is usually stable with limited daily and seasonal fluctuations, but variation in temperature depends on rates of discharge and aquifer depth among other variables and is useful for interpreting other water quality measures.

Nitrates (mg/L)
Nitrates are essential for wildlife and plants, but an excess of nitrates from agricultural practices and pollution can cause overgrowth of aquatic plants and algae (USGS 2016b). While nitrates are naturally occurring in the environment, they can also be limiting in certain environments. Maintaining a healthy balance is critical to ecological function (USGS 2016b).

Bacteria: Fecal and total coliform (MPN/100 ml)
As described above for water quality, bacteria data were downloaded from the NWQMC water quality portal (NWQMC 2017) on 4 April 2017. We reported fecal coliform and total coliform in MPN (most probable number) per 100 ml. Total coliform bacteria was historically thought to serve as an indicator of fecal coliform, which is associated with the gastrointestinal tract of warm-blooded mammals and is harmful to human health above certain thresholds (USGS 2016b). However, total coliforms are widely spread in nature and do not necessarily indicate fecal contamination by mammals. Fecal coliform are a subgroup of coliform bacteria and serve as a better indicator fecal contamination by mammals (USGS 2016b). *E. coli* is a member of the fecal coliform group and their presence provides the most direct evidence of fecal contamination of water resources; however, *E. coli* data were not available.

Biodiversity: Plant Presence, Aquatic Invertebrate Presence, and Herpetofauna Presence
Plant Presence
We used plant species data presented in Springer et al. (2006). Plant species were inventoried at Alpine Pond Spring and Sunset Spring as part of a 2005 effort to assess baseline condition for 75 springs across the Northern and Southern Colorado Plateau I&M Network parks. We report a species list for plants identified at these two springs in the monument. For each plant species, we determined its wetland status for the western mountain subregion (USDA-NRCS 2006) 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 were: 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).

Aquatic Invertebrate Presence
We used aquatic invertebrate species data provided in Springer et al. (2006) and Govedich and Bain (2012). In August 2005, aquatic invertebrates were inventoried at Alpine Pond Spring and Sunset Spring (Springer et al. 2006). From 2008 to 2011, invertebrates were sampled at fourteen springs in and around Cedar Breaks NM (Govedich and Bain 2012). In 2016, invertebrates were also sampled at Alpine Pond Spring only (Southern Utah University, F. Govedich, professor, e-mail communication, 25 January 2017).

Herpetofauna Presence
We used herpetofauna data provided in Platenberg and Graham (2003). During 2001 and 2002, NCPN staff surveyed reptiles and amphibians in 11 national parks across the network. Cedar Breaks NM was surveyed during 2001-2002 using a variety of methods, including diurnal visual encounter surveys, nocturnal spotlight surveys, night road driving, and time-and-area constrained searches. Random encounters were also recorded. The authors also included a review and evaluation of others' past observations, and museum specimens (Platenberg and Graham 2003).

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 or moderate/significant concern for each of the four indicators and 12 measures.

Water Quantity
Spring discharge and stream flow vary considerably in response to seasonal variation in precipitation and snowmelt (Spangler 2012). This, coupled with the paucity of data, necessitated qualitative reference conditions. We considered a spring or seep with an overall stable annual discharge to be in good condition. Moderate to significant concern condition would be warranted if annual spring discharge has declined over time. We also considered water quantity to be in good condition if the 2000 Water Rights Agreement (Utah Division of Water Rights 2000) protects water

Table 4.6.3-1. Reference conditions used to assess springs and seeps.

Indicator	Measure	Good	Moderate Concern	Significant Concern
Water Quantity	Spring Discharge (L/s)	Spring discharge was stable over time.	Spring discharge has declined over time.	Spring discharge has declined over time.
	Water Rights	Cedar Breaks NM retains all water rights for the monument and is not adversely affected by water rights claims outside the monument boundaries.	Cedar Breaks NM does not retain all water rights for the monument and is adversely affected by water rights claims outside the monument boundaries.	Cedar Breaks NM does not retain all water rights for the monument and is adversely affected by water rights claims outside the monument boundaries.
Water Chemistry: Core Water Quality	Specific Conductance (μ/cm)	State of Utah standards not established.	State of Utah standards not established.	State of Utah standards not established.
	pH (SU)	6.5 to 9.0	< 6.5 or > 9.0	< 6.5 or > 9.0
	Dissolved Oxygen (mg/L)*	≥8.0/4.0	<8.0/4.0	<8.0/4.0
	Temperature (°C)	≤ 20	> 20	> 20
	Nitrates (mg/L)	≤ 4	> 4	> 4
Bacteria	Fecal coliform (MPN/100 ml)	Standards for natural systems not established.	Standards for natural systems not established.	Standards for natural systems not established.
	Total coliform (MPN/100 ml)	Standards for natural systems not established.	Standards for natural systems not established.	Standards for natural systems not established.
Biodiversity	Plant Presence	No reference conditions developed.	No reference conditions developed.	No reference conditions developed.
	Aquatic Invertebrate Presence	No reference conditions developed.	No reference conditions developed.	No reference conditions developed.
	Herpetofauna Presence	No reference conditions developed.	No reference conditions developed.	No reference conditions developed.

* First number applies to when early life stages are present; second number applies to when all other life stages are present.

resources in the monument with no adverse affects of water rights claims outside the monument boundary.

Water Quality

We compared water quality data (pH, dissolved oxygen, temperature, and nitrates) to reference conditions for aquatic wildlife using water quality standards developed by the Utah Division of Water Quality (Utah-DWQ 2016). There were no water quality standards for specific conductance. Although these water quality standards were not meant to specifically address groundwater-based systems (i.e., springs and seeps), they provide a useful starting point for assessing water quality condition. However, assessing condition based solely on these standards is not recommended. There were no water quality standards for groundwater.

Bacteria

There were no reference conditions for natural systems where the primary concern is for wildlife and plants (USGS 2016b). Therefore, we present total coliform and fecal coliform data but do not report on condition.

Biodiversity

We did not develop reference conditions for biodiversity in Cedar Breaks NM. Instead, we created species lists that can be used for future comparisons.

4.6.4. Condition and Trend

Spring Discharge (L/s)

In August 2005, discharge measured 0.4 L/s at Sunset View Spring and 1.0 L/s at Alpine Pond Spring (Springer et al. 2006). These data were the most recent discharge data for springs and seeps in the monument but were of limited value since they are instantaneous one-time measurements, and spring discharge is expected to vary seasonally with snowmelt and even daily during the summer in response to local precipitation (Spangler 2012).

Figures 4.6.4-1, -2, -3, and -4 show discharge data reported for four springs between the years 1957 and 1984, primarily from May through October. In general, flows declined throughout the summer into the autumn months. This is expected for springs driven largely by snowmelt, but as noted, heavy

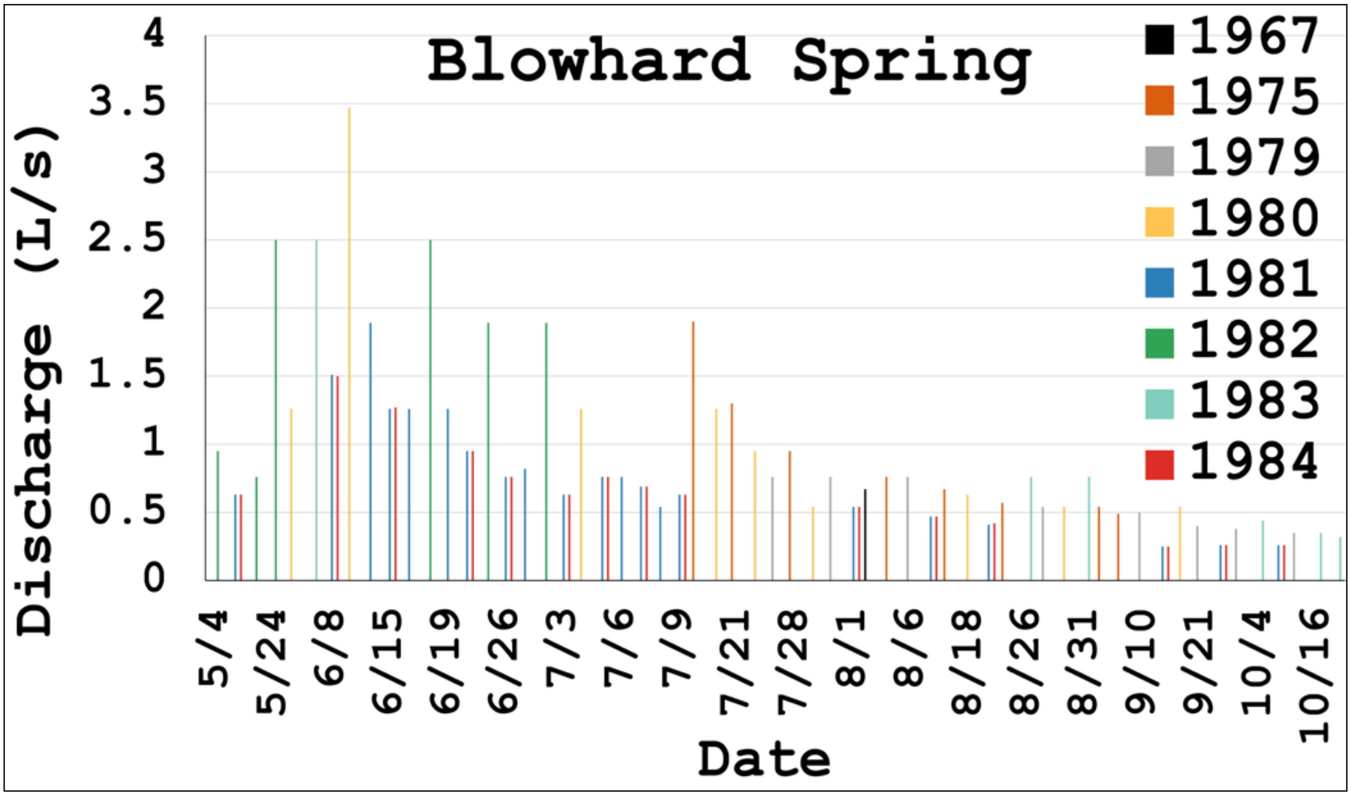


Figure 4.6.4-1. **Discharge at Blowhard Spring from 1967 to 1984.**

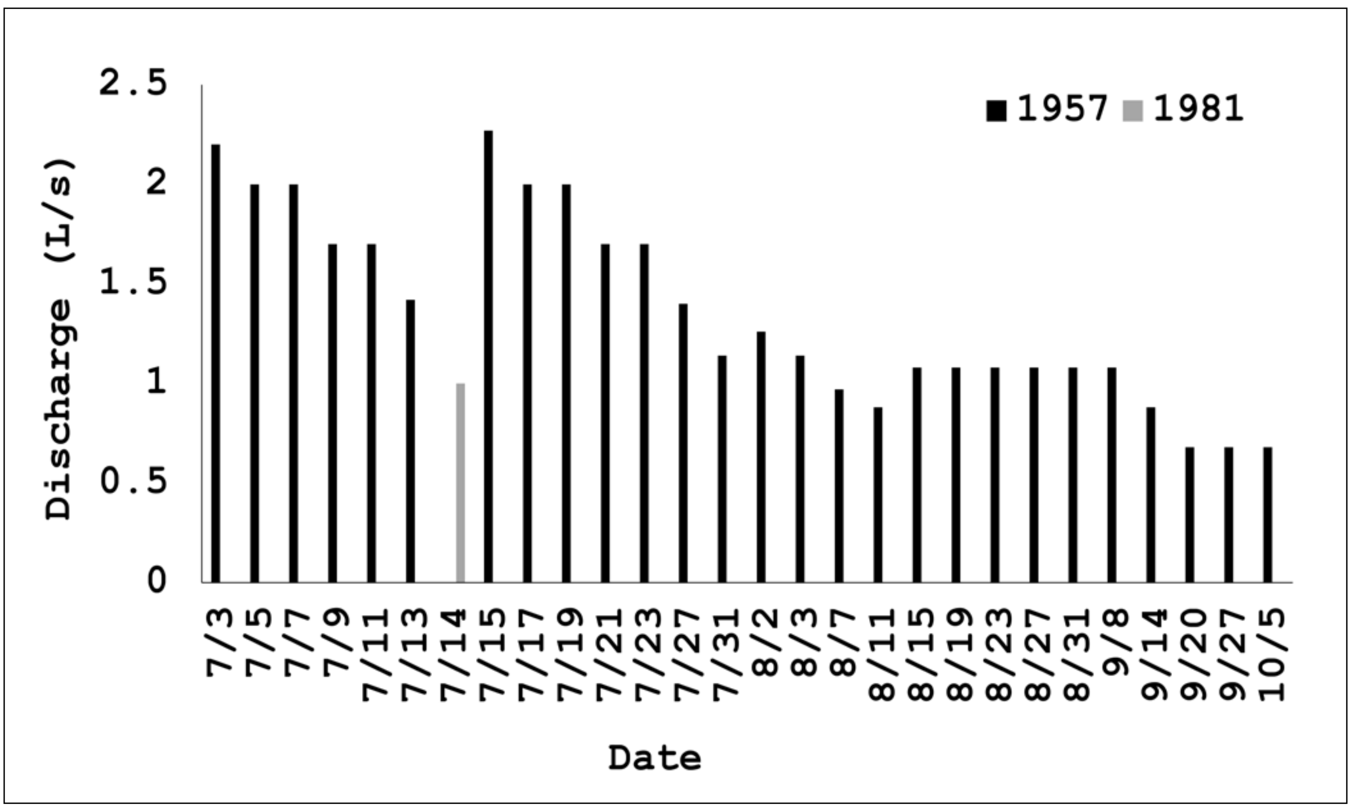


Figure 4.6.4-2. **Discharge at Alpine Pond Spring in 1957 and 1981.**

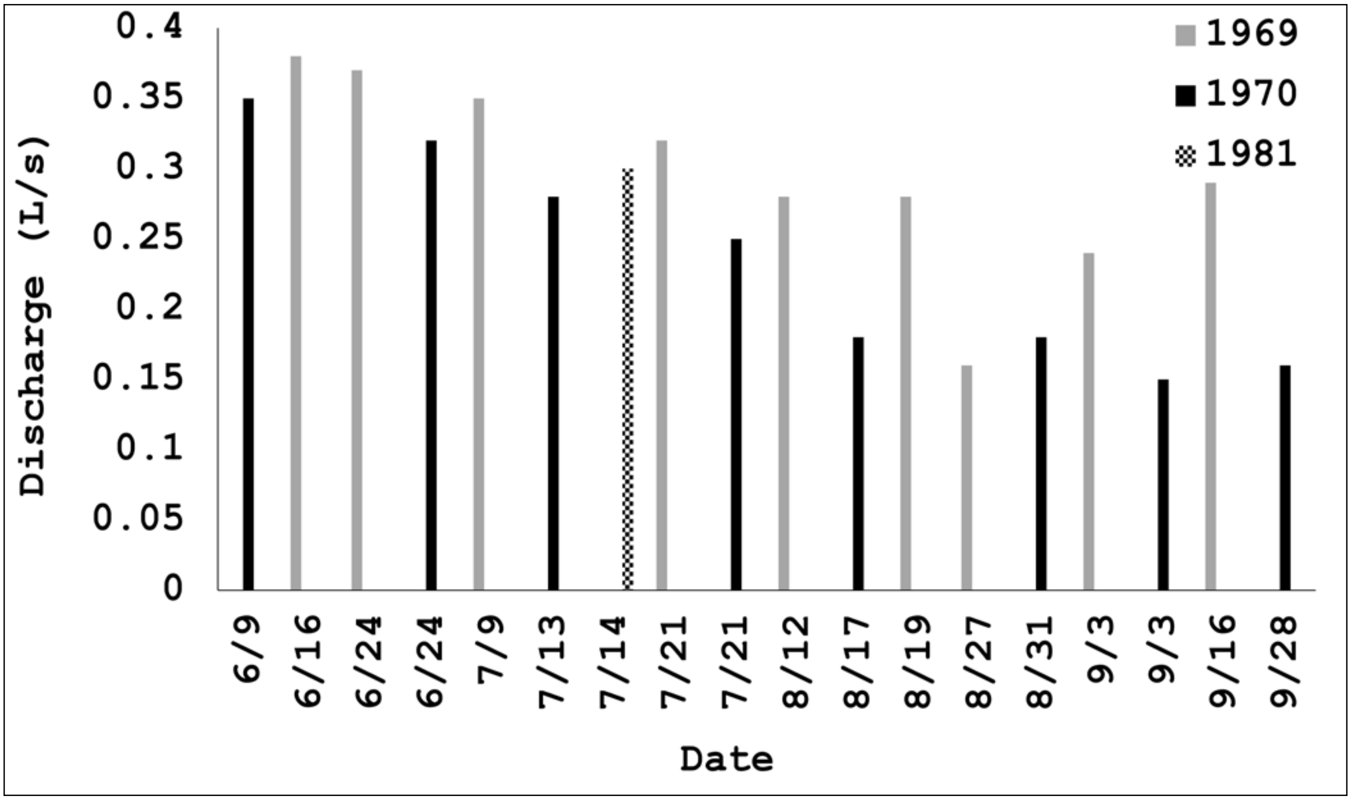


Figure 4.6.4-3. Discharge at Sunset View Spring in 1969, 1970, and 1981.

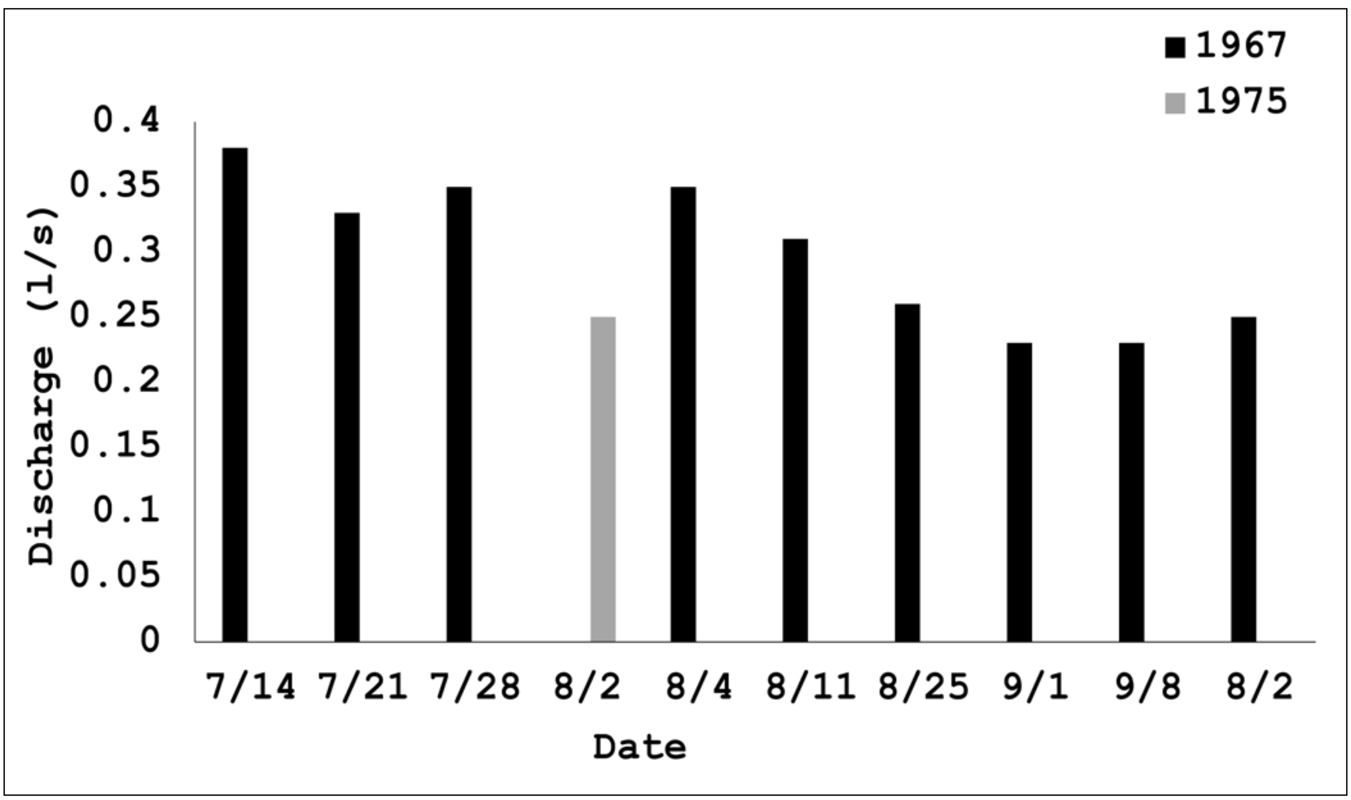


Figure 4.6.4-4. Discharge at Twin Spring in 1967 and 1975.

monsoonal precipitation also affects spring discharge. Blowhard spring is impacted to some degree by water withdrawals by the NPS for administrative uses (Figure 4.6.4-1). At Alpine Pond Spring, similar discharge data were reported on 23 August 2005 (1.00 L/s) and on 23 August 1957 (1.08 L/s), which suggests unchanging conditions (Figure 4.6.4-2). At Sunset View Spring, discharge was slightly lower for similar dates in 1969 (0.28 L/s on 19 August and 0.16 L/s on 27 August) than for a similar date during 2005 (0.4 L/s) (Figure 4.6.4-3). While these data provide some insights into patterns of spring discharge, the lack of continuous measurements that reflect daily, seasonal, and annual patterns limit their utility for assessing the current condition of springs and seeps in the monument. Given these factors, the condition and trend for this measure is unknown and confidence is low.

<u>Water Rights</u>
Cedar Breaks NM has retained water rights for all water resources in the monument as described in the Water Rights Settlement Agreement (Utah Division of Water Rights 2000). The monument is allowed to deplete up to 2 acre-feet of water per year from the Sevier River Basin and 3 acre-feet per year from the Cedar City Valley drainage (Figure 4.6.4-5). Per the agreement, the monument "has reserved a right to all water underlying, originating within or flowing through Cedar Breaks National Monument, including perennial, intermittent and ephemeral streams, springs, seeps, lakes, ponds, ground water, and other natural sources of water, pertaining or belonging to the reserved lands, that was unappropriated as of the dates of the reservation of the lands now within the boundaries of the monument..." (Utah Division of Water Rights 2000).

The only appropriated water rights prior to the 2000 agreement were the water rights to develop Blowhard Spring and Twin Spring for administrative and visitor use by the NPS. A state water right appropriated in 1933 was terminated via 2000 agreement so that the

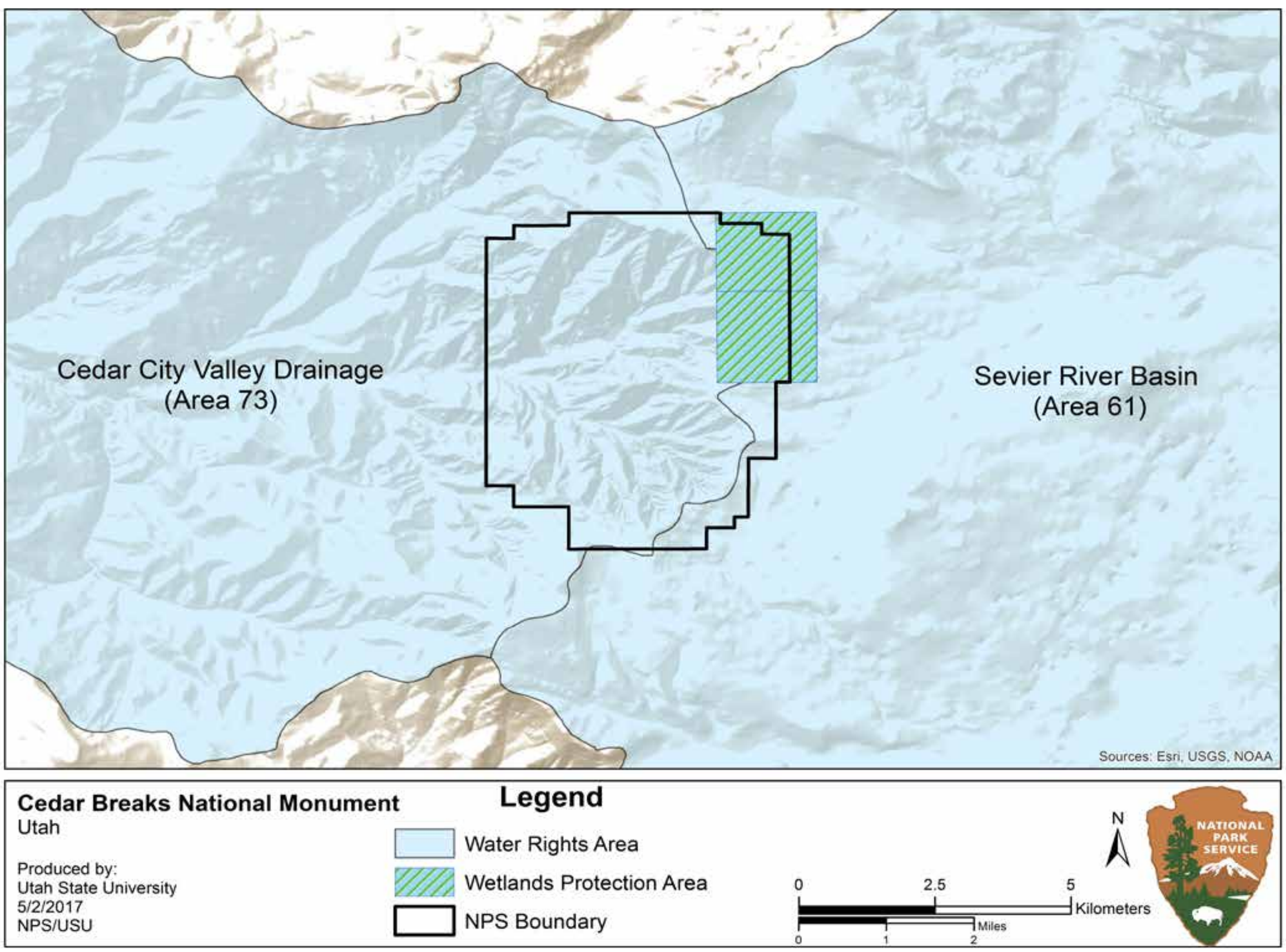


Figure 4.6.4-5. **Map of water rights for Cedar Breaks NM.**

monument has full control of water rights within the monument as outlined in the agreement. Furthermore, a wetland resources protection zone was established within 0.40 km (0.25 mi) of the eastern boundary of the monument, so that no new applications for water development will be awarded unless the applicant demonstrates no adverse effects within the protection zone (Figure 4.6.4-2). Since the monument retains water rights for the lands within the NPS boundary and the monument is considered the headwaters for both drainages, we consider this measure of water quantity to be good. Confidence is high.

Specific Conductance (µS/cm)

Specific conductance was measured at six springs in the monument with the most recent data collected at Arch Spring in 2007 (Table 4.6.4-1). Specific conductance ranged from 199 µS/cm at Alpine Pond Spring in 2005 to 449 µS/cm at Sunset View Spring in 1981. In a study of Mammoth Spring north of the monument, specific

Table 4.6.4-1. Water quality data for springs in Cedar Breaks NM.

Spring Name	Date (yyyy-mm-dd)	Specific Conductance (µS/cm)	pH (SU)	Dissolved Oxygen (mg/L)	Temperature (°C)	Nitrates (mg/L)	Data Source
Alpine Pond Spring	1967-08-02	276	7.6	–	3.3	–	NWQMC
	1981-07-14	255/290	7.8	–	3.0	–	NWQMC
	2005-08-23	199	7.4	7.57	3.6		Springer et al. (2006)
Arch Spring	2007-09-14	291/302	6.8/8.0	–	4.6	–	NWQMC
	2009-09-26	–	8.1	–	–	<0.10	Govedich and Bain (2012)
Ashdown Seeps*	2008/2011	–	7.3	6.25	–	<0.10	Govedich and Bain (2012)
Bigfoot Spring	2010-07-02	–	8.3	7.50	–	0.20	Govedich and Bain (2012)
Blowhard Spring	1967-08-02	–	–	–	3.3	–	NWQMC
	1974-07-30	375/400	6.9	–	–	–	NWQMC
	1988-11-01	373	8.0	–	–	–	NWQMC
Bojangles Spring	2008-2011	–	7.8	6.57	–	<0.10	Govedich and Bain (2012)
Bubbling Spring	2008-2011	–	7.4	3.98	–	<0.10	Govedich and Bain (2012)
Little Cave Spring	2010-07-02	–	6.8	7.30	–	0.20	Govedich and Bain (2012)
Mini Rapids Spring	2008-2011	–	7.3	8.81	–	<0.10	Govedich and Bain (2012)
Rain Spring	2008-2011	–	7.5	7.93	–	<0.10	Govedich and Bain (2012)
Rattle Spring	2008-2011	–	6.8	7.01	–	0.20	Govedich and Bain (2012)
Shooting Star Spring	1974-07-30	400	6.8	–	–	–	NWQMC
Striation Falls Spring	2008-2011	–	8.6	8.63		<0.10	Govedich and Bain (2012)
Sunset View Spring	1968-07-12	241	7.7	–	13.0	–	NWQMC
	1969 (June-September)	–	–	–	7.2	–	NWQMC
	1970-09-03	260/438	7.5/7.9	–	–	–	NWQMC
	1970 (June-September)	–	–	–	7.2	–	NWQMC
	1974-05-22	260	7.7	–	13	–	NWQMC
	1981-07-14	410/449	7.8/7.9	–	9	–	NWQMC
	2005-08-22	325	6.6	5.93			Springer et al. (2006)
Twin Spring	1967-08-02	–		–	3.3	–	NWQMC
	1974-07-30	340	7	–	–	–	NWQMC
Victory Spring	2008-2011	–	7.3	11.43	–	<0.10	Govedich and Bain (2012)
Victory 2 Spring	2008-2011	–	7.2	8.87	–	<0.10	Govedich and Bain (2012)
Walt Spring	2010-07-02	–	7.56	7.00	–	0.12	Govedich and Bain (2012)
Waterfall Spring	2008-2011	–	8.6	8.07	–	<0.10	Govedich and Bain (2012)

* Located in Ashdown Gorge Wilderness.

conductance was highly variable and was inversely related to changes in discharge during snowmelt and rainfall events (Spangler 2012). Thus, specific conductance can be useful for determining the source of groundwater (e.g., snowmelt vs. groundwater) and age of the water, which varied depending on time of year (Spangler 2012). Since there were no standards for specific conductance, there were too few measurements to assess trend, and no recent data, we could not determine condition or trend for this measure. Confidence is low.

pH (SU)

Data on pH were reported at least once between 1967 and 2011 for each of 19 springs (Table 4.6.4-1). All of the measurements were within the allowable limits established by the state of Utah (Utah DWQ 2016). The pH ranged from 6.8 to 8.6 SU. Although the data indicate good condition, the most recent measurements were collected between 2008 and 2011 and do not inform current condition. Therefore, the condition and trend for this measure is unknown. Confidence is low.

Dissolved Oxygen (mg/L)

Dissolved oxygen was measured at 13 springs (Table 4.6.4-1). At all springs except Bubbling Spring, dissolved oxygen was greater than 4.0 mg/L, or the threshold for aquatic wildlife at all life stages. The threshold of 8.0 mg/L was only met in five of the 13 springs during the 2008-2011 sampling period. However, dissolved oxygen in groundwater is naturally lower than in surface water (USGS 2016b). Since data were collected 10 or more years ago, we consider this measure to be unknown with unknown trend and low confidence.

Temperature (°C)

Temperature data were collected at least once at five springs from 1967 to 2007 (Table 4.6.4-1). All measurements were well below the 20°C threshold established by the state of Utah for cold water game and fish (Utah DWQ 2016). Since the most recent data are 10 years old and there were only 10 measurements over the 40 years of data collection, the condition is unknown and trend could not be determined. Confidence is low.

Fecal coliform (MPN/100 ml)

Water samples collected at Blowhard Spring (n = 8) and Shooting Star Spring (n = 6) tested positive on one occasion each in 1990 and 1984, respectively (Table 4.6.4-2). No bacteria were detected on the twelve additional sample dates for these two springs. No fecal coliform bacteria were detected for the single Twin Spring sample. No reference conditions have been established for naturally occurring bacteria in freshwater springs. Furthermore, the most recent data were collected 20 years ago. Therefore, we consider this measure to be unknown with low confidence and unknown trend.

Total coliform (MPN/100 ml)

Total coliform bacteria were detected one out of four samples at Blowhard Spring and three out of five samples at Shooting Star Spring (Table 4.6.4-2). No bacteria were detected at Twin Springs, but this is based on a single sample. Since the data are more than ten years old, we could not determine condition in total coliform bacteria. The trend is unknown and confidence is low.

Plant Presence

A total of 56 plant species were recorded at Sunset View Spring, four of which were non-native (Table 4.6.4-3). At Alpine Pond Spring, 21 species were recorded with only two non-native species. In total, there were 64 species recorded between the two

Table 4.6.4-2. Indicator bacteria for seeps and springs in Cedar Breaks NM.

Spring	Date (yyyy-mm-dd)	Fecal coliform (MPN/100 ml)	Total Coliform (MPN/100 ml)
Blowhard Spring	1985-08-08	*Non detected	–
	1990-05-17	1	2
	1991-05-14	*Non detected	–
	1993-05-18	*Non detected	–
	1994-05-06	*Non detected	–
	1995-05-09	*Non detected	*Non detected
	1996-04-22	*Non detected	*Non detected
	1997-04-21	*Non detected	*Non detected
Shooting Star Spring	1984-07-10	*Non detected	*Non detected
	1984-07-20	32	100
	1984-08-06	*Non detected	200
	1984-08-07	*Non detected	100
	1989-05-31	*Non detected	–
	1997-10-15	*Non detected	*Non detected
Twin Spring	1997-10-15	*Non detected	*Non detected

* Value entered in legacy STORET was 0. This value was identified as below an unspecified detection limit.

Table 4.6.4-3. Plants documented at Sunset View Spring and Alpine Pond Spring in Cedar Breaks NM.

Lifeform	Species	Common Name	Wetland Status
Trees	*Picea spp.*[2]	Spruce	FAC
	Picea engelmannii[3]	Columbian spruce	FAC
Shrubs	*Castilleja miniata*[3]	Giant red Indian paintbrush	FACW
	Lonicera involucrata[2,3]	Bearberry honeysuckle	FAC
	[Dasiphora] Potentilla fruticosa[3]	Shrubby cinquefoil	FAC
	Ribes montigenum[2,3]	Alpine prickly currant	UPL
	Salix brachycarpa[3]	Shortfruit willow	FACW
	Moss[2,3]	Undesignated moss	UNK
Grasses	*Agrostis idahoensis*[2]	Idaho bentgrass	FACW
	Carex aquatilis[2,3]	Water sedge	OBL
	Carex aurea[2,3]	Golden sedge	FACW
	Carex interior[3]	Inland sedge	OBL
	Carex microptera[2,3]	Ovalhead sedge	FACU
	Carex norvegica ssp. stevensii[3]	Steven's sedge	FAC
	Carex pellita[3]	Woolly sedge	OBL
	Carex scirpoidea[3]	Canadian single-spike sedge	FAC
	Carex utriculata[3]	Beaked sedge	OBL
	Carex vesicaria[2]	Blister sedge	OBL
	Deschampsia caespitosa[2,3]	Tufted hairgrass	FACW
	Eleocharis palustris[3]	Common spikerush	OBL
	Elymus trachycaulus[3]	Slender wheatgrass	FAC
	Hordeum brachyantherum[3]	Meadow barley	FACW
	Juncus arcticus[3]	Arctic rush	OBL
	Juncus ensifolius[3]	Swordleaf rush	FACW
	Juncus longistylis[3]	Long-style rush	FACW
	Luzula parviflora[2]	Millet woodrush	FAC
	Phleum alpinum[2,3]	Alpine timothy	FAC
	Poa compressa[1,2]	Canada bluegrass	FACU
	Poa pratensis[1,3]	Kentucky bluegrass	FAC
	Poaceae[3]	Grasses	UNK
Forbs	*Achillea millefolium*[3]	Bloodwort	FACU
	Aconitum columbianum[3]	Columbia monkshood	FACW
	Agoseris glauca[3]	Pale agoseris	FAC
	Angelica pinnata[3]	Small-leaf angelica	FACW
	Symphyotrichum foliaceum parryi [*Aster foliaceus var. parryi*[3]]	Parry's aster	UPL
	Caltha leptosepala[2,3]	Elkslip marshmarigold	OBL
	Cardamine cordifolia[2]	Heartleaf bittercress	FACW
	Chenopodium album[1,3]	Common lambsquarters	FACU
	Cirsium spp.[3]	Thistle	FAC

[1] Species are non-native.

[2] Alpine Pond Spring.

[3] Sunset View Spring.

Table 4.6.4-3 continued. Plants documented at Sunset View Spring and Alpine Pond Spring in Cedar Breaks NM.

Lifeform	Species	Common Name	Wetland Status
Forbs *continued*	*Dodecatheon pulchellum*[3]	Dark-throat shootingstar	FACW
	Epilobium[3]	Willow weed	UNK
	Epilobium ciliatum[2]	Fringed willowherb	FACW
	Epilobium hornemannii ssp. hornemannii[3]	Hornemann's willowherb	FACW
	Erigeron ursinus[3]	Bear daisy	UPL
	Gentianopsis detonsa[3]	Western fringe gentian	FACW
	Geranium richardsonii[2,3]	Richardson geranium	FAC
	Geum triflorum[3]	Old man's whiskers	FACU
	Platanthera aquilonis [*Habenaria hyperborea*][3]	Northern green orchid	FACW
	Haplopappus clementis[3]	Clement's goldenweed	UPL
	Mertensia arizonica[2,3]	Aspen bluebell	UPL
	Osmorhiza depauperata[2]	Blunt-fruit sweet-cicely	UPL
	Pedicularis groenlandica[3]	Bull elephant's-head	OBL
	Pedicularis parryi[3]	Parry cinchweed	FACU
	Polemonium caeruleum[1,3]	Charity	FACW
	Polygonum bistortoides[3]	American bistort	FACW
	Polygonum viviparum[3]	Alpine bistort	FAC
	Potentilla diversifolia[3]	Mountain-meadow cinquefoil	UPL
	Rumex occidentalis[3]	Western dock	FACW
	Saxifraga odontoloma[2]	Brook saxifrage	FACW
	Solidago multiradiata var. scopulorum[3]	Manyray goldenrod	FACU
	Swertia radiata[3]	Elkweed	UPL
	Taraxacum officinale[1,2,3]	Blowball	FACU
	Trifolium longipes var. rusbyi[3]	Rusby's clover	FAC
	Zigadenus elegans[3]	Mountain deathcamas	UPL

[1] Species are non-native.

[2] Alpine Pond Spring.

[3] Sunset View Spring.

springs, five of which were non-native. Of the native species, nine are considered obligate wetland species and 19 are considered facultative wetland species in the western mountain subregion. The high diversity and dominance of wetland species indicates that there is adequate water to support a wetland plant community. However, these data were collected in 2005, more than 10 years ago and may no longer reflect current conditions at these two springs. Furthermore, plants were only documented at two of the 19 known springs in the park, which were both located on the plateau. Plants were not sampled at the remaining 17 springs nor at any of the springs located in the breaks. Plant communities may differ between the breaks and the plateau. Since no reference conditions were developed for this measure, the condition and trend is unknown.

Aquatic Invertebrate Presence

Table 4.6.4-4 shows the invertebrates that were documented at 14 springs sampled from 2008-2011 (Govedich and Bain 2012), at Alpine Spring during 2016 (Southern Utah University, F. Govedich, professor, e-mail communication, 25 January 2017), and at the two springs surveyed in 2005 (Alpine Pond Spring and Sunset View Spring (Springer et al. 2006). As of the writing of this assessment, invertebrates collected in 2005 had not been identified to species (NPS, L. Thomas, SCPN Program Manager, NRCA scoping meeting, May 2016). Insects represented the largest group with many aquatic families and species. Since no reference conditions were developed for this measure the condition is unknown.

Table 4.6.4-4. Aquatic Invertebrates documented at seeps and springs in Cedar Breaks NM.

Class	Order	Family	Species	Common Name
Arachnida	Acari/Hydrachnidiae	Stygothrombidiidae	–	Water mite[1]
Bivalvia[3]	–-	–	–	Clam[1]
Branchiopoda	Diplostraca	–	*Daphnia pulicaria*	Water flea[1]
Entognatha	Collembola	Isotomidae	–	Springtail[1]
Hirudinida	Rhynchobdellida	Glossiphoniidae	*Glossiphonia* sp.	Leech[1]
Hydrozoa	Hydroida	–	*Hydra braueri*	Hydra[1]
Insecta	Coleoptera[3]	Dytiscidae	*Agabus sp.*	Predaceous diving beetle
	–	–	*Brachyvatus sp.*	–
	Diptera[2,3]	Ceratopogonidae	*Dasyhelea sp.*	Midge
	–	Chironomidae	–	Midge[1]
	–	Culicidae	*Culex sp.*	Mosquito
	–	Muscidae	*Limnophora sp.*	House Flies
	–	Psychodidae	*Gen. nr. Pericoma sp.*	True Flies
	–	Simuliidae	*Simulium canadense*	Black Flies
	–	Stratiomyidae	–	Soldier Flies
	–	Tipulidae	*Prionocera sp.*	Crane flies
	–	Acalyptratae	–	Acalyptrates
	Ephemeroptera[3]	Baetidae	*Acerpenna sp.*	Mayflies[1]
	–	–	*Callibaetis sp.*	Mayflies
	–	Heptageniidae	*Cinygmula sp.*	Mayflies
	Hemiptera[2,3]	Corixidae	–	Water Boatman[1]
	–	Gerridae	–	Water Strider[1]
	–	Notonectidae	*Notonecta sp.*	Backswimmers
	Hymenoptera[2,3]	Apidae	*Bombus sp.*	Bees
	Lepidoptera	Pyralidae	*Gen. sp.*	Moths
	Odonata[2]	Coenagrionidae	*Argia sp.*	Damselflies
	Odonata/Anisoptera	–	–	Dragonflies[1]
	Odonata/Zygoptera	–	–	Damselflies[1]
	Plecoptera[1]	Capniidae	*Gen. nr. Capnia sp.*	Stoneflie w
	–	Nemouridae	*Malenka sp.*	Stoneflies
	–	Perlodidae	*Megarcys sp.*	Springflies
	Trichoptera[2,3]	Hydropsychidae	*Ceratopsyche sp.*	Caddisflies
	–	Leptoceridae	*Hesperophylax sp.*	Caddisflies
	–	Limnephilidae/Limnephilinae	–	Caddisflies[1]
	–	Limnephiloidea/Phryganeinae	*Agrypnia or Banksiola*	Caddisflies[1]
Maxillopoda	–	–	–	Copepoda[1]
Nematoda	–	–	–	Roundworm[1]
Oligochaeta[3]	–	–	–	Annelid Worm[1]
Ostracoda	–	–	–	Seed shrimp[1]
Turbellaria	Lecithoepitheliata	–	*Geocentrophora*	Flatworm[1]

[1] Species were identified at Alpine Spring in 2016 (Southern Utah University, F. Govedich, professor, e-mail communication, 25 January 2017).

[2] Orders identified at Alpine Pond Spring (Springer et al. 2006).

[3] Class and orders identified at Sunset View Spring (Springer et al. 2006).

Herpetofauna Presence
Only one species was detected during the 34 surveys conducted by the NCPN in 2001 and 2002 (Platenberg and Graham 2003). Four boreal chorus frogs (*Pseudacris maculata*) were recorded at a small slump pond on the rim in the northeastern corner of the monument. The authors report that the frogs were breeding there (Platenberg and Graham 2003). Boreal chorus frog is the only species of amphibian known to occur in the monument although several other species, including northern leopard frog (*Rana pipiens*) and tiger salamander (*Ambystoma tigrinum*) may occur in the monument; however, there are not data to support these claims (Platenberg and Graham 2003).

Alpine Pond is a good candidate for the reintroduction of boreal chorus frogs. Historically the pond was stocked with non-native fish by the Utah Division of Natural Resources (Davis 1962). Information on past stocking efforts are lacking, but a 1962 memo notes that rainbow trout (*Oncorhynchus mykiss*) were stocked at Alpine Pond in 1944 (Davis 1962). Park staff, however, have only documented non-native brook trout (*Salvelinus fontinalis*) there (NPS, B. Larsen, biologist, e-mail communication, 28 April 2017). Either the memo is inaccurate or the rainbow trout did not survive. Regardless, the pond is no longer stocked, and the brook trout died out by 2013 in the absence of stocking efforts (NPS, B. Larsen, biologist, e-mail communication, 28 April 2017). Since boreal chorus frogs occur approximately 1.9 km (1.2 mi) west of the northeast corner of the monument they may re-colonize the pond sometime in the future. The aquatic invertebrate data at Alpine Pond collected in 2005, 2008-2011, and in 2016 indicate adequate food sources when and if chorus frogs recolonize the pond. Since no reference conditions were developed for this measure, we did not determine condition or trend. Confidence is low.

Overall Condition, Trend, Confidence Level, and Key Uncertainties
Table 4.6.4-5 summarizes the condition rating and rationale used for each indicator and measure. There were few current data on springs and seeps in the monument, and virtually all measures used in this assessment reveal a gap in knowledge. However, data from the untrammeled natural springs of Cedar Breaks NM could represent baseline conditions for regional water resources if monitoring occurred regularly. Although historic data indicate good conditions for some measures, it is unknown whether these conditions have persisted. For this reason, current condition and trend could not be determined for springs and seeps at Cedar Breaks NM. As a result of unknown condition, confidence is low. 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.

Threats, Issues, and Data Gaps
With the exception of invertebrate data collected at Alpine Pond on the plateau and at 14 springs located in the breaks, there were no current data for springs and seeps in Cedar Breaks NM. This resource topic represents a significant data gap for the monument. Instead, we presented historic data that may be useful as baseline information should monitoring of springs and seeps occur. Although springs and seeps occupy a limited area in Cedar Breaks NM, they provide critical habitat for birds, invertebrates, amphibians, and mammals. This habitat type is especially important given the monument's arid landscape.

Although there are significant data gaps for springs and seeps in Cedar Breaks NM, there are relatively few threats to these water resources, largely because of the monument's situation in the headwaters of the watershed (Spangler 2012). Furthermore, given Cedar Breaks NM's protected status as a national monument and protected water rights for all water flowing in and through the monument, springs and seeps are likely to

Non-native brook trout pulled from Alpine Pond in 2013. Photo Credit: NPS.

Table 4.6.4-5. Summary of springs and seeps indicators, measures, and condition rationale.

Indicators of Condition	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Water Quantity	Spring Discharge (L/s)		Discharge data were reported for four springs between the years 1957 and 1984, primarily from May through October. The most recent discharge data were single measurements for two springs collected in 2005. While these data provide some insights into patterns of spring discharge, the lack of continuous measurements that reflect daily, seasonal, and annual patterns limit their utility for assessing the current condition of springs and seeps in the monument. Given these factors, the condition and trend for this measure is unknown and confidence is low.
	Water Rights		Since the monument retains water rights for the lands within the NPS boundary and the monument is considered the headwaters for both drainages, this measure of water quantity to be good. Confidence is high.
Water Quality	Specific Conductance (µ/cm)		Specific conductance was measured at six springs in the monument with the most recent data collected at Arch Spring in 2007. Since there were no standards for specific conductance, there were too few measurements to assess trend, and no recent data, we could not determine condition or trend for this measure. Confidence is low.
	pH (SU)		The pH ranged from 6.8 to 8.6 SU. Although the data indicate good condition, the most recent measurements were collected between 2008 and 2011 and do not inform current condition. Therefore, the condition and trend for this measure is unknown. Confidence is low.
	Dissolved Oxygen (mg/L)		Dissolved oxygen was measured in 13 springs. At all springs except Bubbling Spring, dissolved oxygen was greater than 4.0 mg/L, or the threshold for aquatic wildlife at all life stages. The threshold of 8.0 mg/L was only met in five of the 13 springs during the 2008-2011 sampling period. Since data were collected more than 10 years ago, we consider this measure to be unknown with unknown trend and low confidence.
	Temperature (°C)		Temperature data were collected at least once at five springs from 1967 to 2007. All measurements were well below the 20°C threshold established by the state of Utah for cold water game and fish. Since the most recent data are 10 years old and there were only 10 measurements over the 40 years of data collection, the condition is unknown and trend cannot be determined. Confidence is low.
Bacteria	Fecal coliform		Water samples collected at Blowhard Spring and Shooting Star Spring tested positive on one occasion each in 1990 and 1984, respectively. No bacteria were detected on the twelve additional sample dates for these two springs. No fecal coliform bacteria were detected for the single Twin Spring sample. Since there were no reference conditions for naturally occurring bacteria in springs, this measure was unknown with low confidence and unknown trend.
	Total coliform		Total coliform bacteria were detected one out of four samples at Blowhard Spring and three out of five samples at Shooting Star Spring. No bacteria were detected at Twin Springs, but this was from a single measurement. Since there were no reference conditions for naturally occurring bacteria in springs, we could not determine condition or trend for total coliform bacteria. Confidence is low.
Biodiversity	Plant Presence		Sixty-four species were recorded at two springs, including five non-native species. Of the native species, nine are considered obligate wetland species and 19 are considered facultative wetland species. The high diversity and dominance of wetland species indicates that there is adequate water to support a wetland plant community. However, these data are were collected more than 10 years ago and may not reflect current conditions. Furthermore, plants were only recorded at only two of the 19 known springs in the park. Since no reference conditions were developed for this measure the condition is unknown.
	Aquatic Invertebrate Presence		Insects represented the largest group with many aquatic families and species. Since no reference conditions were developed for this measure the condition is unknown.

Table 4.6.4-5 continued. Summary of springs and seeps indicators, measures, and condition rationale.

Indicators of Condition	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Biodiversity	Herpetofauna Presence		Four boreal chorus frogs (*Pseudacris maculata*) were recorded at a small slump pond on the rim in the northeastern corner of the monument. No other species were detected. Since no reference conditions were developed for this measure, we did not determine condition or trend.
Overall Condition			There are few current data on springs and seeps in the monument, and virtually all measures used in this assessment reveal a gap in knowledge. Historic data indicate good conditions, but it is unknown if these conditions have persisted. Given the monument's protected status, including protected water rights and high elevation within the watershed, springs and seeps are likely to be in good condition. Overall, current condition could not be determined and due to lack of data, confidence is low.

be in good condition but further study is required to support this assumption.

A total of 19 springs and seeps have been mapped in the monument. While it is likely that most springs above the breaks have been located, there may be several additional springs and seeps below the breaks that are undocumented due to difficult terrain. The occurrence of springs and seeps is a result of regional geologic and hydrologic conditions and long-term patterns of precipitation (Thornberry-Ehrlich 2006, Kreamer and Springer 2008, Spangler 2012), but the hydrologic connectivity underlying springs and seeps in the monument is unknown. A dye tracer study revealed that the maximum travel time for snowmelt water to reach Mammoth Spring, which is located approximately 12.0 km (7.5 mi) east of the monument, took seven days but only one or two days for summer monsoonal rains (Spangler 2012). For Mammoth Spring, the total water recharge area included a 104 km^2 (40 mi^2) area within the Mammoth Creek Watershed and an additional 65 km^2 (25 mi^2) area outside and to the south of the watershed (Spangler 2012). This suggests that the boundary of recharge for springs and seeps in Cedar Breaks NM may also include areas outside of the watershed in which they occur.

Spring discharge can show substantial variation with season, time of day, and localized summer precipitation (Spangler 2012). These factors partially determine water quality, but water chemistry is also affected by human use and development, nutrient loading from livestock grazing, and pollution (O'Dell et al. 2005). Although there is a boundary fence to prevent livestock trespass, feces from sheep may infiltrate the water supply (NPS 2015a). Pesticides used by the U.S. Forest Service to control beetle outbreaks also have the potential to contaminate the water supply in the monument (Jenkins et al. 2014). However, data from Mammoth Spring, downstream of the monument, do not indicate any contamination of water resources (Spangler 2012). Wildlife species are adapted to survive within range of water quality conditions; however, large or extreme fluctuations in water quality may result in the loss of sensitive species, a shift in community composition, or even the loss of all species (O'Dell et al. 2005).

Of all the threats to water resources in the monument, climate change has the greatest potential to alter the structure and function of springs and seeps. 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 Cedar Breaks NM were summarized in Monahan and Fischelli (2014). Extreme climate changes were defined as temperature and precipitation conditions exceeding 95% of the historical range of variability. These results indicate a trend toward warmer but not necessarily drier conditions within the monument (Monahan and Fisichelli 2014). While there were no apparent changes in total precipitation, warmer temperatures influence whether precipitation falls as snow or rain, which in turn may affect spring discharge (Dudley et al. 2017). The distinction between the amount of precipitation falling as snow as opposed to rain is particularly important in the snow-dependent hydrologic landscape of the western U.S. (Pugh and Gordon 2013). Furthermore, warmer temperatures may increase the rate of evapotranspiration, thereby reducing the amount of water in aquifers (Kreamer and Springer 2008).

Finally, large-scale beetle kill in and around the monument (DeRose and Long 2007) may reduce snowpack because dead trees, especially those without needles, influence snow interception, wind patterns, and snow surface albedo (Pugh and Gordon 2013). In Cedar Breaks NM snow cover is highly variable both within and between years making it more difficult to detect changes in snow cover without long-term data (Thoma 2011). How the forest canopy affects water resources within the monument is unknown and is likely dependent on a variety of site specific factors such as soil type, scale of the beetle infestation, topography, and size of the water shed (Pugh and Gordon 2013).

The combined effects of climate change and beetle kill could result in large stand-replacing fires in and near the monument, and the resulting change in vegetation cover would likely result in an increase in spring discharge lasting several years (Neary et al. 2005). In June and July 2017, a (17,673 ac) human-caused wildfire swept across the Markagunt Plateau, burning many of the dead Engelmann spruce but did not burn inside the monument (InciWeb 2017).

4.6.5. Sources of Expertise

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

4.7. Upland Vegetation

4.7.1. Background and Importance

In Cedar Breaks National Monument (NM) upland vegetation occurs above 2,896 m (9,500 ft) on the Markagunt Plateau, which slopes gently eastward and away from the steep slopes of the breaks (Spangler 2012, Tendick et al. 2011). Upland vegetation is dominated by subalpine fir (*Abies lasiocarpa*) and Engelmann spruce (*Picea engelmannii*) forests (Tendick et al. 2011). Small patches of Douglas-fir (*Pseudotsuga menzeisii*), limber pine (*Pinus flexilis*), and western bristlecone pine (*Pinus longaeva*) may also occasionally occur in the uplands (Fertig 2009). The understory of the monument's forested areas often includes aspen bluebell (*Mertensia arizonica*), alpine prickly currant (*Ribes montigenum*), Oregon-grape (*Mahonia repens*), common juniper (*Juniperus communis*), and Ross' sedge (*Carex rossii*) depending on soil moisture characteristics (Fertig 2009).

Spruce-fir forests are interspersed with subalpine meadows (Figure 4.7.1-1) and occasional remnant stands of quaking aspen (*Populus tremuloides*) (Witwicki et al. 2013). Upland meadows support a variety of wildflowers including Markagunt penstemon (*Penstemon leiophyllus*), little sunflower (*Helianthella uniflora*), and scarlet paintbrush (*Castilleja miniata*) in semi-moist meadows, and darkthroat shooting star (*Dodecatheon pulchellum*), monkshood (*Aconitum columbianum*), and elephanthead lousewort (*Pedicularis groenlandica*) in marshy meadows (Fertig 2009, Tendick et al. 2011).

Historically, the monument's uplands were heavily grazed by cattle and sheep, but grazing became more limited after Cedar Breaks's establishment as a national monument in 1933 (Tendick et al. 2011). Today, grazing is currently excluded with a boundary fence, although livestock trespass may occasionally occur if the fence is damaged (Tendick et al. 2011). Although grazing is largely excluded, other disturbances, including the invasion of subalpine meadows by non-native species, conifer encroachment of upland meadows, bark beetle outbreaks, and sudden aspen decline (SAD), are of concern for upland plant communities (Witwicki 2010). Recovery from these types of disturbances is often slow as a result of the monument's limited growing season and harsh high-elevation conditions (Witwicki et al. 2013).

4.7.2. Data and Methods

Three indicators, community composition and structure, forest health, and productivity, with a total of seven measures were used to assess the current condition of upland vegetation in Cedar Breaks NM. We relied on data collected by the National Park Service's (NPS) Northern Colorado Plateau Network (NCPN), U.S. Forest Service's (USFS) Forest Health

Figure 4.7.1-1. Subalpine meadow in Cedar Breaks NM. Photo Credit: NPS.

Monitoring (FHM) program (USFS 2016), and USFS and U.S. Department of Interior LANDFIRE (Landscape Fire and Resource Management Planning Tools) data (LANDFIRE 2014).

From 2009 to 2016, NCPN staff monitored upland vegetation in each of twenty-eight 50 × 50 m (164 × 164 ft) plots (Witwicki 2010) in a panel rotation. Plots were distributed across subalpine meadows, spruce-fir forests, and aspen stands (data provided by D. Witwicki, NCPN vegetation ecologist). Three 50-m (164-ft) transects positioned 25 m (82 ft) apart were established within each plot. Each plot was sampled for two consecutive years from 2009 to 2015 (i.e., 7 or 8 plots per year) to complete one round of surveys. The second round of surveys began in 2016. For the following three measures, data from the first round of sampling were averaged across years (i.e., 2009–2015), with data from 2016 listed separately. Condition was based on the averages of the first complete round of sampling. Refer to Witwicki et al. (2013) for further details on monitoring protocol for each of the measures listed below.

Species Richness (# of species)
Species richness data were collected using 1-m- (3-ft) wide belts located upslope of each of the three plot transects for understory plants, a 5-m- (15-ft) wide belt centered on the middle transect for saplings, and in one 25 x 25 m (82 x 82 ft) quadrant within each plot for mature trees (Witwicki 2010). Data were summarized by overall mean species richness and mean richness by life form (i.e., trees, shrubs, perennial grasses, annual grasses, and forbs/herbs). Richness values provided by SODN did not account for nativity. Therefore, richness in this assessment includes non-native species. Non-native plants were addressed in a separate assessment.

Tree Density (#/ha)
Density was recorded for live seedlings, saplings, and overstory trees based on diameter at breast height (DBH) (Witwicki et al. 2013). Seedling (<2.5 cm DBH [<1.0 in DBH]) density was measured upslope of the three plot transects in 1-m- (3-ft) wide belts (Witwicki 2010). If seedling density was exceptionally high, then density was estimated (Witwicki et al. 2013). The density of saplings (2.5–15.0 cm DHB [1.0–6.0 in DBH]) was measured along the middle transect but in a 5-m- (16-ft) wide belt, and tree density (>15.0 cm DBH [>6.0 in DBH]) was measured in a 25 x 25 m (82 x 82 ft) quadrant within each plot (Witwicki et al. 2013). Data were summarized by lifeform.

Crown Health (% live)
For each tree that measured >15 cm DBH (>6.0 in DBH) the percent live foliage was recorded in each of six crown health classes as follows: 1 = 90–100% live, 2 = 50–89% live, 3 = 16–49% live, 4 = 0.1–15% live, 5 = standing dead, and 6 = dead and down (Witwicki et al. 2013). The latter class was only used to record trees that were previously tagged and standing but had fallen down since the last plot visit (Witwicki et al. 2013). Data were summarized by species.

Bark Beetle Infestation (ha)
Insect detection survey (IDS) geospatial data for Utah State were downloaded from the USFS Forest Health Monitoring program database for the years 1997 to 2015 (USFS n.d.). Geospatial data included polygons of forested areas damaged or killed by bark beetles, the damage agent (i.e., species of beetle), and survey boundaries by year. Data were collected via low-altitude aerial aircraft and ground survey efforts by FHM staff and State of Utah staff (USFS 2016). The shapefiles were clipped to Cedar Breaks NM's boundary. Because some infestations were mapped in multiple years, the Dissolve tool in ArcGIS 10.4 was used to determine the total area affected over the 15-year period. Data were summarized by area affected, area surveyed, and the proportion of affected area that had been surveyed by year. We also described previous research on bark beetles in the region to provide context.

Fuels Volume (tonnes/ha)
Woody fuels were measured along four 15-m (50-ft) transects that extended beyond each NCPN plot on two corners (Witwicki 2010). Fuel volume was summarized in each of four categories as follows: 1-hr, 10-hr, 100-hr, and 1,000-hr fuels. The 1,000-hr fuels were subdivided into sound and rotten fuels. Depth of the litter and duff layers were also recorded along the four transects. Woody fuels included twigs, dead branches, and stems that were lying on the ground. Litter included leaves, bark, cones, and other non-woody plant material, while duff included decomposing organic matter that was below the leaf litter but above the mineral soil layer. Litter and duff depth measurements were recorded at every 2 m (7 ft) along each fuel transect (Witwicki et al. 2013).

Vegetation Condition Class

The Vegetation Condition Class (VCC) raster Version LF 1.4.0 for the contiguous U.S. was downloaded from the LANDFIRE website (LANDFIRE 2014). LANDFIRE is a multi-agency program that "provides landscape scale geospatial products to support cross-boundary planning, management, and operations" across the U.S. (LANDFIRE 2014). The VCC indicates the level at which the current vegetation has departed from historical reference conditions. The VCC layer was previously known as the Fire Regime Condition Class layer but was renamed to more accurately reflect the output (LANDFIRE 2014). VCC was derived from modeled reference conditions, a layer of biophysical settings, and modeled vegetation succession data (LANDFIRE 2014). Vegetation was classified into one of five departure categories as follows:

- Low (17–33% departure)
- Low to Moderate (34–50% departure)
- Moderate to High (51–66% departure)
- High (67–83% departure) and,
- Very High (84–100% departure)

Normalized Difference Vegetation Index (NDVI)

Normalized Difference Vegetation Index (NDVI) is a measure of primary productivity that is obtained from reflectance in red and near infra-red wavelengths via satellite imagery (Thoma et al. 2017). The term NDVI is used interchangeably with productivity or production in this assessment. The moderate resolution imaging sensor (MODIS) on the Terra satellite operated by NASA has been collecting daily imagery of the entire earth since early 2000 at 250 m (820 ft) spatial resolution (NASA n.d.).

We extracted NDVI from all coarse-scale forested polygons greater than 6.25 ha (15.44 ac) as mapped by Tendick et al. (2011). This area is larger than the resolution of MODIS satellite image pixels, which ensured that satellite image pixels represented target polygons. A total of 63 polygons across five forest types met this requirement (Figure 4.7.2-1). The five coarse scale vegetation types were aspen forest complex, blue spruce (*Picea pungens*) forest alliance, ponderosa pine (*Pinus ponderosa*)-Douglas fir forest woodland complex, subalpine fir-Engelmann spruce forest complex, and white fir (*Abies concolor*) forest.

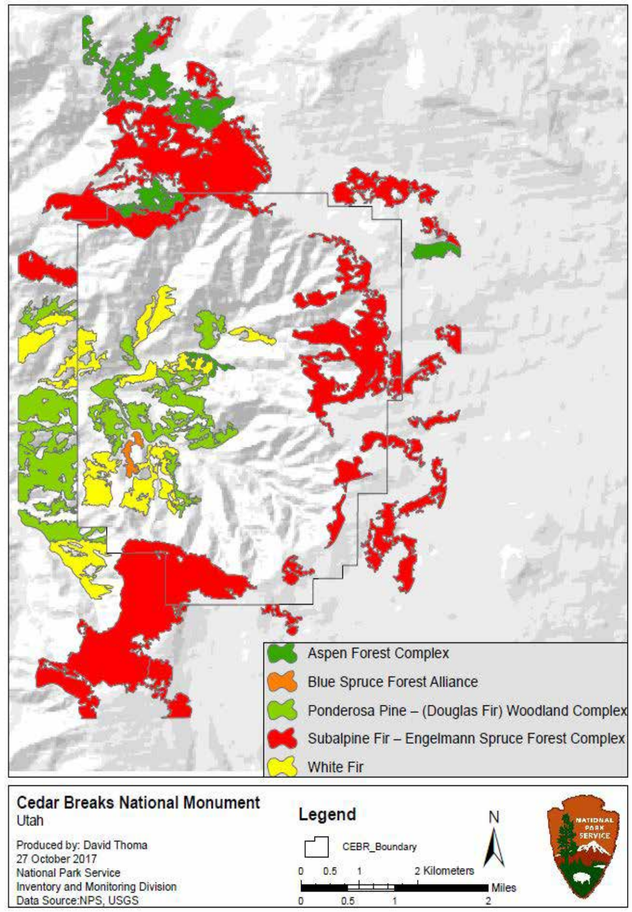


Figure 4.7.2-2. A map of the polygons in five forest types used to assess NDVI (productivity) in Cedar Breaks NM.

For each of the five forest types we determined trend in three NDVI variables from 2000 to 2016. The three variables were mean annual NDVI (average monthly values), maximum annual NDVI (maximum value regardless of month in which it occurred), and NDVI anomaly (difference from the long-term average where the average value is scaled to zero). Mean and maximum annual NDVI trends were assessed via the aggregated annual time-series method of Forkel et al. (2015) and linear regression for trends in anomaly. Each target polygon was analyzed independently, which enables detection of trend and condition for each polygon for each polygon as well as spatial patterns of change.

We also determined which of 12 climate variables were most strongly correlated with NDVI during 2000 to 2016 and whether the effect on production was positive or negative. The climate variables were growing degree days (gdd); water deficit (D); total precipitation (P); precipitation as rain (RAIN);

precipitation as snow (SNOW); a combination of rain, snow and snowmelt (W); potential evapotranspiration (PET); actual evapotranspiration (ET); average soil moisture (SOIL); and three temperature variables (average [TAVG], maximum [TMAX], and minimum [TMIN]). Finally, for each forest type we determined the strength of the NDVI response to climate variables by using the coefficient of determination (adjusted r^2). Adjusted r^2 is the percent of variation in annual production that is explained by the climate variable.

4.7.3. Reference Conditions

Table 4.7.3-1 summarizes the thresholds for measures in good condition and moderate concern/significant concern conditions. Moderate concern and significant concern conditions were combined because there was a general lack of specific information to separate

Table 4.7.3-1. Reference conditions used to assess upland vegetation.

Indicator	Strata	Measure	Good	Moderate Concern	Significant Concern
Community Composition and Structure	Uplands (subalpine meadow, mixed coniferous forest, aspen forest)	Species Richness	Native species richness has remained stable over time.	Native species richness has declined over time.	Native species richness has declined over time.
	Uplands (subalpine meadow, mixed coniferous forest, aspen forest)	Tree Density by Size Class (#/ha)	A stable or growing population for multiple species as indicated by more seedlings, saplings, and young mature trees than mature and old growth trees. Density data indicate co-dominance by several species for mixed conifer forest only.	A declining population for one or more species as indicated by few or no seedlings, saplings, and young mature trees. Density data indicate dominance by one or two species rather than co-dominance of several species typical of mixed coniferous forests.	A declining population for one or more species as indicated by few or no seedlings, saplings, and young mature trees. Density data indicate dominance by one or two species rather than co-dominance of several species typical of mixed coniferous forests.
	Uplands (subalpine meadow, mixed coniferous forest, aspen forest)	Crown Health	Trees exhibit more live foliage than standing dead, and the majority of the live foliage is within crown health class 1 or 2 (50-100% live foliage).	Trees exhibit more standing dead than live foliage, or the majority of the live foliage is crown health class 3 or 4 (0.1-49% live foliage) with a lot of standing dead.	Trees exhibit more standing dead than live foliage, or the majority of the live foliage is crown health class 3 or 4 (0.1-49% live foliage) with a lot of standing dead.
Forest Health	Monument-wide	Bark Beetle Infestation (ha)	No reference conditions developed.	No reference conditions developed.	No reference conditions developed.
	Uplands (subalpine meadow, mixed coniferous forest, aspen forest)	Fuels Volume (tonnes/ha)	No reference conditions developed.	No reference conditions developed.	No reference conditions developed.
	Monument-wide	Vegetation Condition Class	A majority (>70%) of the monument was mapped as Low to Moderate departure, and no areas of the monument were mapped as High or Very High departure.	Less than 70% of the monument was mapped as Low to Moderate Departure, and areas mapped as Moderate to High, High, and Very High departure or were common.	Less than 70% of the monument was mapped as Low to Moderate Departure, and areas mapped as Moderate to High, High, and Very High departure or were common.
Forest Productivity	Forested Areas Monument-wide	Normalized Difference Vegetation Index	No reference conditions developed.	No reference conditions developed.	No reference conditions developed.

condition at three levels. Ideally, reference conditions would be based on the natural range of variability for a particular forest type. However, there were few studies that attempted to determine natural range of variability prior to Euro-American settlement (i.e,. pre-1900) in the southwest (but see Battaglia and Shepperd 2007, DeRose and Long 2007, DeRose and Long 2012, Morris et al. 2015). Therefore, some reference conditions were necessarily qualitative and draw on the above mentioned studies.

No reference conditions were developed for fuels volume because fuel loads 1) were historically variable, especially in mixed coniferous forests, and 2) are dependent on time since the last fire and other disturbances, such as bark beetle outbreaks and windthrow (Baker et al. 2007, Covington and Moore 1994, Battaglia and Shepperd 2007). Similarly, no reference conditions were developed for bark beetle infestation because bark beetles are a natural disturbance agent and determining what is beyond the natural range of variability likely requires a larger geographic area and longer time range than what is available in the scientific literature (Jarvis and Kulakowski 2015, Morris and Brunelle 2012). Finally, no reference conditions were developed for NDVI. Rather, NDVI data provided a baseline for which to compare future NDVI results.

4.7.4. Condition and Trend

Species Richness

An average of 39 species occurred across the 28 plots during 2009 to 2015 (Table 4.7.4-1). In 2016 mean species richness was slightly higher at 42 species, but this was based on a subset of all sample plots. During 2009 to 2015 forbs and herbs exhibited the highest average species richness (27) followed by perennial grasses (9). The tree and shrub classes were less diverse (only one species each), and annual grasses were completely absent during the sampling period. Since the reference conditions for this measure were based on changes over time, and only one round of sampling has occurred to date, the condition and trend are both unknown. Because the condition was unknown, confidence was low.

Tree Density (#/ha)

Subalpine fir and Engelmann spruce were the two tree species that dominated upland monitoring plots (Figure 4.7.4-1). Subalpine fir exhibited the highest tree density (109 trees/ha [44 trees/ac]), while Engelmann spruce exhibited the lowest tree density (38 trees/ha [15 trees/ac]). Both subalpine fir exhibited high seedling density, but seedling density for Engelmann spruce was low (307 seedlings/ha [124 trees/ac]). Limber pine (*Pinus flexilis*) was also occasionally surveyed, but because this species rarely occurred, we did not report its density. Quaking aspen was rare except for in a few plots even though it had the highest seedling density of the four species but because saplings were almost completely absent and tree density was low, these results indicate low recruitment into larger size classes. The high seedling density for aspen reflects the species' typical clonal reproduction from the roots of mature overstory trees rather than from sexual reproduction (Shinneman et al. 2015). Aspen often regenerate after disturbances such as fire, which would result in the high seedling (more accurately known as suckers when they are clonal) density and low sapling density observed in upland plots (NPS, D. Witwicki, vegetation ecologist, comments to draft assessment, 7 December 2017). The high seedling density suggests that these aspen may be in good condition. A high density of seedlings/suckers also suggests they are not being over-browsed by ungulates (NPS, D. Witwicki, vegetation ecologist, comments to draft assessment, 7 December 2017).

Although all size classes were represented for both conifer species, only subalpine fir appears stable or growing since this species exhibited a distribution of age classes that is expected for a stable or growing population. The low density of all age classes for Engelmann spruce may indicate a declining population with little recruitment, primarily as a result of a past spruce beetle (*Dendroctonus rufipennis*) outbreak, which is discussed later in this assessment (DeRose and Long 2007, DeRose and Long 2012).

Table 4.7.4-1. Mean richness by life form during 2009-2016.

Life form	Average (2009-2015)	2016
Tree	1	1
Shrub	1	1
Perennial Grass	9	9
Annual Grass	0	0
Forb/Herb	27	31
Total	39	42

Source: NCPN data.

Note: Averages do not include 2016 data since they represent the beginning of the second round of sampling.

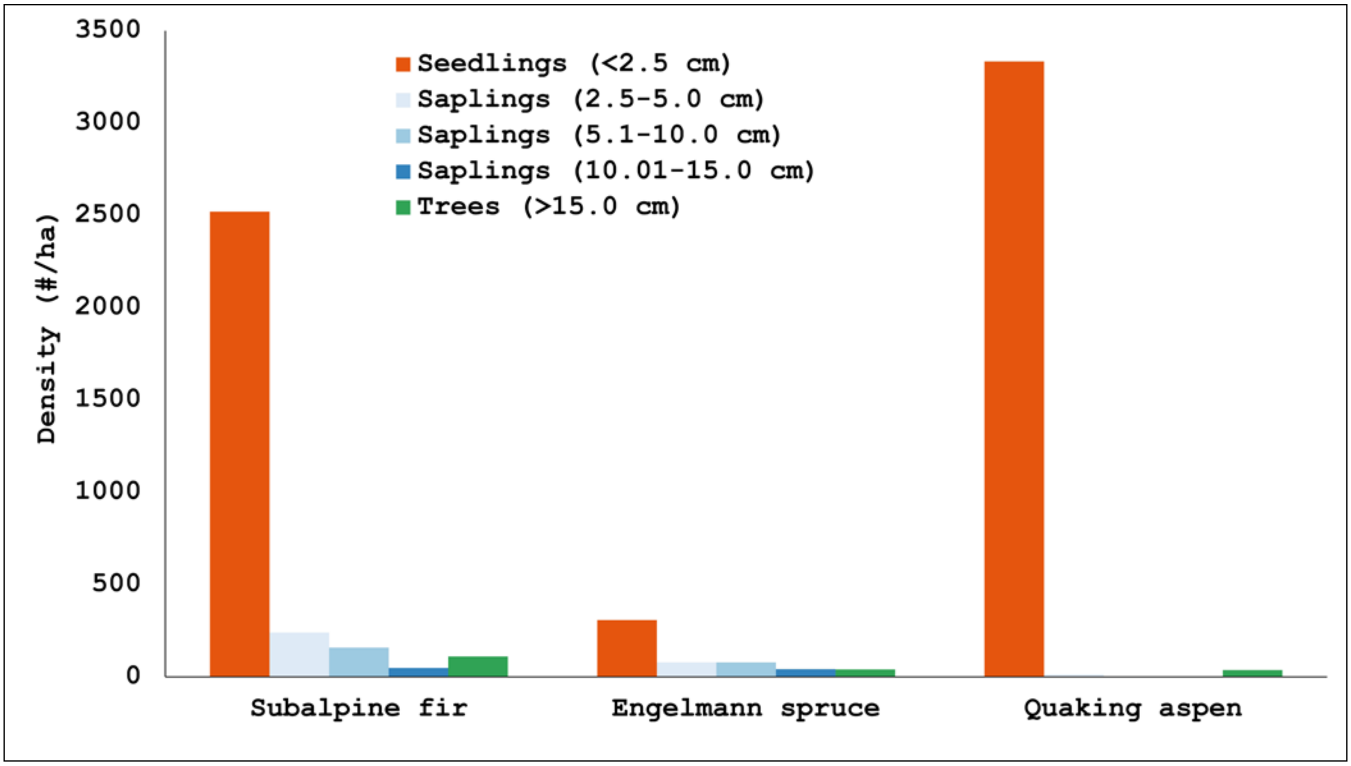


Figure 4.7.4-1. Tree density by size class in upland monitoring plots.

Data from 2016 show a similar pattern in density (Table 4.7.4-2). Overall, the results reveal a forest that is dominated by subalpine fir with a low density and declining population of Engelmann spruce and rare pockets of aspen. The results indicate good condition for subalpine fir and aspen but warrant moderate to significant concern for Engelmann spruce, especially since Engelmann spruce and subalpine fir were historically co-dominant in these spruce-fir forests (i.e., densities should be similar for the two species). The overall condition warrants moderate/significant concern. Trend could not be determined based on one round of sampling. Confidence in the condition is high since the data were recently collected.

Crown Health (% Live)

Figure 4.7.4-2 shows a high proportion of standing dead Engelmann spruce (61%) compared to subalpine fir (30%) and aspen (14%). Aspen exhibited the healthiest crowns with 79% of all overstory trees in crown health class 1. Engelmann spruce and subalpine fir exhibited similar patterns in overstory tree crown health, but a greater proportion of subalpine fir trees were in crown health class 1 and 2 (28%) versus Engelmann spruce trees (38%). Data from 2016 exhibited roughly the same crown health patterns. These results indicate good condition for aspen and subalpine fir but warrant moderate/significant concern condition for Engelmann spruce. The overall condition was moderate concern, primarily because of Engelmann spruce. Trend could not be determined based on one round of sampling. Confidence in the condition is high.

Bark Beetle Infestation (%)

A total of 4,448 ha (1,800 ac), or about 29% of the monument, were mapped as affected by bark beetles during 1997 to 2015 (Figure 4.7.4-3). Spruce beetle, which affects Engelmann spruce, was the primary disturbance agent. According to Table 4.7.4-3 most of affected areas were mapped during 1999-2001; however, nearly all the beetle-kill occurred during the

Table 4.7.4-2. Density of trees for plots sampled during 2016.

Size Class	Subalpine fir	Engelmann spruce	Quaking aspen
Seedlings (<2.5 cm)	900	667	5,400
Saplings (2.5-5.0 cm)	600	100	0
Saplings (5.1-10.0 cm)	120	100	0
Saplings (10.01-15.0 cm)	40	60	0
Trees (>15.0 cm)	109	38	96

Source: NCPN data.

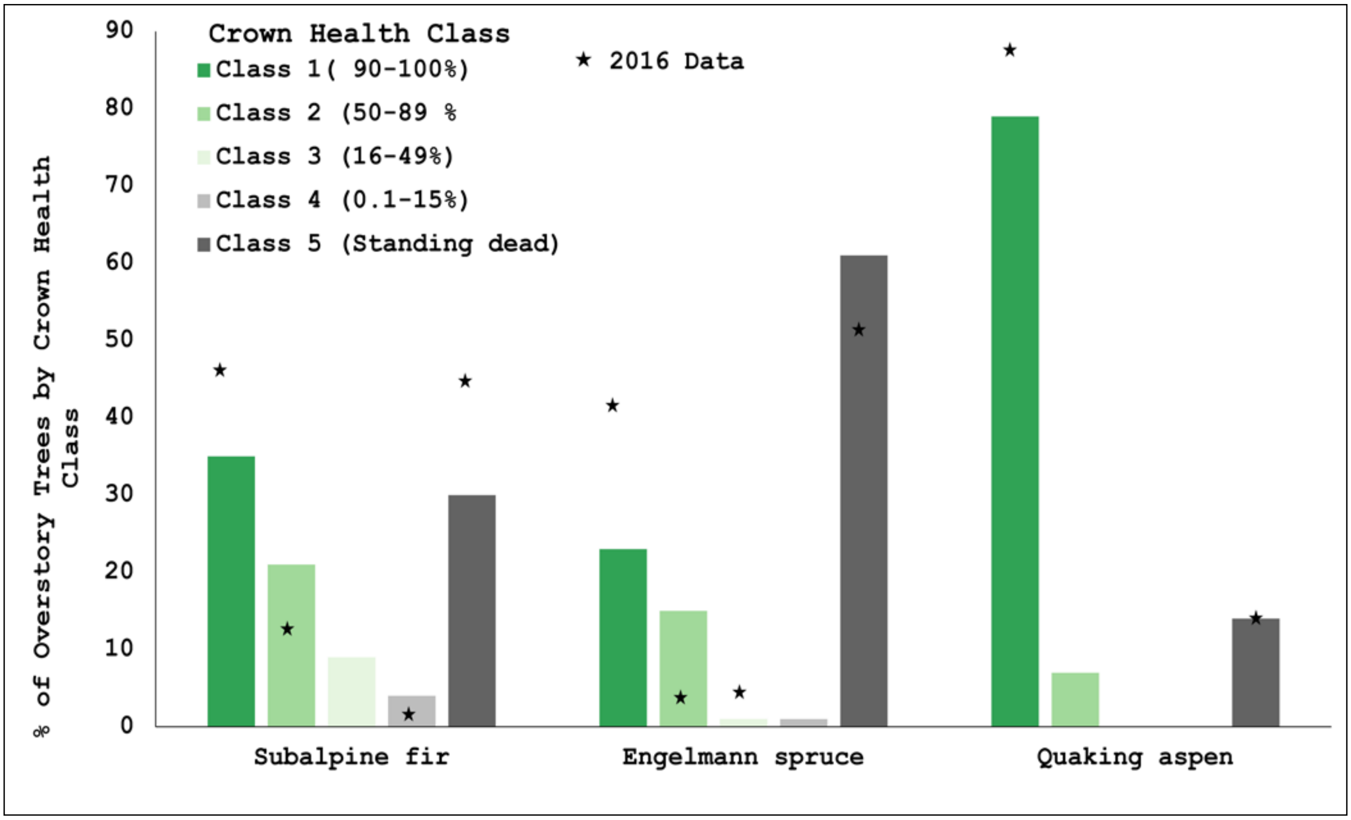


Figure 4.7.4-2. Crown health of overstory trees in upland monitoring plots.

early 1990s (DeRose and Long 2007). It was estimated that > 90% of all Engelmann spruce on the Markagunt Plateau had been killed by beetles (DeRose and Long 2007). By about 2005, spruce beetles had essentially exhausted their supply of host trees (DeRose and Long 2012). This outbreak is unprecedented in the past few centuries, but events of this magnitude may have occurred prior to the last few centuries (Morris and Brunelle 2012).

As a result of anthropogenic climate change, the severity and scale of the outbreak was likely greater than it otherwise would have been under natural conditions. Increasing winter minimum temperatures, increasing summer maximum temperatures, drought, and wide-scale host tree suitability likely contributed to the outbreak (DeRose and Long 2007, DeRose and Long 2012, USEPA 2016d). Warmer temperatures accelerates the life cycle of beetles and decreases their winter mortality rates, and prolonged drought increases the susceptibility of trees to beetle infestation (Hebertson and Jenkins 2008). Therefore, the condition for this measure warrants significant concern. Confidence in the condition rating is high. Trend is deteriorating.

<u>Fuels Volume (tonnes/ha)</u>

During 2009 to 2015, total fuel volume averaged 49.28 tonnes/ha (22.0 tons/ac), most of which was composed of 1,000-hr fuels (Table 4.7.4-4). Fuels in 2016 averaged slightly higher. Litter and duff depth averaged 1.0 cm (0.4 in) during 2009 to 2015. Fuels data are most often used to predict future fire behavior; however, for the purposes of this assessment, the historical range of variability is the reference condition of interest. Spruce-fir forests are characterized by long fire return intervals that are often stand-replacing (Battaglia and Shepperd 2007). Because of low rates of decomposition in high elevation spruce-fir forests, fuels are expected to be high, particularly long-burning fuels (Battaglia and Shepperd 2007). Fuel loads are reflective of the time since the last fire and disturbances other than fire (e.g., beetle-kill). According to the monument's fire history map however, there have not been any recent fires in the uplands (i.e., since the 1960s), but fire history data prior to the 1960s were not available. However, fire history at Red Valley Bog near the monument indicates a fire return interval for the region of every 300 to 400 years over the last 6,500 years (Madsen et al. 2002). In spring 2017, the human-caused Brian Head Fire burned 7,152 ha

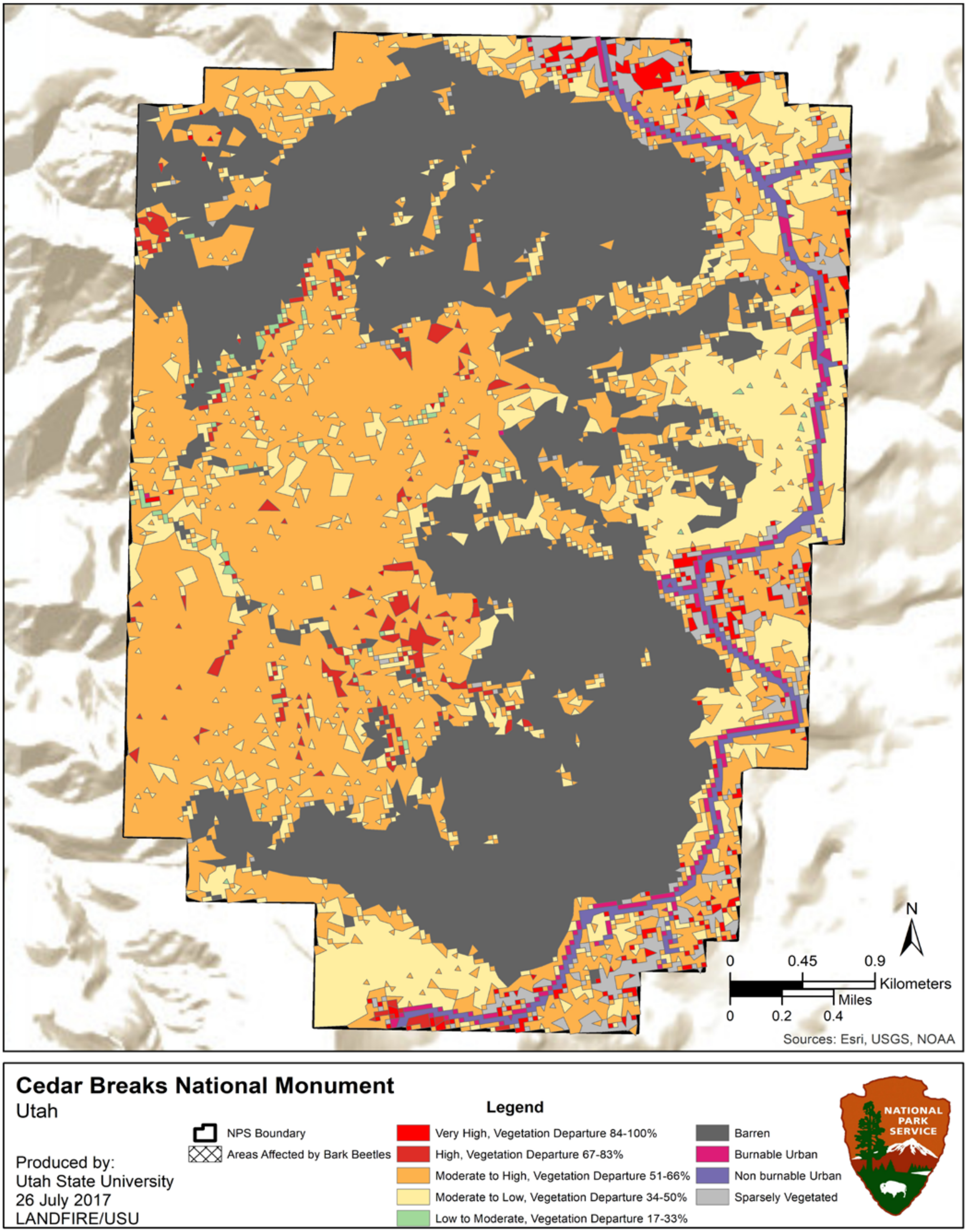


Figure 4.7.4-3. **Map of forested area affected by bark beetles and vegetation condition class in Cedar Breaks NM.**

Table 4.7.4-3. Forest insect damage and survey area mapped by year.

Year	Affected Area ha (ac)	Total Surveyed Area ha (ac)	% of Total
1997	66.3 (163.8)	No Data	–
1998	386.4 (955.0)	No Data	–
1999	396.6 (980.2)	2,483 (6,137)	15.97
2000	339.7 (839.5)	2,483 (6,137)	13.68
2001	575.9 (1,423.1)	2,483 (6,137)	23.19
2002	0.0 (0.0)	No Data	–
2003	0.0 (0.0)	2,483 (6,137)	0.00
2004	20.1 (49.7)	2,483 (6,137)	0.81
2005	0.0 (0.0)	2,483 (6,137)	0.00
2006	2.0 (5.0)	2,483 (6,137)	0.08
2007	0.0 (0.0)	2,483 (6,137)	0.00
2008	0.0 (0.0)	2,453 (6,062)	0.00
2009	1.3 (3.1)	2,315 (5,722)	0.05
2010	4.0 (9.9)	2,222 (5,492)	0.18
2011	1.0 (2.5)	2,483 (6,137)	0.04
2012	1.1 (2.8)	2,483 (6,137)	0.05
2013	0.8 (1.9)	2,483 (6,137)	0.03
2014	1.0 (2.5)	2,483 (6,137)	0.04
2015	2.1 (5.2)	2,483 (6,137)	0.09

Source: USFS Forest Health Protection Program (2015).

(17,673 ac) around the monument but did not burn inside the monument (InciWeb 2017). Since reference conditions were not established for this measure, the condition was unknown and confidence was low. Trend could not be determined.

Vegetation Condition Class

Of all the mapped areas, 46% of the monument was mapped as barren, sparsely vegetated, or urban (Table 4.7.4-5). Only 3% of the monument was considered High or Very High (67-100%) vegetation departure, but 35% of the monument was considered Moderate to High (51-66%) vegetation departure. When considering only the classified areas, 68% was mapped as Moderate to High departure and 28% was mapped as High (67-83%) departure. Figure 4.7.4-4 shows that the uplands in the western portion of the monument were a mix of Moderate to High and Low Moderate (34-50%) vegetation departure with scattered patches of Very High (84-100%) departure. The lowest elevation areas, which are currently composed primarily of mixed coniferous forest, were mapped as Moderate to High departure with smaller patches of Low to Moderate or Very High departure. These results indicate moderate/significant concern condition. Trend has deteriorated. Confidence is medium since these results were extracted from a national database that has an unknown classification error at the monument.

Normalized Difference Vegetation Index (NDVI)

Recent Condition and Trends in NDVI

The median and range in NDVI anomaly among polygons of each forest type was highly variable across the 17 year period of study (Figure 4.7.4-4). The box plot furthest right in each panel represents the most recently assessed condition relative to the long-term mean. In 2016, subalpine fir-Engelmann spruce forests was the only type above its long-term average (0.7 percentile), whereas aspen was slightly below average (0.41 percentile) and the other types were all well below average (0.12 percentile for each) experiencing near record low productivity (see Appendix E for all forest types time-series box plots). Annual production experienced set-backs occurring in 2006 and 2010 followed by periods of recovery and a recent decline since 2014 in all of the coarse forest types.

Spatial Pattern in NDVI Trends

We identified significant trends ($p < 0.10$) over time (Forkel et al. 2015) for the 63 polygons and found blue spruce forests exhibited the greatest change with 100% of the area declining in maximum NDVI (Figure 4.7.4-5, Table 4.7.4-6). However, only one polygon met our criteria for inclusion as blue spruce forests are uncommon in the monument (Tendick et al. 2011). Ponderosa pine (Douglas fir) woodland complex and

Table 4.7.4-4. Mean fuel volume and litter and duff depth.

Year	Total	1-hr	10-hr	100-hr	1,000-hr Sound	1,000-hr Rotten	Litter Depth (cm)	Duff Depth (cm)
Average (2009-2015)	49.28	0	2.24	4.48	24.64	17.92	1.0	1.0
2016	57.12	0.224	2.016	4.928	32.928	17.024	0.6	1.4

Source: NCPN data.

Note: Averages do not include 2016 data since they represent the beginning of the second round of sampling.

Table 4.7.4-5. Proportion of Cedar Breaks NM in each vegetation condition class.

Class Description	Proportion of Monument	Proportion of Classified Areas
Low to Moderate	<1	2
Moderate to Low	16	<1
Moderate to High	35	68
High	2	28
Very High	1	2
Non-burnable Urban	2	–
Burnable Urban	1	–
Barren	40	–
Sparsely Vegetated	3	–

Source: USFS LANDFIRE Program (2014).

white fir also decreased in maximum NDVI in 27% and 25% of their respective areas. In contrast, there were no trends in aspen forests. Approximately 33% of subalpine fir-Engelmann spruce area across the 28 polygons increased in maximum NDVI and 3% of the area increased in mean NDVI. Nearly all of these polygons occurred outside of the monument, which may be a result of different management practices between the monument and the Dixie National Forest. For example, salvage logging on the forest following the spruce beetle epidemic may have stimulated understory productivity by opening up the canopy.

Overall, 21% of the area analyzed in and near the monument increased in maximum NDVI and 8% decreased, while 2% increased in mean NDVI and none decreased. Confidence in mean NDVI trend is high for each polygon (*n* = 12months*17 years), whereas confidence is low for trend in maximum NDVI (*n* = 17 years).

Correlations between Climate and NDVI

In general, at Cedar Breaks NM the temperature variables gdd, PET, TAVG, TMAX, and TMIN had a significant and positive effect on vegetation productivity whereas water variables P, SOIL, RAIN, W, and SNOW had significant and negative effects on productivity (Figure 4.7.4-6 and 4.7.4-7). These relationships were strong indication that forest types in Cedar Breaks NM were temperature limited in most years. This does not mean these forests were immune from drought stress, which may occur in some years,

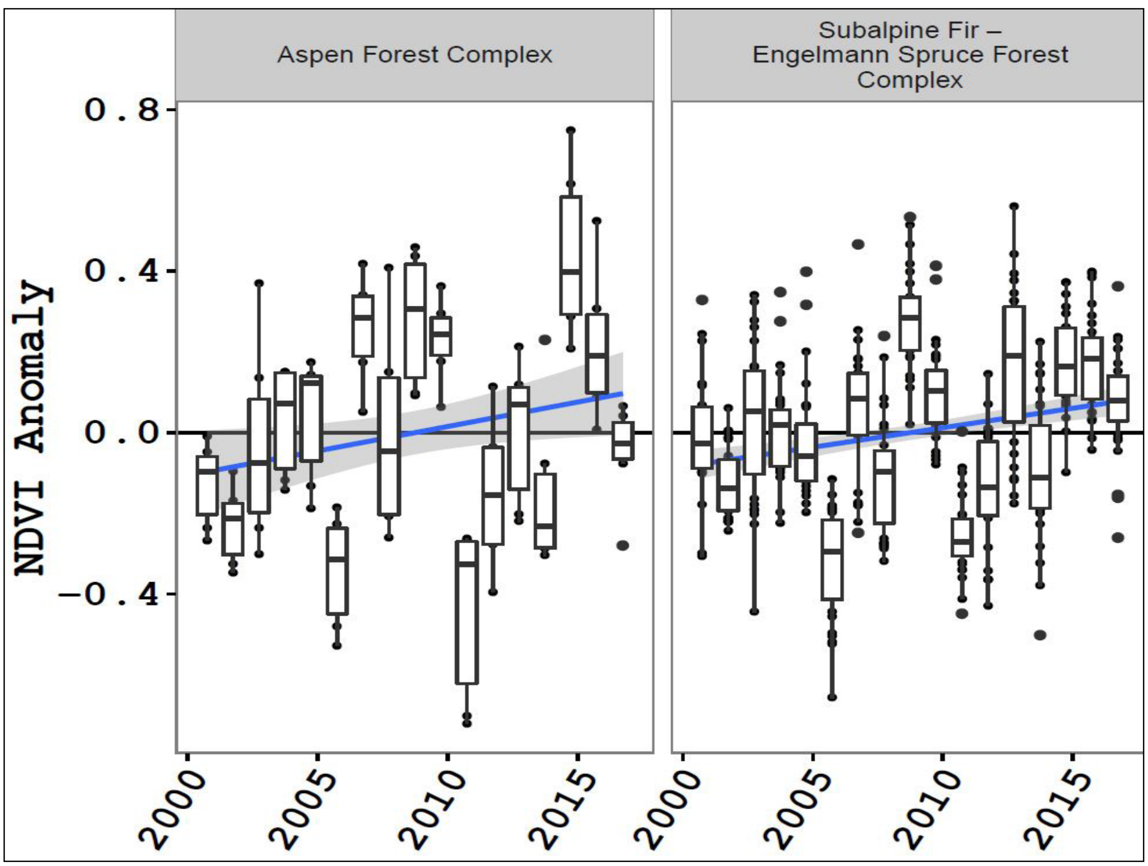


Figure 4.7.4-4. Anomaly trends for aspen and subalpine fir-Engelmann spruce forest. All trends shown are statistically significant (p < 0.10).

typically late in the growing season. Drought stress estimated as water deficit increased in all forest types, but increased significantly ($p < 0.10$) in aspen, blue spruce, Engelmann spruce polygons. Warmer temperatures are often associated with forest disease and wildfire, that often have indirect effects on forest condition and trend that could limit temperature induced increases in productivity (Allen et al. 2015). Annual vegetation production was most strongly correlated with and sensitive to average annual temperature. Long-term trends (1980-2016) indicated that mean annual temperature was variable with a significant ($p < 0.10$) positive trend in all of the forest types.

Utah Forest Dynamics Plot

The Utah Forest Dynamics Plot (UFDP) on the north rim of Cedar Breaks NM is one of 63 plots located in 24 countries throughout the world in order to better understand forest ecosystem processes and to monitor climate change effects using a single method for comparison (Smithsonian Tropical Research Institute 2017). The plots are administered by The Center for Tropical Forest Science and Forest Global Earth Observatories in collaboration with multiple institutions worldwide, including Utah State University, the Utah Agricultural Experiment Station, and the University of Montana (Smithsonian Tropical Research Institute 2017). The monument's 13.6 ha (33.6 ac) plot was established in 2014 and is surveyed annually (Furniss 2016). The plot is characterized by spruce-fir forest interspersed with subalpine meadow and aspen patches, similar to NCPN upland monitoring plots (Furniss 2016). Bristlecone and limber pine also occur near cliff edges (Furniss 2016). Results from this study may be incorporated into future upland vegetation assessments, but because of its similarity to existing NCPN upland monitoring, data from this plot were not included here.

Overall Condition, Trend, Confidence Level, and Key Uncertainties

Although the conditions for some measures were unknown, the assessment as a whole suggests moderate/significant concern condition for upland vegetation in Cedar Breaks NM (Table 4.7.4-7). Spruce-fir forests have shifted to a subalpine fir-dominated forest as indicated by density and crown health class data. These changes were the result of the spruce beetle outbreak during the 1990s. Much of the standing Engelmann spruce has been killed by spruce beetles, and the vegetation condition class suggests a significant departure from historical conditions. Overall trend in the condition of upland vegetation was unknown but has probably deteriorated. Confidence in the overall condition for upland vegetation is medium. The primary key uncertainty is in determining how climate change has and will continue to shift vegetation in the monument outside the range of historical/natural variability. Given current climate change scenarios a return to historical vegetation conditions is unlikely (Settele et al. 2014).

Threats, Issues, and Data Gaps

Disturbances such as fire, bark beetles, and windthrow are natural occurrences that promote overall forest health by creating gaps in the canopy, a mix of uneven aged stands, and higher plant diversity (Jenkins et al. 2008, Morris and Brunelle 2012). However, the extent and severity the recent beetle outbreak and other disturbances such as fires are unprecedented and indicate a shift to alternative states (Eisenhart and Veblen 2000, Morris and Brunelle 2012).

Table 4.7.4-6. Trends in maximum and mean NDVI from 2000 to 2016.

Vegetation Type	Area Analyzed (ha)	Polygon Count	NDVI Max Increase	NDVI Max Decrease	NDVI Mean Increase	NDVI Mean Decrease
Aspen Forest Complex	131	6	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Blue Spruce Forest Alliance	8	1	0 (0%)	8 (100%)	0 (0%)	0 (0%)
Ponderosa Pine – (Douglas Fir) Woodland Complex	272	13	0 (0%)	74 (27%)	0 (0%)	0 (0%)
Subalpine Fir – Engelmann Spruce Forest Complex	947	28	315 (33%)	0 (0%)	24 (3%)	0 (0%)
White Fir	190	15	11 (6%)	47 (25%)	11 (6%)	0 (0%)
Monument Area Totals	1549	63	326 (21%)	129 (8%)	36 (2%)	0 (0%)

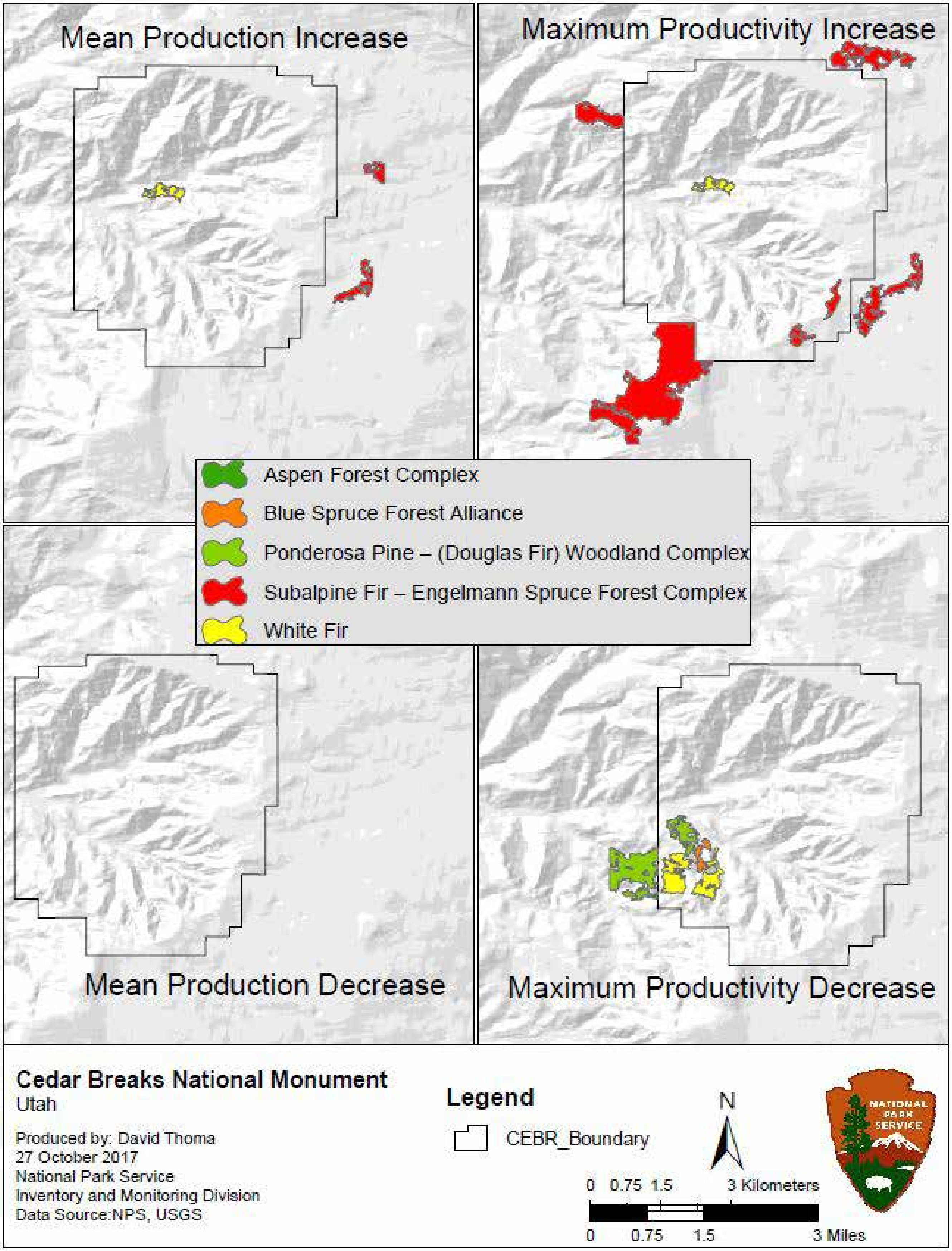


Figure 4.7.4-5. Spatial pattern of trends in forest productivity assessed by change in mean annual NDVI over time. Only polygons with statistically significant trends ($p < 0.1$) are shown.

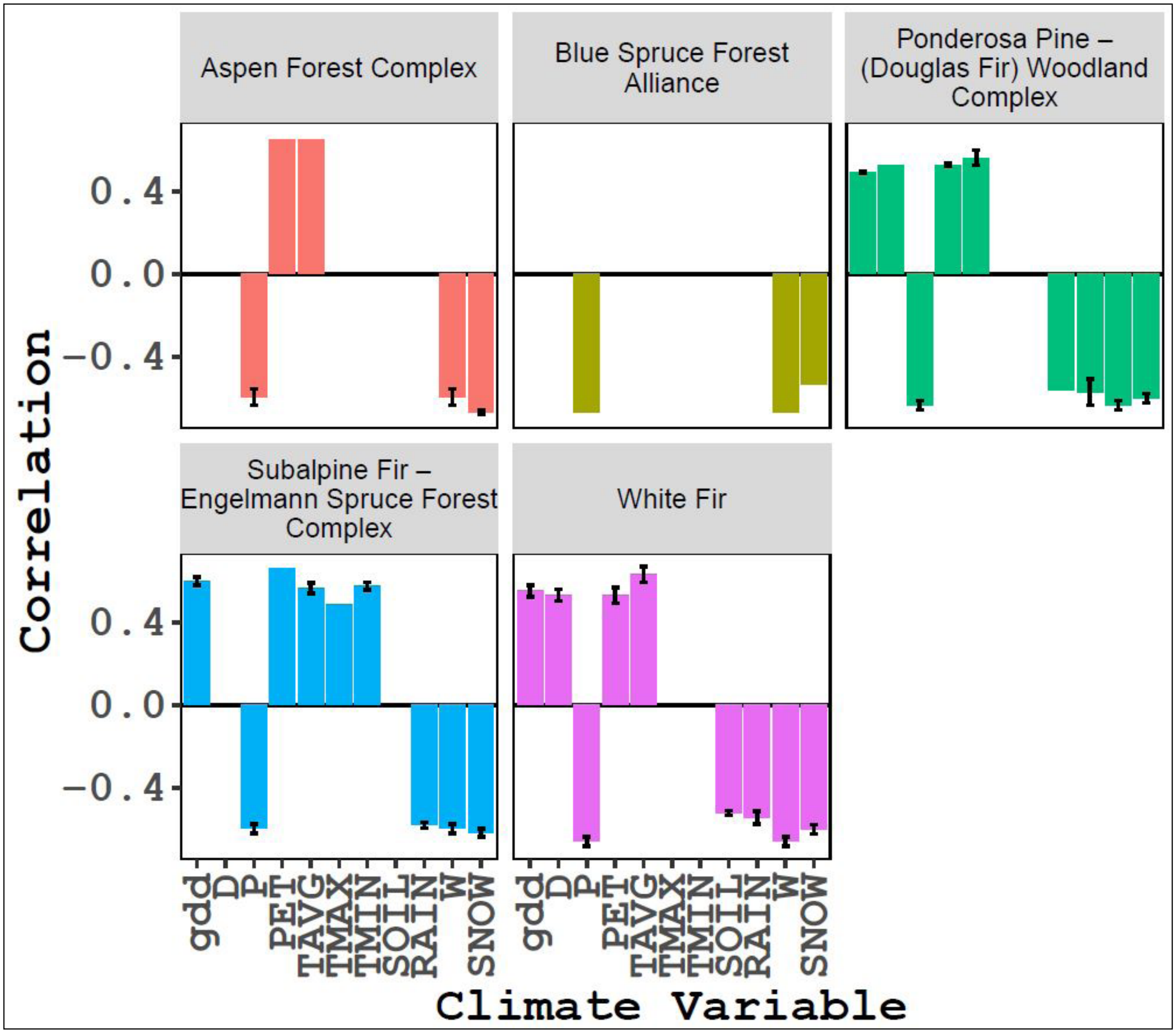


Figure 4.7.4-6. **Correlation between climate variables and forest type productivity for the period 2000-2016.**

Region-wide drought, rising temperatures, long-term fire suppression resulting in dense and over-mature forests, are all factors that have increased the susceptibility of western coniferous forests to bark beetle infestations (Hebertson and Jenkins 2008, Hart et al. 2014). In Cedar Breaks NM, climate change data indicate a trend toward warmer conditions but few changes in precipitation (Monahan and Fisichelli 2014). Even if precipitation remained the same, the monument could become drier because warmer temperatures increase rates of evapotranspiration (USEPA 2016d). Warmer winter temperatures enhance over-winter beetle survival, and warmer late summer-early autumn temperatures accelerate beetle development (Hebertson and Jenkins 2008). While there were no apparent changes in total precipitation in the monument, warmer temperatures influence whether precipitation falls as snow or rain (Monahan and Fisichelli 2014, Pugh and Gordon 2013). The distinction between the amount of precipitation falling as snow as opposed to rain is particularly important in the snow-dependent hydrologic landscape of the western U.S. (Pugh and Gordon 2013).

Studies of forests on the Markagunt Plateau show that disturbances, such as beetle-kill, prior to the 1990s resulted in a mosaic of uneven aged trees (DeRose and Long 2007). As a result of the most recent beetle outbreak, however, historically co-dominant subalpine fir and Engelmann spruce forests are now

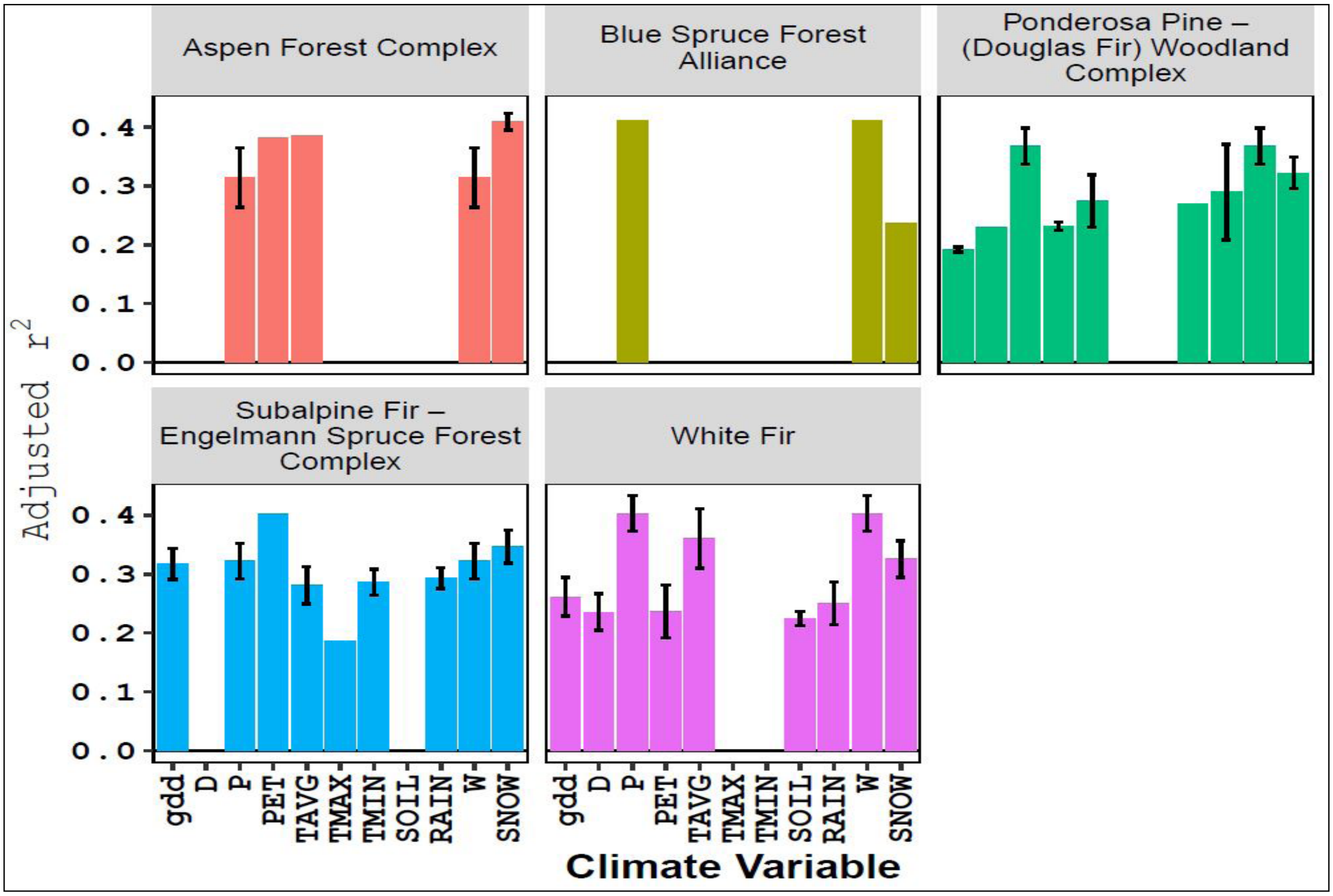


Figure 4.7.4-7. Coefficient of determination (adjusted r^2), which is the percent of variation in annual production explained by the climate variable.

dominated almost exclusively by subalpine fir (DeRose and Long 2007). Data for historical spruce-fir forest densities were limited but were estimated at 150 trees/ha (61 trees/ac) (Battaglia and Shepperd 2007). For the three dominant species presented in this assessment, total density averaged 243 trees/ha (98 trees/ac). This suggests that current densities in the monument may be high.

The scale of beetle-killed spruce forests has raised concerns about wildfire risk and severity, but the majority of studies show that these assumptions may be inaccurate (Black et al. 2013, Hart et al. 2015, Meigs et al. 2016). For example, the amount of area burned in the western U.S. in recent decades has not increased as a result of widespread mountain pine beetle (*Dendroctonus ponderosae*) outbreaks (Hart et al. 2015). Furthermore, outbreaks of mountain pine beetle and western spruce budworm (*Choristoneura freemani*) reduced the severity of subsequent wildfires but severity varies with the density of susceptible trees and beetle type (Meigs et al. 2016).

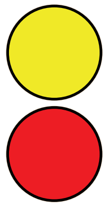
One study indicated that spruce beetle outbreaks, regardless of severity, accounted for only minor variations in downed woody fuel loads (Jorgensen and Jenkins 2011). Although fuel volume gives some indication of potential future fire behavior, it may not be as informative in predicting fire behavior as fuel moisture and the condition of live vegetation (Bradley et al. 1992). Given the high amount of standing dead Engelmann spruce, understory vegetation may have increased. Many understory grasses and shrubs, such as Oregon-grape, alpine prickly currant, and Ross' carex, sprout vigorously following disturbances (Bradley et al. 1992). Fire is also important for maintaining subalpine meadows and stimulating aspen growth and recruitment (Shinneman et al. 2015).

As mentioned previously, a 7,152 ha (17,673 ac) human-caused wildfire swept across the Markagunt Plateau in 2017, burning many of the dead Engelmann spruce, but the fire did not burn inside the monument (InciWeb 2017). Fire effects surveys following the Brian Head Fire may inform how forest structure and

Table 4.7.4-7. Summary of upland vegetation indicators, measures, and condition rationale.

Indicator	Measure	Condition/ Trend/ Confidence	Rationale
Community Composition and Structure	Species Richness		An average 39 species (mostly forbs and herbs) occurred in upland plots during 2009 to 2015. In 2016, an average of 42 species occurred in a subset of the 28 plots. However, condition could not be determined because the reference conditions were based on trends over time, and only one round of sampling has occurred to date. Therefore, confidence was low and trend was unknown.
	Tree Density by Size Class (#/ha)		Although all size class were represented for both conifer species, only subalpine fir appears stable or growing. The low density of all age classes for Engelmann spruce indicates a declining population. Aspen saplings were almost completely absent, tree density was low, and seedling/sucker density was high, which reflects the expected distribution following a disturbance such as fire. The overall condition warrants moderate/significant concern primarily because the historically dominated spruce-fir forests are now dominated by fir. Trend could not be determined based on one round of sampling. Confidence was high since the data were recently collected.
	Crown Health		There was a high proportion of standing dead spruce (61%) compared to spruce foliage that in crown health class 1 and 2 (38%). Subalpine fir exhibited more foliage in crown class 1 and 2 (56%) than standing dead (30%), and nearly all mature aspen was live (86%) versus dead (14%). These results indicate good condition for aspen and fir but warrant moderate to significant concern condition for spruce for an overall condition of moderate concern. Trend could not be determined. Confidence was high since these data were collected recently.
Forest Health	Bark Beetle Infestation (ha)		During 1997-2015, 29% of the monument has been affected by bark beetles (mostly spruce beetles), but the majority of the beetle-kill occurred during the early 1990s. The recent outbreak is unprecedented in scientific observation and was likely exacerbated by human-caused climate change. Therefore, the condition warrants significant concern. Confidence in the condition is high and trend is deteriorating.
	Fuels Volume (tonnes/ha)		During 2009 to 2015, total fuel volume averaged 54.3 tonnes/ha (22.0 tons/ac), most of which was composed of 1,000-hr fuels. Litter and duff depth averaged 1.0 cm (0.4 in). The recent beetle epidemic has altered the fuels profile and past forest management practices, including fire suppression, has altered the fire regime. Because of low rates of decomposition in high elevation spruce-fir forests, fuels are expected to be high, particularly long-burning fuels. Since no reference conditions were developed for this measure, the condition was unknown and confidence was low. Trend could not be determined.
	Vegetation Condition Class		Sixty-eight percent of the monument's classified areas were mapped as Moderate to High Departure, and 28% was mapped as High Departure. Therefore, the condition warrants moderate/significant concern. Trend has deteriorated and confidence was moderate since these data were modeled and may not reflect actual conditions.
Productivity	NDVI		NDVI anomaly increased in aspen and spruce-fir forests during the 17-year period. Blue spruce forests exhibited the greatest change in with 100% of the area declining in maximum NDVI, but only one polygon met the criteria for inclusion. Ponderosa pine (Douglas fir) woodland complex and white fir also decreased in maximum NDVI in 27% and 25% of their respective areas. In contrast, there were no trends in aspen forests. Approximately 33% of subalpine fir-Engelmann spruce area across the 28 polygons increased in maximum NDVI and 3% of the area increased in mean NDVI. Temperature variables had a significant and positive effect on vegetation productivity whereas water variables had significant and negative effects on productivity.

Table 4.7.4-7 continued. ***Summary of upland vegetation indicators, measures, and condition rationale.***

Indicator	Measure	Condition/ Trend/ Confidence	Rationale
Overall Condition			Although some measures were unknown, the assessment as a whole suggests moderate/significant concern. The forest has shifted from a mix of spruce-fir to a subalpine fir-dominated forest. Much of the standing Engelmann spruce has been killed by spruce beetles, and the vegetation condition class suggests a significant departure from historical conditions. These shifts could be partly natural but given anthropogenic-driven climate change, many of these changes were likely human-caused. Overall trend was unknown but has likely deteriorated. Confidence in the condition is medium.

species composition may change following a fire in the monument. Provided the soil seed bank remains intact post-fire, Engelmann spruce seeds may remain viable for many centuries (DeRose and Long 2010).

Aside from natural disturbance, the introduction and spread of invasive plants is of concern in the monument. Twenty non-native plants have been documented at Cedar Breaks NM and most of them occur in the uplands (Dewey and Anderson 2005, Fertig 2009, Fertig et al. 2012). However, many of these species were rarely encountered even in the uplands. In the 28 NCPN upland monitoring plots, only four non-native species were observed during 2009 to 2015 (data presented in the Non-native Invasive Plants assessment). Smooth brome (*Bromus inermis*) was one of the most widely spread and invasive species found in a survey of upland areas during 2004 (Dewey and Anderson 2005). In the 531 ha (1,313 ac) surveyed, 17 (42 ac), or 3.2%, were infested with smooth brome (Dewey and Anderson 2005). Smooth brome was most common in subalpine meadows and cushion plant communities above the rim, in addition to roadsides and other disturbed areas (Dewey and Anderson 2005, Fertig and Reynolds 2009).

In Cedar Breaks NM the main road corridor is the primary pathway for dispersal (Dewey and Anderson 2005). Once established, invasive plants can be extremely difficult to control and most will never be completely eradicated (Mack et al. 2000). The protective cover of snow and about 250 days of frost per year (NPS 2016a) limits the growing season for non-native species, but warmer temperatures and declining snowfall may increase the monument's favorability to non-native plants through direct effects or by shifting native species out of their ranges (Hellmann et al. 2008).

4.7.5. Sources of Expertise

Assessment authors were Lisa Baril, science writer, Utah State University, and David Thoma, hydrologist, NPS I&M Program. Dana Witwicki, ecologist, NPS NCPN, assisted in establishing indicators and measures most important for NCPN data. Taiga Rohrer, Fire and Aviation Management Officer, Zion NP/Utah Parks Group, provided assistance in gathering fire history data.

4.8. Unique and Distinctive Vegetation

4.8.1. Background and Importance

Variable topography, soil moisture attributes, and erosional processes drive plant distribution patterns in Cedar Breaks National Monument (NM) (Tendick et al. 2011). The monument's plant communities can be roughly divided into five assemblages. At the lowest elevations and slopes white fir (*Abies concolor*) and Douglas-fir (*Pseudotsuga menziesii*) forests with a shrubby understory dominate. Ashdown Creek and its main tributaries along the canyon bottom support riparian forests of narrowleaf cottonwood (*Populus angustifolia*), Engelmann spruce (*Picea engelmannii*), and water birch (*Betula occidentalis*) (Fertig 2009). Numerous seeps, springs, and small ponds located throughout the monument also support a variety of wetland plants.

Above the canyon bottom, the steep and highly erodible slopes of the Red and White Members of the Claron Formation, otherwise known as the breaks, support sparse bristlecone pine (*Pinus longaeva*) and limber pine (*Pinus flexilis*) woodlands (Tendick et al. 2011). The breaks region is characterized by some of the harshest environmental conditions in the monument—soils are poorly developed, erosion is rapid and continuous, and multiple freeze-thaw cycles occur during winter (Tendick et al. 2011). Despite these challenges most of the monument's rare plants, including narrow endemics such as spiked ipomopsis (*Ipomopsis spicata* ssp. *tridactyla*) and Panguitch buckwheat (*Eriogonum panguicense* var. *alpestre*), thrive in this region (Figure 4.8.1-1). Rare plants also occur in calcareous clayey soils along the edge of the rim just above the breaks (Fertig 2009). Subalpine fir (*Abies lasiocarpa*) and Engelmann spruce forests dominate at the highest elevations in the monument. Spruce-fir forests are interspersed with aspen (*Populus tremuloides*) woodlands and subalpine meadows that support a variety of wildflowers, such as the Markagunt penstemon (*Penstemon leiophyllus*), scarlet paintbrush (*Castilleja miniata*), and little sunflower (*Helianthella uniflora*) (Fertig 2009).

These broad plant communities have been mapped into 71 unique associations based on dominant species (Tendick et al. 2011). Of the 71 plant associations, 26 were considered "park specials" (Tendick et al. 2011). Park specials are novel plant communities not found elsewhere; however, it's possible that these apparently endemic associations occur outside the monument but have yet to be mapped (Tendick et al. 2011). Of the 71 associations, one (quaking aspen/mountain gooseberry [*Populus tremuloides/Ribes montigenum*]) was considered globally imperiled by NatureServe, which ranks plant communities by risk of elimination across their ranges (NatureServe 2017). Park special plant associations, however, were not ranked by

Figure 4.8.1-1. Spiked ipomopsis. Photo Credit: NPS/B. Larsen.

NatureServe because they are not recognized in the National Vegetation Classification system (Tendick et al. 2011). Although only one association was considered imperiled by NatureServe, Tendick et al. (2011) caution that because so little is known about many of the monument's plant communities, particularly those considered park specials, their status remains unclear.

4.8.2. Data and Methods

A list of rare plants of conservation concern for the monument was developed using the Utah Native Plant Society (UNPS) rare plant list for the state (UNPS 2016) and cross-referencing this list with the annotated checklist of plants for Cedar Breaks NM (Fertig 2009) and updates to the 2009 checklist (Fertig et al. 2012). Species appearing on the UNPS list were ranked by conservation priority based on the following factors: geographic range, number of populations, abundance, habitat specificity, intrinsic rarity, threats, and population trend (UNPS 2016). The ranks in order from highest to lowest priority were as follows: Extremely High, High, Watch, Medium, and Low. UNPS reported all species in first four categories.

In addition, we included NatureServe's Global Species G-Rank for each species on the UNPS list (NatureServe 2017). NatureServe's G-Ranks assess abundance and conservation priority on a scale of 1–5 (1 = critically imperiled and 5 = secure) for full species (G) and varieties or subspecies (T) across their entire range. Rank qualifiers "?" and "Q" indicate inexact numeric rank and questionable taxonomy, respectively. Multiple G- and T-Ranks indicate the range of uncertainty. Species names were updated to reflect current accepted plant taxonomy according to the United States Department of Agriculture's PLANTS Database (USDA 2017). We also included a list of the 26 park special plant communities mapped in the monument during 2006 (Tendick et al. 2011).

Overall, there were few data with which to assess unique and distinctive vegetation in Cedar Breaks NM. Therefore, this assessment was based on only two independent datasets: a 2007-2008 study targeted at eighteen rare plant species (Fertig and Reynolds 2009) and 2006 NPS vegetation classification and mapping project data (Tendick et al. 2011).

<u>Population Estimate</u>

During 2007 and 2008, eighteen species of rare and locally endemic plants (Table 4.8.2-1) were surveyed across suitable habitat both within and around the monument (Fertig and Reynolds 2009). Surveys were conducted primarily in the breaks below the rim where most rare plants occur, with a few exceptions. Surveys for Arizona willow (*Salix arizonica*) were conducted in wet seep and meadow habitats west of the Amphitheater, breaks draba (*Draba subalpina*) was surveyed in the forested habitats above the rim, and spiked ipomopsis was surveyed in the exposures of the Brian Head Formation in the northeast corner of the monument (Fertig and Reynolds 2009). The objectives were to locate and map populations of each target species, record population abundance and environmental attributes (e.g., elevation, vegetation, geology), identify threats, and establish a monitoring protocol for the Arizona willow (Fertig and Reynolds 2009).

When a target species was encountered, observers approximated the population size using one of five size classes (i.e., 1-10, 11-100, 101-500, 501-1,000, and >1,000). The minimum population size for 17 of the 18

Table 4.8.2-1. Targeted rare plants.

Scientific Name	Common Name
Aster wasatchensis	Wasatch aster
Astragalus limnocharis var. *limnocharis*	Cedar Breaks milkvetch
Castilleja revealii	Bryce Canyon Indian paintbrush
Cymopterus minimus	Least spring-parsley
Draba asprella var. *zionensis*	Zion draba
Draba subalpina	Breaks draba
Ericameria zionis	Subalpine goldenbush
Erigeron proselyticus	Professor's fleabane
Erigeron vagus var. *madsenii*	Rambling fleabane
Eriogonum panguicense var. *alpestre*	Panguitch buckwheat
Ipomopsis spicata ssp. *tridactyla*	Spiked ipomopsis
Jamesia americana var. *rosea*	Rosy cliff jamesia
Lomatium minimum	Little desertparsley
Packera malmstenii	Podunk ragwort
Salix arizonica	Arizona willow
Silene petersonii	Plateau catchfly
Symphyotrichum welshii	Welsh's aster
Townsendia alpigena var. *minima*	Wyoming Townsend daisy

Source: Fertig and Reynolds (2009).

target species was based on sampled points collected during 2008. The total population estimates were derived by summing the midpoint of each category multiplied by the number of points in that category for each species (Fertig and Reynolds 2009). This estimate was then divided by the percentage of all sampled populations and rounded to the nearest 100 (Fertig and Reynolds 2009). All species except Arizona willow were mapped as point features. Willow patches were mapped as polygon features by walking the perimeter of patches that were spaced more than 100 m (328 ft) apart (Fertig and Reynolds 2009). For each target species we reported the estimated population size and conservation status as based on abundance, distribution, and potential threats as determined by Fertig and Reynolds (2009).

Frequency (%)

Frequency was determined for the 18 plant species surveyed by Fertig and Reynolds (2009) and those listed as Extremely High and High Priority by UNPS (2016) using the NPS vegetation classification and mapping project data (Tendick et al. 2011). In 2006, frequency data were collected in 172 plots distributed throughout the monument (Tendick et al. 2011). Plot size and shape varied by vegetation class. In forests and woodlands, plots were 20 x 20 m (66 x 66 ft), or 400 m^2 (4,306 ft^2). In shrublands, plots were also 400 m^2 but were either square (20 x 20 m) [66 x 66 ft]) or rectangular (40 x 10 m [131 x 33 ft]). In herbaceous areas, plots were 10 x 10 m (33 x 33 ft), or 100 m^2 (1,076 ft^2). Frequency by species was calculated by summing the number of plots containing a target plant and dividing by the total number of plots. The vegetation map classes that supported targeted species were also summarized along with the number of plots that contained a particular species. We did not calculate frequency by plant association because of high variability in sample size among associations.

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.

4.8.4. Condition and Trend

Table 4.8.4-1 lists the 18 rare plants of conservation concern in Cedar Breaks NM along with their UNPS rank and NatureServe G-Rank. There were no plants on the U.S. Fish and Wildlife Service's List of Threatened and Endangered Wildlife and Plants (USFWS 2017a). Four species were ranked as High Priority, ten species were ranked as Watch, and four species were ranked as Medium Priority. Fourteen of the 18 species were ranked as G1 (critically imperiled), G2 (imperiled), or G3 (vulnerable). Among the most imperilled species were Podunk ragwort (*Packera malmstenii*), Bryce Canyon Indian paintbrush (*Castilleja revealii*), and Welsh's aster (*Symphyotrichum welshii*). The two ranking systems were generally consistent, especially when considering the T-Ranks for varieties and subspecies. Montane coneflower (*Rudbeckia montana*), was assigned a T-Rank by NatureServe since *R. occidentalis* var. *montana* is considered a synonym for *R. montana*. However, *R. montana* is the USDA PLANTS accepted taxonomic name (USDA 2017).

Nearly half (11 of 26) of the park special plant communities occurred as upland herbaceous associations (Table 4.8.4-2). Upland herbaceous communities occur in the upper plateaus of the monument and along the edge of the breaks (Tendick et al. 2011). Upland forest and upland woodland associations accounted for an additional eight park special plant communities. Five plant communities were associated with riparian areas and the last two communities were upland shrublands. The reader should refer to Tendick et al. (2011) for a thorough description of each of these communities.

Table 4.8.3-1. Reference conditions used to assess unique and distinctive vegetation.

Indicator	Measure	Good	Moderate Concern	Significant Concern
Prevalence	Population Estimate	Populations were secure with few threats.	Populations were moderately secure to somewhat vulnerable with some threats.	Populations were vulnerable or imperiled and/or there were several threats to their populations.
	Frequency (%)	Target rare plans were common in appropriate habitat.	Target rare plants were uncommon or absent from appropriate habitat.	Target rare plants were uncommon or absent from appropriate habitat.

Population Estimate

Population size was estimated for 16 of the 18 target species (Table 4.8.4-3). All but two target species were ranked in UNPS (2016). These were Wasatch aster (*Aster wasatchensis*) and rosy cliff jamesia (*Jamesia americana* var. *rosea*). The latter species was identified as in need of data before assigning a priority rank (UNPS 2016).

Panguitch buckwheat and little desertparsley (*Lomatium minimum*) were estimated at 35,200 and 33,600 individuals, respectively. In contrast, rosy cliff jamesia (misidentified as Zion jamesia as cited in Fertig and Reynolds (2009)) was found to be extremely rare with only 100 known individuals. Zion draba (*Draba asprella* var. *zionensis*) was not found during surveys. The monument's only known specimen of Zion draba was collected in 1977 but has not been reported since (Fertig and Reynolds 2009). However, it's possible that the specimen was mislabeled (Fertig and Reynolds 2009). The population of Arizona willow could not be estimated because willows often reproduce clonally and because its stems become deeply buried in soils, making it impossible to distinguish individual plants (Fertig and Reynolds 2009). However, three main willow clusters were mapped across 16 polygons for a total of 1.06 ha (2.62 ac).

Based on population size and potential threats, such as human disturbance, grazing, or non-native invasive plants, four species were considered secure, nine species were considered probably secure, and five species were considered potentially vulnerable (Fertig and Reynolds 2009). Since 30% of the 17 species were considered potentially vulnerable, the condition for this measure warrants moderate concern., but confidence was low because the data were collected 10 years ago and this assessment is meant to address current condition (Fertig and Reynolds 2009). Trend was unknown. However, these data provide valuable baseline information regarding rare plants in the monument. In fact, Fertig and Reynolds (2009) provide the only study to date of rare plants in Cedar Breaks NM. A repeat of this study would provide valuable information on changes in rare plants.

Frequency (%)

Ten of the 18 target species, which includes the four UNPS High Priority species, were encountered across 21 of the 71 vegetation associations during the 2006 mapping project (Table 4.8.4-4). *Pinus longaeva*

Table 4.8.4-1. Rare plants of conservation concern in Cedar Breaks NM.

Scientific Name	Common Name	UNPS Rank	NatureServe G-Rank*
Astragalus limnocharis var. *limnocharis*	Cedar Breaks milkvetch	Watch	G2T1
Castilleja revealii	Bryce Canyon Indian paintbrush	High	G2
Cymopterus minimus	Least spring-parsley	Watch	G1G2Q
Draba asprella var. *zionensis*	Zion draba	Medium	G3T3?
Ericameria zionis	Subalpine goldenbush	Watch	G3
Erigeron proselyticus	Professor's fleabane	Watch	G3
Erigeron vagus var. *madsenii*	Rambling fleabane	High	G4T1
Eriogonum panguicense var. *alpestre*	Panguitch buckwheat	Watch	G3T2T3Q
Gentianella tortuosa	Jones' gentian	Medium	G3?
Ipomopsis spicata ssp. *tridactyla*	Spiked ipomopsis	High	G5T2
Lesquerella rubicundula	Breaks bladderpod	Medium	G3
Lomatium minimum	Little desertparsley	Medium	G3
Packera malmstenii	Podunk ragwort	High	G1
Penstemon tusharensis	Tushar Range beardtongue	Watch	G2Q
Rudbeckia montana	Montane cone-flower	Watch	G5T2T4
Salix arizonica	Arizona willow	Watch	G2G3
Symphyotrichum welshii	Welsh's aster	Watch	G2
Townsendia alpigena var. *minima*	Townsend daisy	Watch	G4T3

Note: Plant list is based on UNPS (2016), Fertig (2009), and Fertig et al. (2012).

* NatureServe's global ranks assesses abundance and conservation priority on a scale of 1–5 (1 = critically imperiled and 5 = secure) for full species (G) and varieties or subspecies (T) across their entire range. Rank qualifiers "?" and "Q" indicate inexact numeric rank and questionable taxonomy, respectively. Multiple G- and T-Rranks indicate range of uncertainty.

Table 4.8.4-2. Plant associations specific to Cedar Breaks NM.

Association	Plant Association Scientific Name	Plant Association Common Name
Upland Forest	*Abies lasiocarpa - Picea engelmannii / Ligusticum porteri* Forest	Subalpine Fir – Engelmann Spruce / Porter's Licorice-root Forest
	Picea pungens / Acer glabrum Forest	Blue Spruce / Rocky Mountain Maple Forest
	Pseudotsuga menziesii / Ribes montigenum Forest	Douglas-fir / Gooseberry Currant Forest
	Populus tremuloides - Pseudotsuga menziesii / Sparse Understory Forest	Quaking Aspen - Douglas-fir Sparse Understory Forest
Upland Woodland	*Cercocarpus ledifolius / Chrysothamnus nauseosus* Woodland	Curl-leaf Mountain-mahogany / Rubber Rabbitbrush Woodland
	Picea pungens / Purshia tridentata Woodland	Blue Spruce / Antelope Bitterbrush Woodland
	Pinus ponderosa - Pseudotsuga menziesii / Arctostaphylos patula Colorado Plateau Woodland	Ponderosa Pine - Douglas-fir / Greenleaf Manzanita Colorado Plateau Woodland
	Pinus ponderosa / Cercocarpus ledifolius / Arctostaphylos patula Woodland	Ponderosa Pine / Curl-leaf Mountain Mahogany / Greenleaf Manzanita Woodland
Upland Shrubland	*Acer glabrum* Colluvial Slope Shrubland	Rocky Mountain Maple Colluvial Slope Shrubland
	Ericameria discoidea Dwarf-shrubland Herbaceous Sparse Vegetation	Sharp-scaled Goldenweed Dwarf-shrubland Herbaceous Sparse Vegetation
Upland Herbaceous	*Aster adscendens* Herbaceous Vegetation	Western Aster Herbaceous Vegetation
	Calamagrostis scopulorum Herbaceous Vegetation	Jones Reedgrass Herbaceous Vegetation
	Carex egglestonii Herbaceous Vegetation	Eggleston Sedge Herbaceous Vegetation
	Elymus trachycaulus Herbaceous Vegetation	Slender Wheatgrass Herbaceous Vegetation
	Erigeron ursinus Herbaceous Vegetation	Bear Daisy Herbaceous Vegetation
	Eriogonum panguicense Herbaceous Vegetation	Panguitch Wild Buckwheat Herbaceous Vegetation
	Eriogonum umbellatum - Potentilla hippiana Herbaceous Vegetation	Sulfur Buckwheat – Woolly Cinquefoil Herbaceous Vegetation
	Helianthella uniflora Herbaceous Vegetation	Oneflower Helianthella Herbaceous Vegetation
	Viguiera multiflora Herbaceous Vegetation	Showy Goldeneye Herbaceous Vegetation
	Lomatium minimum - Arenaria fendleri Herbaceous Vegetation	Little Desert Parsley – Fendler Sandwort Herbaceous Vegetation
	Solidago multiradiata Herbaceous Vegetation	Rocky Mountain Goldenrod Herbaceous Vegetation
Riparian and Wetland Forest	*Picea pungens / Salix brachycarpa* Woodland	Blue Spruce / Shortfruit Willow Woodland
	Populus angustifolia - Picea pungens / Acer glabrum Woodland	Narrowleaf Cottonwood – Blue Spruce / Rocky Mountain Woodland
	Populus angustifolia Temporarily Flooded Terrace Woodland	Narrowleaf Cottonwood Temporarily Flooded Terrace Woodland
Riparian and Wetland Shrubland	*Salix arizonica* Shrubland	Arizona Willow Shrubland
Riparian and Wetland Herbaceous	*Carex scirpoidea* Seasonally Flooded Herbaceous Vegetation	Canadian Single-spike Sedge Seasonally Flooded Herbaceous Vegetation

Source: Tendick et al. (2011).

woodlands contained six of the 10 species, while the remaining 20 associations contained four or fewer species. Wasatch aster, (12%) Panguitch buckwheat (8%), and breaks draba (8%) occurred most frequently. Wasatch aster occurred in 12 vegetation associations and little desertparsley occurred in nine vegetation associations. This measure was difficult to assess because of the often low and uneven number of samples within the range of plant associations surveyed, and because of the apparently widespread but low frequency exhibited by some species. Eight of the 18 target species were not encountered at all. Rare plants are by their nature uncommon, and the 2006 vegetation mapping effort was not designed to survey rare species. Rare plants are better surveyed through targeted efforts such as the Fertig and Reynolds (2009)

Table 4.8.4-3. Population estimates in Cedar Breaks NM for targeted rare plants.

Target Species	Estimated Population	Conservation Status
Panguitch buckwheat	35,200	Secure
Little desertparsley	33,600	Secure
Wasatch aster	15,100	Secure
Least spring-parsley	12,500	Secure
Breaks draba	8,700	Probably Secure
Professor's fleabane	4,200	Probably Secure
Cedar Breaks milkvetch	4,100	Probably Secure
Subalpine goldenbush	4,100	Probably Secure
Wyoming Townsend daisy	4,100	Probably Secure
Plateau catchfly	2,900	Probably Secure
Spiked ipomopsis	2,800	Probably Secure
Welsh's aster	1,700	Probably Secure
Podunk ragwort	1,500	Potentially Vulnerable
Bryce Canyon Indian paintbrush	500	Potentially Vulnerable
Rambling fleabane	400	Potentially Vulnerable
Rosy cliff jamesia	100	Potentially Vulnerable
Zion draba	Unknown	Potentially Vulnerable
Arizona willow	NA	Probably Secure

Source: Fertig and Reynolds (2009).

study. For these reasons, the condition for this measure was unknown. Trend was unknown. Confidence was low given the age of the data (i.e., >10 yrs).

Overall Condition, Trend, Confidence Level, and Key Uncertainties

Overall, the current condition of unique and distinctive vegetation in Cedar Breaks NM is unknown because of the lack of monitoring since 2008 (Table 4.8.4-5). In 2009, data suggested the condition of 4-5 plant species was potentially vulnerable and 13 other rare species were secure or probably secure. A monitoring program is needed to assess the status of all of these high priority species every 5 years (or possibly less for the 4-5 most vulnerable taxa). In the absence of more frequent monitoring the overall confidence rating is low.

There are 18 rare species of conservation concern and 26 distinct plant community associations in Cedar Breaks NM; however as stated in the introduction, it's possible that these 26 apparently endemic associations occur outside the monument but have yet to be mapped. In a comparison of floristic composition across 14 protected areas in Utah, Cedar Breaks NM exhibited high rates of endemism relative to the monument's overall species richness (Fertig and Reynolds 2012). Nearly 18% of the monument's plant species were not found in any of the other protected areas studied, and 10 species were endemic to the monument (Fertig and Reynolds (2012). Areas of high endemism often occur in common habitat types that are usually species-poor (e.g., *Pinus longaeva* woodlands) but critical for protecting the high number of rare species they support (Stohlgren et al. 2005). Species richness in Cedar Breaks NM is not particularly high, even when controlling for it's small size (Fertig and Reynolds 2012). In contrast, areas of high species richness, or "hotspots", may lack rare or endemic species, but these areas play a critical role for birds, invertebrates, and mammals in arid regions (Stohlgren et al. 2005). Efforts that focus on both "hotspots" and areas of high endemism will protect the greatest variety of unique and distinctive vegetation (Fertig and Reynolds 2012).

Threats, Issues, and Data Gaps

Since there were few data with which to assess this resource topic and those that were available were collected 10 or more years ago, the resource topic itself represents a data gap, at least with respect to current condition. Fertig and Reynolds (2009) provide an excellent baseline for which future studies could be compared. Fertig and Reynolds (2009) was the only study included in this assessment that specifically targeted rare plants. Note that during final review of the full NRCA report draft, Doug Reynolds indicated that he and others developed a fairly simple monitoring protocol for rare species, collected data in 2014, and recommended future data collection every five years. Park staff can perhaps utilize this information if a monitoring program is developed for unique and distinctive vegetation at the monument

Additional data gaps include a lack of plant phenological data, information about the diversity and abundance of pollinators, and the absence of long-term studies to track changes (NPS 2015a). Although NPS staff have implemented a citizen science project focused on rare plants, which may eventually fill this gap in knowledge, data from this project were not yet available for inclusion in this assessment (NPS,

Table 4.8.4-4. Frequency and vegetation associations of rare plants in Cedar Breaks NM.

Common Name	Frequency (%)	Plant Associations
Wasatch aster	12	*Calamagrostis scopulorum* Herbaceous Vegetation [Park Special] (2 of3), *Populus angustifolia - Picea pungens / Acer glabrum* Woodland [Park Special] (1 of 1), *Abies concolor / Mahonia repens* Forest (3 of 12), *Picea pungens / Juniperus communis* Forest (1 of 18), *Populus angustifolia* Temporarily Flooded Terrace Woodland (3 of 8), *Cercocarpus ledifolius* Woodland Alliance (1 of 3), *Pinus longaeva* Woodland (1 of 23), *Salix exigua* Temporarily Flooded Shrubland (1 of 1), *Acer glabrum* Colluvial Slope Shrubland [Park Special] (3 of 4), *Pinus ponderosa / Arctostaphylos patula* Woodland (2 of 13), *Juniperus scopulorum / Cercocarpus ledifolius* Woodland (1 of 3), *Abies concolor / Juniperus communis* Forest (1 of 12)
Breaks draba	8	*Pinus ponderosa / Arctostaphylos patula* Woodland (5 of 13), *Abies concolor / Arctostaphylos patula* Forest (2 of 16), *Abies lasiocarpa - Picea engelmannii / Ribes (montigenum, lacustre, inerme)* Forest (1 of 34), *Pinus longaeva* Woodland (4 of 23), *Elymus trachycaulus* Herbaceous Vegetation [Park Special] (1 of 6), *Pseudotsuga menziesii / Juniperus communis* Forest (1 of 3)
Panguitch buckwheat	8	*Pinus longaeva* Woodland (5 of 23), *Ericameria discoidea* Dwarf-shrubland Herbaceous Sparse Vegetation [Park Special] (3 of 5), *Poa pratensis - (Pascopyrum smithii)* Semi-natural Herbaceous Vegetation (1 of 8), *Acer glabrum* Colluvial Slope Shrubland [Park Special] (1 of 4), *Bromus inermis - (Pascopyrum smithii)* Semi-natural Herbaceous Vegetation (1 of 7), *Eriogonum panguicense* Herbaceous Vegetation [Park Special] (4 of 6)
Little desertparsley	6	*Pinus longaeva* Woodland (2 of 23), *Abies lasiocarpa - Picea engelmannii / Ribes (montigenum, lacustre, inerme)* Forest (1 of 34), *Ericameria discoidea* Dwarf-shrubland Herbaceous Sparse Vegetation [Park Special] (1 of 5), *Lomatium minimum - Arenaria fendleri* Herbaceous Vegetation [Park Special] (1 of 3), *Bromus inermis - (Pascopyrum smithii)* Semi-natural Herbaceous Vegetation (1 of 7), *Elymus trachycaulus* Herbaceous Vegetation [Park Special] (1 of 6), *Eriogonum panguicense* Herbaceous Vegetation [Park Special] (1 of 6), *Populus angustifolia* Temporarily Flooded Terrace Woodland (1 of 8), *Acer glabrum* Colluvial Slope Shrubland [Park Special] (1 of 4)
Spiked ipomopsis	5	*Ericameria discoidea* Dwarf-shrubland Herbaceous Sparse Vegetation [Park Special] (4 of 5), *Eriogonum panguicense* Herbaceous Vegetation [Park Special] (4 of 6)
Cedar Breaks milkvetch	3	*Pinus longaeva* Woodland (3 of 23), *Pinus ponderosa / Purshia tridentata* Woodland (1 of 2), *Ericameria discoidea* Dwarf-shrubland Herbaceous Sparse Vegetation [Park Special] (1 of 5)
Least spring-parsley	3	*Pinus longaeva* Woodland (6 of 23)
Arizona willow	3	*Salix arizonica* Shrubland [Park Special] (3 of 4), *Carex scirpoidea* Herbaceous Vegetation [Park Special] (2 of 2)
Professor's fleabane	1	*Populus angustifolia* Temporarily Flooded Terrace Woodland (2 of 8)
Plateau catchfly	1	*Eriogonum panguicense* Herbaceous Vegetation [Park Special] (2 of 6)

Source: Tendick et al. (2011).

B. Larsen, natural resource specialist, NRCA scoping meeting, 10-12 April 2017).

A portion the park's rare plants are naturally protected because many populations occur in areas that are hard to reach (i.e., the breaks) (Fertig and Reynolds 2009). However, thirteen species also occur in areas of high visitor use (i.e., along the rim where visitors concentrate for views into the breaks) (Fertig and Reynolds 2009). Fertig and Reynolds (2009) suggest that since many of these species are small and short, they are difficult to see and are easily trampled (Fertig and Reynolds 2009). Although barriers have been erected in some areas to discourage the use of social trails and to protect native vegetation, visitors sometimes ignore them (Fertig and Reynolds 2009). Trampling by sheep trespass also has the potential to affect rare plants on the plateau above the rim (Fertig and Reynolds 2009). However, livestock grazing is no longer permitted in the park, and a boundary fence in the uplands limits trespass (Tendick et al. 2011). Trespass may occasionally occur if the fence is damaged by windthrow or other factors.

Some of the overlooks where rare plants occur have been invaded by smooth brome (*Bromus inermis*) (Fertig and Reynolds 2009). Smooth brome is one of the most widely spread and invasive species found in the monument and largely occurs in subalpine meadows and cushion plant communities (i.e., compact, low growing, mat forming plants) above

Table 4.8.4-5. Summary of unique and distinctive vegetation indicators, measures, and condition rationale.

Indicators of Condition	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Prevalence	Population Size		Based on population size and potential threats four species were considered secure, nine species were considered probably secure, and five species were considered potentially vulnerable. Since 30% of the 17 species were considered potentially vulnerable, the condition for this measure warrants moderate concern. However, confidence is low because the data were collected 10 years ago and the population was roughly estimated. No trend data were available.
	Frequency (%)		This measure was difficult to assess because of the small and uneven number of sample sizes across plant associations and because these data were collected more than 10 years ago. Targeted surveys are necessary to adequately sample rare plants in the monument.
Overall Condition			Neither of the two studies used to assess condition reported recent data (i.e., < 5 yrs), and only one study focused on rare plants. This resulted in an unknown condition rating for this resource, although one of the two measures used suggests moderate concern. Given the age of the data and the fact that one study was not specifically targeted at surveying rare plants, confidence for both measures was low, which resulted in an overall low confidence. Trend could not be determined. These results suggest that the topic itself is a data gap.

the rim, in addition to roadsides and other disturbed areas (Dewey and Anderson 2005, Fertig and Reynolds 2009). Once established, invasive plants can be extremely difficult to control and most will never be completely eradicated (Mack et al. 2000). The harsh environmental conditions of the breaks, where many rare plants occur, may help limit the spread of non-native species, but climate change may alter the susceptibility of the breaks to non-native plants.

The western U.S., and especially the Southwest, has experienced increasing temperatures and decreasing rainfall over the last 40 years (Prein et al. 2016). Since 1974 there has been a 25% decrease in precipitation, a trend that is partially counteracted by increasing precipitation intensity (Prein et al. 2016). In Cedar Breaks NM, climate change data indicate a trend toward warmer but not necessarily drier conditions (Monahan and Fisichelli 2014). While there were no apparent changes in total precipitation, warmer temperatures influence whether precipitation falls as snow or rain. The distinction between the amount of precipitation falling as snow as opposed to rain is particularly important in the snow-dependent hydrologic landscape of the western U.S. (Pugh and Gordon 2013). The protective cover of snow and about 250 days of frost per year (NPS 2016a) limit the growing season for non-native species. Warmer temperatures and decreased snowfall, however, may make the park more favorable to non-native plants through direct effects or by shifting native species out of their ranges (Hellmann et al. 2008). How climate change will affect rare plant communities in the monument is unknown.

4.8.5. Sources of Expertise

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

4.9. Non-native Invasive Plants

4.9.1. Background and Importance

Vegetation in Cedar Breaks National Monument (NM) ranges from low elevation, sparsely vegetated breaks below the rim to montane forests and subalpine meadows at the highest elevations above the rim (Tendick et al. 2011). While non-native plants have been documented in all areas of the park, most species occur in the uplands, which tend to exhibit low resistance to invasion and slow recovery times once invasion occurs (Tendick et al. 2011; Witwicki et al. 2013). All roads in the monument occur in the uplands, which are vectors for non-native species dispersal (Dewey and Anderson 2005). Other disturbed areas, such as around buildings, trails, and observation points, are also prone to the establishment of non-native plants (Dewey and Anderson 2005).

Smooth brome (*Bromus inermis*) and dandelion (*Taraxacum officinale*) are the most widespread non-native plant species in the monument (NPS 2015a). 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).

Nonnative 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).

Figure 4.9.1-1. NPS staff spraying a smooth brome infestation in Cedar Breaks NM. Photo Credit: NPS.

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.

4.9.2. Data and Methods

We used three indicators, potential to alter native plant communities, rate of invasion, and prevalence of non-native plants, with a total of four measures, to determine current condition of non-native plants at Cedar Breaks NM. There have been several efforts over the years to document non-native plant presence in the monument. Roberts and Jean published one of the first lists of non-native plants found during their two-year study (1988-1989) (Roberts and Jean 1989), and in 1997 staff from Zion National Park conducted a survey of non-native plants in the monument (Mason and LaBarre 1997 as cited in Dewey and Anderson 2005). These surveys were followed by a non-native plant inventory and mapping effort in 2004 (Dewey and Anderson 2005). Although not specifically targeted at non-native plants, the 2006 NPS vegetation classification and mapping project included field data on non-native plant cover and frequency (Tendick et al. 2011). Based on the above-mentioned surveys (and others), a review of museum specimens, and field work conducted during 2006-2007, non-native plants were compiled in an annotated checklist in 2009 (Fertig 2009) and in an update to the checklist in 2012 (Fertig et al. 2012). Finally, NCPN staff began long-term monitoring of upland vegetation in the monument in 2009, including cover and frequency of non-native plants (Witwicki 2010).

NatureServe Invasive Species Impact Rank

The NatureServe database (NatureServe Explorer 2017), 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 rank protocol assesses four major categories for each species (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). We used the rounded I-rank if a species was split between two rankings (e.g., high/medium), unless the rounded I-rank was unknown. Rounded I-ranks usually occurred when a species was split between two categories that were not near each other in the ranking system (e.g., high/low).

New Non-native Plants Detected

During 2005-2007, Fertig (2009) reviewed existing literature and museum specimens to develop a list of vascular plants in the monument. The museum and literature review was supplemented by field work conducted during 2006-2007 to verify existing reports and to locate new species (Fertig 2009). Appendix A in Fertig (2009) lists all plants known to occur in the monument as of 2007, including non-native species and the year in which they were first documented. In 2012, Fertig and Topp (2012) published an update to the original annotated checklist, which included additional species identified during subsequent studies through 2011. We cross-referenced these lists with NCPN upland plant data collected after the checklists were published (i.e., 2012-2015). The rate of invasion was calculated as the proportion of cumulative plant species documented by decade that are considered non-native. Additional potentially occurring but unconfirmed species were listed in Fertig (2009) and NPSpecies (NPS 2017a). These species were not included in this assessment because they have never been documented in the monument but occur in the vicinity.

Frequency (%) andCover (%)

We used three datasets to evaluate non-native plant frequency and cover: 2004 NCPN non-native plant inventory and mapping data (Dewey and Anderson 2005), 2006 NPS vegetation classification and mapping project data (Tendick et al. 2011), and 2009-2015 NCPN upland plant data (unpublished NCPN data) Figure 4.9.2-1 shows the inventory and monitoring locations for each project.

NCPN Non-native Plant Inventory and Mapping

In August 2004, Dewey and Anderson (2005) surveyed 531 ha (1,313 ac) for non-native plants. The area included nearly all uplands with emphasis on areas of management concern, including all main roads, parking areas, campgrounds, service roads, housing

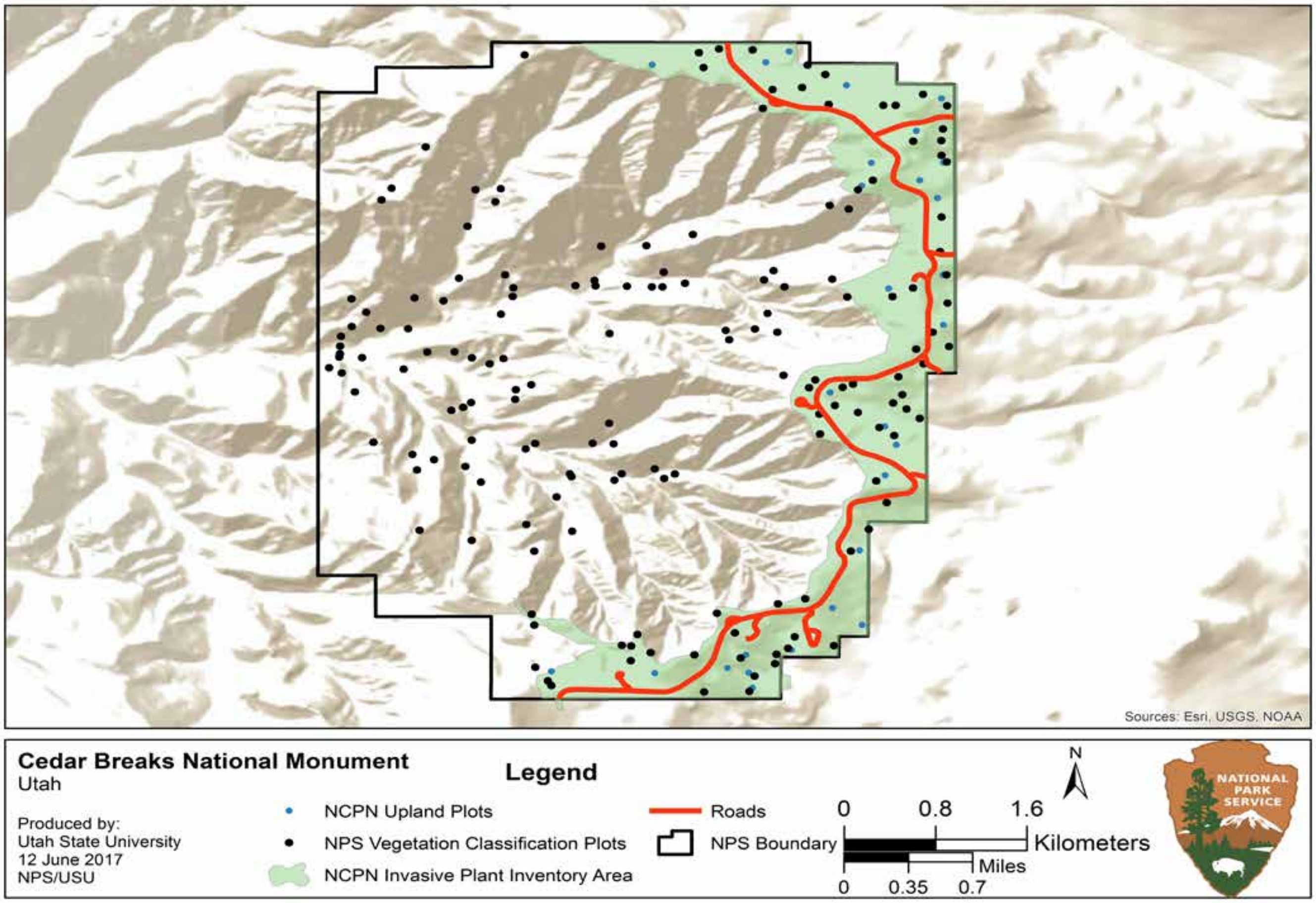


Figure 4.9.2-1. Locations of vegetation monitoring plots and target survey areas in Cedar Breaks NM.

areas, meadows, and forests. Fifteen non-native plants were targeted as high priority for inventory and mapping, only some of which were known to occur in the monument at the time surveys were conducted (Table 4.9.2-1). Additional non-native plants were documented if found but not necessarily mapped. Off-road areas were surveyed by dividing the landscape into 0.25-0.50 km^2 (0.10-0.20 mi^2) blocks. Within each block observers walked transects spaced 25-50 m (82-164 ft) apart depending on the terrain. For road corridors, observers mapped all targeted non-native plants out to 50 m (164 ft) from the road edge. Plant infestations were recorded as point features and were estimated visually by patch size class. Patch size classes were: 0.0004 ha (0.001 ac), 0.004 ha (0.01 ac), 0.04 ha (0.1 ac), 0.10 ha (0.25 ac), 0.2 ha (0.5 ac), 0.4 ha (1.0 ac), 1.0 ha (2.5 ac), 2.0 ha (5.0 ac). Overall canopy cover within the area of infestation was also estimated as follows: <1%, 1-5%, 6-25%, 26-50%, and 51-100%. We could not determine frequency since these are not plot-based data. We reported total cover by species within the inventoried area.

<u>NPS Vegetation Classification and Mapping Project</u>

In support of the NPS vegetation classification and mapping project, field data were collected in 172 plots distributed throughout the monument in 2006 (Tendick et al. 2011). Plot size and shape varied by vegetation class. In forests and woodlands, plots were 20 x 20 m (66 x 66 ft), or 400 m^2 (4,306 ft^2). In shrublands, plots were also 400 m^2 but were either square (20 x 20 m) [66 x 66 ft]) or rectangular (40 x 10 m [131 x 33 ft]). In herbaceous areas, plots were 10 x 10 m (33 x 33 ft), or 100 m^2 (1,076 ft^2). Within each plot the percent cover in increments of 5% (except for the first two classes, which were designated as “few” and 0-1%) was recorded. We calculated cover by using the mid-points of the cover classes and averaging over all plots by species. Total frequency and frequency by species was calculated by summing the number of plots containing a non-native plant and dividing by the total number of plots. We also summarized the vegetation map classes that were the most heavily invaded by non-native plants.

Table 4.9.2-1. Non-native plants targeted for inventory and mapping during 2004.

Species	Common Name
Bromus inermis	Smooth brome
Bromus tectorum	Cheatgrass
Carduus nutans	Musk thistle
Chenopodium album	Lambsquarters
Centaurea diffusa	Diffuse knapweed
Centaurea maculosa	Spotted knapweed
Centaurea repens	Russian knapweed
Cirsium arvense	Canada thistle
Dactylis glomerata	Orchard grass
Elaeagnus angustifolia	Russian olive
Onopordum acanthium	Scotch thistle
Phleum pratensis	Timothy grass
Tamarix ramosissima	Saltcedar
Tragopogon dubius	Common salsify
Ulmus pumila	Siberian elm

Source: Dewey and Anderson (2005).

NCPN Uplands Plant Monitoring

NCPN upland plant monitoring occurred in each of 28, 50 x 50 m (164 x 164 ft) plots during 2009-2015 (Witwicki 2010). Plots were distributed across subalpine meadow, spruce-fir forests (*Picea engelmannii-Abies lasiocarpa*), and aspen (*Populus tremuloides*) stands (data provided by D. Witwicki, NCPN vegetation ecologist). Each plot was sampled for two consecutive years during the 7-year sampling period (i.e., 7 or 8 plots per year). Percent cover for each species was recorded along each of three 50-m (164-ft) transects located within each plot using the point-intercept method (Witwicki et al. 2013). Cover refers to absolute cover and was derived by summing the number of points where each species intercepts the line transect and dividing by the total number of point-intercepts across all three transects (Witwicki et al. 2013). Cover was summarized by species and year and then averaged over all years across all plots. Quadrat frequency was measured in 1 x 1 m (3 x 3 ft) quadrats placed every 5 m (3 ft) along each transect. NCPN staff began collecting quadrat frequency data in 2011. We also calculated frequency based on the 28 large plots (i.e., plot frequency). Plot frequency was calculated by summing the number of plots that contained at least one non-native species and dividing by the total number of plots. We calculated average plot frequency by species and year.

4.9.3. Reference Conditions

Table 4.9.3-1 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 NCPN staff.

Table 4.9.3-1. Reference conditions used to assess non-native plants.

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 and/or one or two species with a high ability to alter ecosystem structure and function are present.	Many non-native species with medium and/or many species with high ability to alter ecosystem structure and function are present.
Rate of Invasion	% of New Non-native Species of Total Species Detected Over Time	The rate of new non-native plant discoveries has remained stable or has increased slightly (i.e,. 1-2%) over time.	The rate of new non-native plant discoveries has increased modestly (i.e., 3-5%) over time.	The rate of new non-native plant discoveries has increased substantially (i.e., >5%) over time.
Prevalence	Frequency by Vegetation Type or Area (% of plots)	<25%	25-50%	>50%
	Cover by Vegetation Type or Area (%)	<1%	1-4%	>4%

4.9.4. Condition and Trend

NatureServe Invasive Species Impact Rank

Of the 20 non-native species listed in Table 4.9.4-1, three have not been assessed by NatureServe, although one, *Tamarix spp.*, is listed as a top priority for three water-based NCPN parks (NPS NCPN Invasive [Plant] Species List 2017). None of the 20 species are considered noxious by the State of Utah (Utah Department of Agriculture and Food 2017). Of the remaining 17 species, three (18%) were given a low rank, one (6%) was given a medium/low rank, four (24%) were given a medium/insignificant rank, six (35%) were given a medium rank, one was given a high/low rank (6%), and two (12%) were given a high rank. Species with the highest rank were smooth brome and cheatgrass (*Bromus tectorum*). Since the majority of species (71%) were ranked as medium, including several with mixed ranks, and only two species were ranked high, we consider this measure to warrant moderate concern. Confidence is high. Trend does not apply to this measure.

New Non-native Plants Detected

By 1949, 36 species had been documented for the park but none of them were non-native. The first non-native plants were documented during the 1950s. These species were smooth brome, Timothy grass (*Phleum pratense*), and Kentucky bluegrass (*Poa pratensis*) (Table 4.9.4-1). Smooth brome was planted along the road as a revegetation species (Dewey and Anderson 1997). Roberts and Jean (1989) reported that smooth brome was introduced during the 1960s but according to Fertig (2009), smooth brome was documented by 1954. By the end of the 1950s, non-native plants represented just over 2% of the total known species in the monument. By the 1970s, only two additional non-native plants had been documented, but nine new species were documented during the 1980s, which represents 4.9% of the total plants known to occur in the monument at the time. The proportion increased slightly during the 1990s and 2000s. By 2010, 5% of all species known to occur in the monument were non-native (Figure 4.9.4-1). The most recent species documented in the monument are bull thistle (*Cirsium vulgare*) and prickly lettuce (*Lactuca serriola*)

Table 4.9.4-1. Non-native plant species documented in Cedar Breaks NM.

Scientific Name	Common Name	NatureServe Invasive Species Impact Rank	Year Documented
Agropyron cristatum	Crested wheatgrass	Medium	1989
Agrostis stolonifera	Redtop	Medium	1970
Bromus inermis	Smooth brome	High	1954
Bromus tectorum	Cheatgrass	High	1981
Chenopodium album	Lambsquarters	Not Assessed	1996
Cirsium vulgare	Bull thistle	Medium	2009
Dactylis glomerata	Orchard grass	Medium/Insignificant	1986
Elymus hispidus	Intermediate wheatgrass	Medium/Insignificant	1989
Lactuca serriola	Prickly lettuce	Low	2009
Malva neglecta	Common mallow	Medium/Insignificant	1987
Melilotus officinalis	Yellow sweetclover	Medium	1986
Phleum pratense	Timothy grass	Medium	1954
Poa annua	Annual bluegrass	Medium/Insignificant	2006
Poa compressa	Canada bluegrass	High/Low	1981
Poa pratensis[1]	Kentucky bluegrass	Medium	1954
Polygonum aviculare	Knotweed	Low	1989
Tamarix chinensis	Five-stamen tamarisk	Not Assessed	2007
Taraxacum officinale	Dandelion	Not Assessed	1977
Thlaspi arvense[2]	Field pennycress	Low	2005
Tragopogon dubius	Common salsify	Medium	1981

[1] Many sources consider *Poa pratensis* to be from Europe. Some others consider there to be native populations in Europe and the Northern mountain regions of the U.S. (such as the Uinta Mtn.) making the designation of non-native uncertain (Laura Schrage, Veg Program Mgr, Zion NP, pers. comm.).

[2] Species listed in the literature for the park but have not been corroborated with a voucher specimen (Fertig 2009).

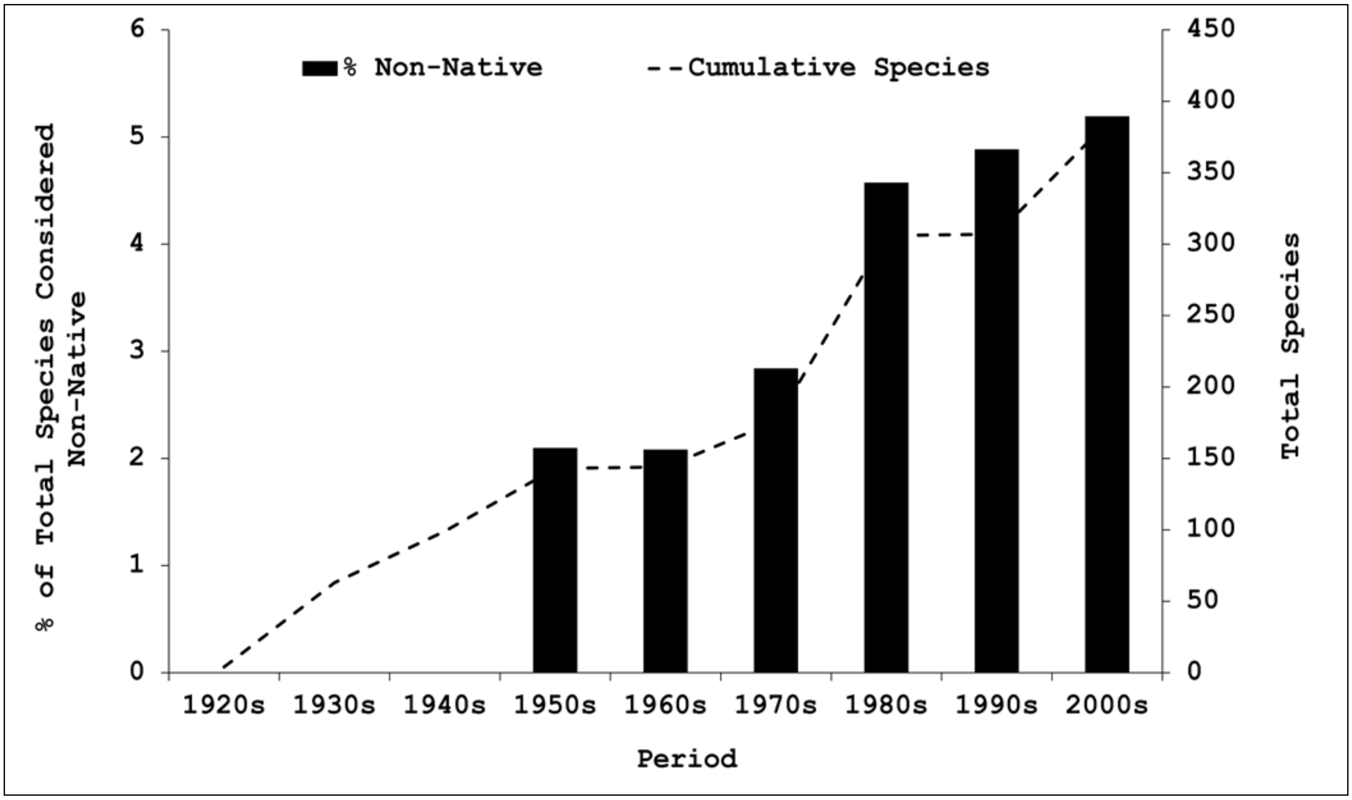


Figure 4.9.4-1. Proportion of total plants documented in Cedar Breaks NM that are non-native.

in 2009. No new non-native species were detected in the NCPN upland plots since Fertig and Topp (2012) published their updated checklist. During the last decade the ratio of non-native plants to native plants was 5.19% and the trend has deteriorated somewhat over time, warranting moderate to significant concern. Confidence is medium since the date of documentation does not necessarily reflect the date of introduction.

Frequency (%)

NPS Vegetation Classification and Mapping Project

At least one non-native species was detected in 42% of the 172 NPS vegetation classification and mapping project plots. Nearly all (83%) of the 72 plots with at least one non-native species were located in the uplands. Four non-native species were detected (Table 4.9.4-2). Smooth brome and common salsify (*Trapopogon dubius*) each occurred in less than 2% of plots, while Kentucky bluegrass (29%) and dandelion (31%) were fairly widespread. Combined, these four species occurred in plots in 15 of the 21 vegetation classes mapped in the monument (including barren wash channels). Smooth brome occurred in only one map class and common salsify occurred in only three map classes. Both dandelion and Kentucky bluegrass were found in 11 and 10 map classes, respectively. Based on reference conditions these results warrant moderate concern. Although the data for smooth brome indicates low occurrence, this is misleading. The perennial disturbed grasslands in which smooth brome and Kentucky bluegrass occurs, includes vegetation associations that are dominated by these species (Tendick et al 2011). This indicates that smooth brome and Kentucky bluegrass are common in certain areas, particularly in meadows. Confidence in the condition rating is medium since these data were collected more than 10 years ago. Trend could not be determined based on this single sampling effort.

NCPN Uplands Plant Monitoring

In the 28 NCPN upland monitoring plots, four non-native species were observed during 2009 to 2015, and at least one non-native species was observed in each plot for 100% frequency (Table 4.9.4-3). On average, both Kentucky bluegrass and dandelion were widely distributed across plots but only moderately distributed within plots. Smooth brome was moderately distributed both within and across plots and common salsify was rare. Based on plot frequency data, the condition warrants significant concern. Confidence is high since data were recently collected and are part of a long-term monitoring effort. Trend

Table 4.9.4-2. Frequency of non-native plants in NPS vegetation classification and mapping project plots.

Species	Frequency (%)	Vegetation Map Classes
Smooth brome	1.16	Perennial disturbed grassland complex
Kentucky bluegrass	28.49	Arizona willow temporarily flooded shrubland, aspen forest complex, dry meadow mixed herbaceous vegetation mosaic, mixed desert forb complex, mixed mountain shrubland complex, perennial disturbed grassland complex, silver sagebrush bottomland shrubland, subalpine fir-Engelmann spruce, wet meadow herbaceous vegetation mosaic, whitestem goldenbush dwarf-shrubland
Dandelion	30.81	Arizona willow temporarily flooded shrubland, aspen forest complex, dry meadow mixed herbaceous vegetation mosaic, manzanita shrubland, mixed desert forb complex, mixed mountain shrubland complex, narrowleaf cottonwood temporarily flooded wash complex, perennial disturbed grassland complex, silver sagebrush bottomland shrubland, subalpine fir-Engelmann spruce
Common salsify	1.74	Barren wash channels, dry meadow mixed herbaceous vegetation mosaic, ponderosa pine-(Douglas fir) woodland complex

Source: NPS vegetation mapping data (Tendick et al. 2011).

Table 4.9.4-3. Average frequency of non-native plants in NCPN upland monitoring plots.

	Frequency (%)			
Year	Smooth brome	Kentucky bluegrass	Dandelion	Common salsify
2009	NA (14.3)	NA (100)	NA (100)	NA (14.3)
2010	NA (12.5)	NA (100)	NA (87.5)	0 (0)
2011	63.3 (25.0)	51.7 (100)	24.8 (87.5)	0 (0)
2012	13.3 (28.6)	19.4 (85.7)	21.4 (100)	0 (0)
2013	0.0 (0.0)	42.9 (57.1)	23.3 (100)	0 (0)
2014	43.3 (14.3)	41.1 (100)	17.6 (100)	0 (0)
2015	10.0 (12.5)	37.5 (100)	24.2 (100)	0 (0)
Average	26.0 (15.3)	38.5 (91.8)	22.6 (96.4)	0 (2.0)

Source: NCPN unpublished data.

could not be determined since these data represent the first round of sampling.

<u>Summary</u>

Together, these data indicate that the majority of non-native plants known to occur in the monument are rare, at least across the plots sampled. Only four of the 20 known non-native species were encountered between the two studies. Although different methods were used, both studies show that Kentucky bluegrass and dandelion were widespread while smooth brome and common salsify (NPS vegetation classification project, Tendick et al. 2011) were limited in distribution. However, the NCPN upland monitoring plots were not located in meadows where smooth brome is expected to be high and the NPS vegetation classification plots were distributed across the 21 vegetation classes which diminished its apparent cover. Although frequency data indicate moderate to significant concern for Kentucky bluegrass and dandelion, especially in the uplands, neither is considered highly invasive. However, smooth brome was ranked high by NatureServe. For these reasons, the condition for this measure is split between moderate and significant concern. Confidence is medium. Trend is unknown.

<u>Cover (%)</u>

NCPN Non-native Plant Inventory and Mapping

In the 531 ha (1,313 ac) surveyed for non-native plants in 2004 as part of the NCPN non-native plant inventory 17 (42 ac), or 3.2%, of the total area was infested (Table 4.9.4-4). Only six of the 15 target species were detected. Smooth brome was the most widespread species, comprising just 3% of the total survey area but 94% of the total infested area. The vast majority of smooth brome was located along roadsides and only in isolated patches in open meadows or along the edges of timber (Dewey and Anderson 2005). Dewey and Anderson (2005) speculate that smooth brome has spread since the 1997 survey conducted by staff from Zion NP. Cheatgrass was the species with the

Table 4.9.4-4. Absolute foliar cover of non-native plants in target upland areas.

Species	Area ha (ac)	Total Cover (%)
Smooth brome	15.96 (39.45)	3.0
Cheatgrass	0.74 (1.82)	0.1
Lambsquarters	0.09 (0.22)	< 0.1
Orchard grass	0.04 (0.11)	< 0.1
Timothy grass	0.10 (0.26)	< 0.1
Common salsify	< 0.00 (0.01)	< 0.1
Total	16.95 (41.88)	3.2

Source: Dewey and Anderson (2005).

second most cover, comprising only 0.1% of the total survey area and 4.3% of the total infested area, but this species was restricted to the northern boundary above Orange Ridge and Highleap Canyon (Dewey and Anderson 2005). The remaining four species were rare and were almost always confined to the road shoulder (Dewey and Anderson 2005). Kentucky bluegrass and dandelion were considered widespread and abundant but were not mapped in 2004 (Dewey and Anderson 2005). Thus, these data do not represent a complete assessment of non-native plant cover in the inventoried area. Based on reference conditions, these results warrant moderate concern since total cover in the target area was more than 1% but less than 4%. However, confidence is medium because these data are more than a decade old and not all non-native species encountered were mapped. Trend could not be determined based on this single survey.

NPS Vegetation Classification and Mapping Project
The four species detected in the NPS vegetation classification and mapping project plots during 2006 exhibited an average cover of 1.75% (Table 4.9.4-5). Kentucky bluegrass had the highest average cover at 1.05%. Based on reference conditions, these results warrant moderate concern. Confidence in the condition rating is medium since these data were collected more than 10 years ago. Trend could not be determined based on this single sampling effort.

NCPN Uplands Plant Monitoring
In NCPN upland plots, total average plant cover ranged from 3.85% in 2012 to 18.59% in 2010 (Table 4.9.4-6) in subalpine meadow, spruce-fir forests and aspen stands above the rim. Over all years, total plant cover averaged 9.19%. Kentucky bluegrass exhibited the highest average cover at 6.59%, while smooth brome and dandelion were low in cover (i.e., < 2%).

Table 4.9.4-5. Cover of non-native plants in NPS vegetation classification and mapping project plots.

Species	Cover (%)
Smooth brome	0.64
Kentucky bluegrass	1.05
Dandelion	0.06
Common salsify	< 0.01
Total	1.75

Source: NPS vegetation mapping data (Tendick et al. 2011).

Since total average cover was greater than 4%, these data warrant significant concern. Confidence is high since data were recently collected and are part of a long-term monitoring effort. Trend could not be determined since this was the first round of sampling.

Summary
Together, these three studies indicate that non-native plant cover warrants moderation to significant concern, at least in the uplands. It is less clear for the breaks, but non-native plant cover was low in 2006. Despite the average cover, only six of the 20 possible non-native species were encountered. This suggests that most species occur only rarely. Confidence is medium and trend is unknown.

Overall Condition, Trend, Confidence Level, and Key Uncertainties
Overall, we consider the condition of non-native and invasive plants to warrant moderate concern in Cedar Breaks NM. This condition rating was based on three indicators and four measures, which are summarized in Table 4.9.4-7. Those measures for which confidence in the condition rating was high were weighted more heavily than measures with medium 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, nearly all measures were assigned medium confidence. This is because, with the exception of NCPN upland data, the most current available data are more than five years old.

Among the three studies included in this assessment, eight of the 20 non-native species were documented. Smooth brome, common salsify, Kentucky bluegrass, and dandelion were documented in all three studies,

Table 4.9.4-6. Absolute foliar cover of non-native plants in NCPN upland monitoring plots.

Year	Cover (%) Smooth brome	Kentucky bluegrass	Dandelion	Total
2009	0.10	6.00	0.81	6.90
2010	5.88	11.42	1.29	18.59
2011	2.42	6.75	0.71	9.88
2012	1.76	1.57	0.52	3.85
2013	0.00	3.81	0.48	4.29
2014	0.81	7.52	0.71	9.04
2015	0.21	9.08	2.46	11.75
Mean	1.86	6.59	1.00	9.19

Source: NCPN unpublished data.

although the latter two species were not mapped by Dewey and Anderson (2005) but were considered widespread and abundant. In fact, these two species were the most widespread of any species encountered among the three studies. Smooth brome and cheatgrass were ranked high by NatureServe, lambsquarters and dandelion were not ranked, but the remaining species were ranked medium. Although several of these species are of particular concern (e.g., smooth brome) the total infested area of the monument was low and occurs primarily in uplands. Few studies have documented non-native plants in the breaks, but their occurrence there is likely low as indicated by the NPS vegetation classification and mapping project data.

Non-native Plant Control and Revegetation Efforts

Non-native plants in the monument are treated annually by staff from Zion NP, with emphasis on treating and controlling smooth brome and other non-native species that have invaded meadows (e.g., orchard grass [*Dactylis glomerata*]). From 2012 to 2016, 4.2 ha (10.5 ac) of smooth brome have been treated (NPS, L. Schrage, vegetation program manager Zion NP, e-mail communication 22 June 2017). 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). Despite the fact that overall cover in the target area during the NCPN invasive plant inventory and mapping effort was low (3%), smooth brome infested nearly 16 ha (40 ac). This is a considerable area to control. Smooth brome is also invading areas that support rare plants (Fertig and Reynolds 2009). In addition to chemical treatments, park staff are also reseeding areas treated areas with native plants, and these efforts have been successful in some areas (NPS 2015a).

Threats, Issues, and Data Gaps

The 12 species known to occur in the monument but not detected during surveys included in this assessment suggest that their abundance and cover is probably low. However, several species have at least a medium invasiveness impact rank and the potential to become more widespread in the monument (e.g., crested wheatgrass [*Agropyron cristatum*]). A significant data gap is the lack of a dedicated non-native plant monitoring program. Although the NCPN uplands monitoring program lists tracking non-native plants as a priority, their surveys only occur in the uplands that are above the rim (Witwicki et al. 2013).

The introduction and spread of invasive plants is influenced by road corridors, trails, and disturbances. In Cedar Breaks NM the main road corridor is the primary pathway for dispersal (Dewey and Anderson 2005). Like most NPS units, visitation has increased dramatically. In 2016, an estimated 900,000 visitors toured the monument (NPS Public Use Statistics Office 2017). People visit the monument from all over the world and may inadvertently contribute to the introduction and spread of non-native species (NPS 2015a).

Smooth brome is spreading into drainages of the Claron and Brian Head formations north and east of North View Overlook (NPS 2016a). The breaks contain most of the rare and sensitive plant species in the monument (NPS 2016a). If invasive species spread into these areas, native vegetation could be outcompeted (Fertig and Reynolds 2009). Mixed coniferous forests dominated by subalpine fir (*Abies lasiocarpa*) and Engelmann spruce (*Picea engelmannii*) usually exhibit high native plant cover and are relatively resistant to invasion by non-native plants (Witwicki et al. 2013), but an altered fire regime may increase this vegetation community's vulnerability. The large-scale beetle kill that occurred in and around the monument during the 1990s may also influence the spread of non-native species (DeRose and Long 2007). Sudden aspen die-off has occurred in several NPS units on the Colorado Plateau, although the reasons for the die-off are unknown (Witwicki et al. 2013). Aspen stands tend to be invaded by dandelion and Kentucky bluegrass, but of all the plant community types, subalpine

Table 4.9.4-7. Summary of non-native and invasive plants indicators, measures, and condition rationale.

Indicators of Condition	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Potential to Alter Native Plant Communities	NatureServe Invasive Species Impact Rank		Since the majority of species (71%) were ranked as medium, including several with mixed ranks, and only two species were ranked high, we consider this measure to warrant moderate concern. Confidence is high. Trend does not apply to this measure.
Rate of Invasion	% of New Non-native Species of Total Species Detected Over Time		The proportion of total species that are non-native increased from about 2% in the 1950s to a little over 5% in the 2000s, warranting moderate to significant concern. Confidence is medium and trend is deteriorating.
Prevalence	Frequency (%)		Kentucky bluegrass and dandelion were widespread while smooth brome and common salsify were limited in distribution. Only four of the 20 possible non-native species were detected. Theses species were most widespread in the uplands. Although frequency data indicate moderate to significant concern for Kentucky bluegrass and dandelion, neither of is considered highly invasive. However, smooth brome was ranked high by NatureServe. For these reasons, the condition for this measure is split between moderate and significant concern. Confidence is medium. Trend is unknown.
	Cover (%)		Percent cover averaged 1.75% across NPS vegetation mapping plots, 3.2% in targeted upland areas, and 9.19% in NPS upland monitoring plots. Despite the average cover, only six of the 20 possible non-native species were encountered. Confidence is medium and trend is unknown.
Overall Condition			Eight of 20 non-native species were documented by frequency and cover. Kentucky bluegrass and dandelion were widespread. Although several species are of particular concern (e.g., smooth brome), the total infested area of the monument, primarily uplands, is low. Few studies have documented non-native plants in the breaks, but their occurrence there is likely low as indicated by the NPS vegetation classification and mapping project data. Confidence is medium because, with the exception of NCPN upland data, the datasets used in this assessment are more than five years old. Trend is unknown.

meadows are the most vulnerable to invasion (Witwicki et al. 2013).

Although any ecosystem or region is susceptible to invasion by non-native species to some degree, Cedar Breaks NM position in the landscape limits its vulnerability. The monument is surrounded on all sides by the Dixie National Forest except for a 1.6-km (1-mi) stretch along the eastern boundary (NPS 2015a). Fortunately, sheep grazing has been excluded in the monument with a boundary fence that is erected each year as soon as the snow melts, but trespass may occur if the fence is damaged by wind or falling trees (Tendick et al. 2011). Furthermore, the monument's developed area footprint is relatively small. All roads and buildings occur atop the rim with no development or trails located below the rim. Although these factors help limit the spread of invasive species, climate change may increase the monument's vulnerability to the introduction and spread of invasive species (Hellmann et al. 2008).

Monahan and Fischelli (2014) climate change results indicate a trend toward warmer (five temperature variables were considered "extreme") but not necessarily drier conditions within the monument (Monahan and Fisichelli. 2014). While there were no apparent changes in total precipitation, warmer temperatures influence whether precipitation falls as snow or rain. The distinction between the amount of precipitation falling as snow as opposed to rain is particularly important in the snow-dependent hydrologic landscape of the western U.S. (Pugh and Gordon 2013). The protective cover of snow and the more than 250 days of frost per year (NPS 2016a) limits the growing season for non-native species, but climate change may make the monument more favorable to non-native plants through direct effects or by shifting native species out of their ranges (Hellmann et al. 2008). A study of plant response to climate change on the Colorado Plateau suggests that increased aridity will likely to lead to the loss of native grasses and the expansion of shrubs (Munson et al. 2011). Once established, invasive plants can be extremely difficult to control and most will never be completely eradicated (Mack et al. 2000).

4.9.5. Sources of Expertise

Assessment author was Lisa Baril, science writer, Utah State University. Subject matter expert reviewers for this assessment are listed in Appendix B.

4.10. Birds

4.10.1. Background and Importance

Hundreds of species of birds occur in the American Southwest, as do some of the best bird watching opportunities. Bird watching is a popular, long-standing recreational pastime in the United States and forms the basis of a large and sustainable industry (Sekercioglu 2002). Birds are a highly visible component of many ecosystems (Figure 4.10.1-1). 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). Like other wildlife, birds are also 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."

4.10.2. Data and Methods

This condition assessment addresses breeding birds at Cedar Breaks NM through the use of data/information from the USGS/NCPN inventory and the current NPSpecies list for the park, as well as other observation efforts. We used one indicator of condition, species occurrence, with two measures, focusing on which bird species have been documented at the national monument. The first measure is simply presence/absence of bird species at the national monument, and the second measure focuses on the species that occur at the monument that are considered species of conservation concern.

Presence/Absence of Bird Species

To assess species occurrence: presence/absence of bird species at the national monument, we used the 2001-2002 U.S. Geological Survey (USGS) / NCPN bird surveys, as well as the current NPSpecies list of birds for the park (NPS 2017a) and other bird observations recorded within the park (Manrodt et al. [2015] and eBird [2017a]). The list of bird species from NPS (2017a), which includes species recorded during the 2001-2003 surveys, served as our foundation list of species documented within the national monument. Because only one set of surveys (with standardized methods) exists for birds within the park, we were unable to conduct a temporal comparison of species presence/absence over time (e.g., comparing species observed in 2001-2003 to results of more recent surveys). However, to provide somewhat of a regional comparison, we compared our overall list of species

Figure 4.10.1-1. Western tanager, a colorful bird species occurring at Cedar Breaks NM. Photo Credit: © Robert Shantz.

for the national monument to a 2004 checklist of birds for Dixie National Forest (U.S. Forest Service 2004).

Primary Data Sources

The USGS conducted an avian inventory at Cedar Breaks NM during the breeding seasons of 2001 and 2002. The primary objective of the work was to provide a baseline inventory of birds within the park, with a goal of documenting at least 90% of the species present (Johnson et al. 2003). Objectives were also to identify the occurrence of species of concern, and to determine the abundance and distribution of species present. Breeding season visits were conducted from mid-May to mid-July in 2001 and 2002, and non-breeding, winter visits were conducted from December to February in 2001-2003. Plant communities within (and immediately adjacent to) the national monument include: pinyon-juniper woodlands; mixed forests of ponderosa pine (*Pinus ponderosa*), blue spruce (*Picea pungens*), and Douglas-fir (*Pseudotsuga menziesii*); Engleman spruce (*Picea engelmannii*) - subalpine fir (*Abies lasiocarpa*) forests including bristlecone pine (*Pinus longaeva*); and subalpine meadows (Johnson et al. 2003). Johnson et al. (2003) sampled in two major habitat types in the park: mixed conifer and meadow habitat mosaic, and mixed conifer with riparian elements.

Over the two years, a total of 131 variable circular plot (VCP) point count surveys were conducted during the breeding season in the two main habitat types. In the 2001 breeding season, the researchers also conducted 15 incidental surveys (to emphasize habitat not sampled thoroughly during point counts), and six crepuscular and nighttime surveys (i.e., tape playback surveys). In the 2002 breeding season, four incidental surveys and four crepuscular and nighttime surveys were conducted at locations throughout the monument.

During each VCP count, all birds seen or heard during the 7-minute sampling period were recorded. Information recorded included the species, mode of detection, and distance to the bird from the observer. During all surveys, researchers also made observations on breeding behavior, designating birds as confirmed breeder, probable breeder, or migrant. Johnson et al. (2003) provided information on species richness, relative abundance, and density of the most common breeding birds. We present some of this information in the condition assessment.

The second critical resource for this assessment was the list of birds for the national monument from NPSpecies (NPS 2017a; obtained from IRMA in March 2017). This list contains all of the species recorded by Johnson et al. (2003) in 2001-2003, as well as many additional species.

Our third source of information was a recent list of birds compiled by Manrodt et al. (2015) during two “bird walks” along Alpine Pond Trail in late July 2015 Mandrodt is an avid birder and seasonal interpretive ranger for the monument and records opportunistic sightings (visual and audible) during daytime hours from June to late September. We combined the lists from the individual walks into one list. Although this information effort was small in scope, we included it because it is a recent and credible source of information.

Our final source of information was a list of birds compiled for the national monument from eBird. eBird is an online checklist program that was launched in 2002 by the Cornell Lab of Ornithology and National Audubon Society (eBird 2017b). eBird reports on the occurrence (presence or absence) of bird species, as well as other information, using data from checklists provided by recreational and professional bird watchers. A cumulative list of bird species was available for Cedar Breaks NM based on observations from a number of individuals (i.e., eBird 2017a). eBird data for the monument spans the years 1991-April 2017. However, the majority of the listings (84% of them) are from the last 10 years, with 66% from the last four years. It should be noted that the years listed here are the “last seen” years for individual species; individual species may have been recorded in multiple, earlier, years. It should also be noted that while we listed all species that were included in eBird for the monument, we filtered species from this list for the condition assessment by using sightings made by Lucy Ormond only (an amateur birder and birding volunteer at Zion NP). She made recent observations in the park during five separate sessions (from 23-25 June 2016).

It is also important to note that NPS produced a *Bird Field Checklist* for Cedar Breaks NM in 2016 (NPS 2016g). The checklist includes species recorded by NPS and from eBird (through June 2016). We confirmed that every species on the checklist (i.e., NPS 2016g) was either on the NPSpecies list (NPS 2017a) or the eBird listing we obtained in April 2017.

Therefore, we did not provide an additional column in the bird species list table in the appendix to explicitly identify the species on NPS (2016g).

Presence of Species of Conservation Concern

The second measure used in this assessment focused on the species that occur or have occurred at Cedar Breaks 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 our final list of species for the national monument and compared it to multiple species of conservation concern lists (e.g., a federal list of endangered and threatened species, those designated by the Utah Division of Wildlife Resources [UDWR] as wildlife species of concern). 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) (North American Bird Conservation Initiative 2016). Bird Conservation Regions are ecologically distinct regions in North America with similar bird communities, habitats, and resource management issues (Figure 4.10.2-1). Cedar Breaks NM is located within the Southern Rockies-Colorado Plateau BCR (BCR-16; Figure 4.10.2-2).

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 F 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 2016a). This Act, which protects 1,026 birds, regulates "the taking, possession, transportation, sale, purchase, barter, exportation, and importation of migratory birds" (USFWS 2013). Some of the lists that we reviewed include birds protected under the MBTA (see bullets below), but we also reviewed the MBTA list itself to compare it to our Cedar Breaks NM bird list. See Appendix G for findings.

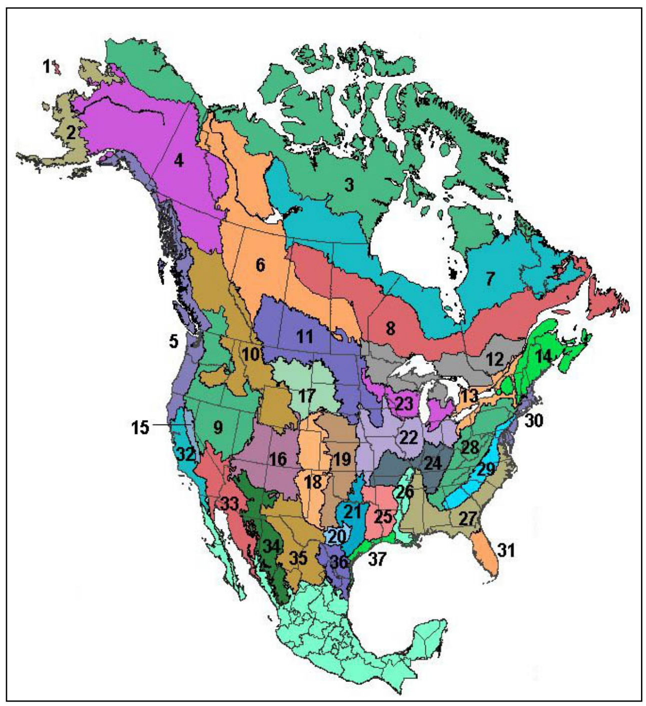


Figure 4.10.2-1. Bird Conservation Regions in North America. Figure Credit: © USFWS (2008).

- U.S. Fish & Wildlife Service: Under the Endangered Species Act (ESA), the USFWS lists species as threatened, endangered, or candidates for listing (USFWS 2017a).
- UDWR: The UDWR prepared and maintains the Utah Sensitive Species List for vertebrate and invertebrate species. The list includes species for which a State conservation agreement exists, wildlife species of concern, and species that are federally listed and candidates for federal listing (UDWR 2015). Wildlife species of concern are species that have scientific evidence substantiating a threat to their continued population viability (UDWR 2015). The idea behind the designation is that timely conservation actions taken for each species will avoid the need to list them under the federal ESA in the future.
- USFWS: This agency also developed lists of birds of conservation concern according to the USFWS Region, and BCR (USFWS 2008). These listings include both migratory and non-migratory bird species (beyond those already designated as federally threatened or endangered). Bird species considered for 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]) (Rich et al. 2004) and Regional Importance (Regional Concern [RC] and Regional Stewardship [RS] (Panjabi et al. 2005). We included only the CC and RC species in our assessment. The list for BCR 16 was obtained online (Partners in Flight Science Committee 2012).

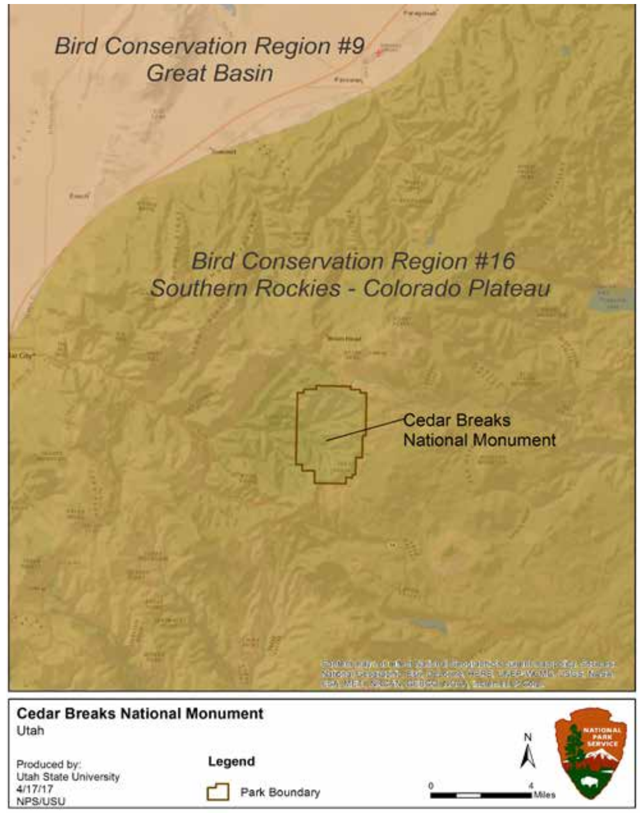


Figure 4.10.2-2. Cedar Breaks NM is located in the Southern Rockies - Colorado Plateau Bird Conservation Region (#16).

4.10.3. Reference Conditions

No specific reference conditions were developed for the two measures used in this assessment. This is because no two similar studies or surveys to compare species occurrence exist (e.g., to examine changes in species occurrence over time), and no comparable recent information (from standardized surveys) is available. However, the information presented from the 2001-2003 USGS/NCPN avian inventory provides a good baseline for future monitoring and assessment of birds at the national monument. In other words, if standardized surveys of birds are conducted in the future, the new survey results could be compared to the survey/inventory results from the early 2000s. For our assessment, some of the other, observational information sources provided an indication of the bird species using the national monument in recent years.

4.10.4. Condition and Trend

Presence/Absence of Bird Species

A total of 121 bird species occur on the NPSpecies list for Cedar Breaks NM (NPS 2017a). Sixty-nine of the species are noted as "present" within the park, 38 are noted as "probably present," and 14 are noted as "unconfirmed." We used the 69 species that are designated as present and two additional species designated as probably present, Virginia's warbler (*Oreothlypis virginiae*) and orange-crowned warbler (*Vermivora celata*), for the remainder of our discussion (a total of 71 species, which are shaded in the bird list that is in Appendix G). The remaining 50 species were omitted from discussion since several of them rely on aquatic, extensive riparian, or large blocks of sagebrush or grassland habitats and are highly unlikely to occur at the monument except for an occasional fly-over.

Sixty of the 71 species (84.5%) included in this assessment were recorded during the 2001-2003 USGS avian inventory (Johnson et al. 2003). All of the 27 species observed by Manrodt et al. (2015) appear on the NPSpecies list, and all but one (orange-crowned warbler) were also observed by Johnson et al. (2003). Of the 23 bird species observed by Ormond (eBird 2017) all appear on the NPSpecies list and were recorded by Johnson et al. (2003), and 20 were recorded by Mandrodt et al. (2015). None of the 71 species are non-native. It's also important to note that for eight of the 71 species considered present (American goldfinch (*Spinus tristis*), California condor (*Gymnogyps californianus*), gray jay (*Perisoreus canadensis*), house finch (*Haemorhous mexicanus*), juniper titmouse (*Baeolophus ridgwayi*), Lewis' woodpecker (*Melanerpes lewis*), red-naped sapsucker (*Sphyrapicus nuchalis*), and Townsend's warbler (*Setophaga townsendi*), the monument is within the species breeding range but has limited breeding habitat so it's unlikely to detect these species regularly, if at all.

The ten species recorded in the highest numbers (in descending order) in each habitat type during the USGS/NCPN point counts are shown in Table 4.10.4-1, representing 16 different species. The numbers in parentheses for each species are average abundance (i.e., [the total # of individuals detected] / [the total # of point count surveys conducted in that habitat type]; Johnson et al. 2003). The last column in the table shows the species with the greatest average abundance overall. All but three species, cordilleran flycatcher (*Empidonax occidentalis),* hermit thrush (*Catharus guttatus)*, and Hammond's flycatcher (*Empidonax hammondii)* were also recorded by Mandrodt et al. (2015) and Ormond (eBird 2017), although the first two listed were recorded by Ormond (eBird 2017) as well.

The following information may be useful for future comparisons if new data are collected. The Johnson et al. (2003) inventory recorded 896 birds of 49 species during point count surveys; nine additional species were recorded during incidental surveys, and one additional species was recorded during the crepuscular/nighttime surveys. During the inventory, 50 species were recorded in the mixed conifer/meadow habitat, with 23 of these species (46%) recorded only in this habitat type (Johnson et al. 2003). Thirty-five species were recorded in the mixed conifer/riparian habitat, with eight (23%) of these species recorded only in this habitat type. During the point count surveys, the vast majority (78%) of all individual birds detected were in the mixed conifer/meadow type, the most prevalent habitat in the park (Johnson et al. 2003).

Johnson et al. (2003) also estimated the density of species that had more than 40 detections. Combining the data for both habitats, they estimated density for eight species: American robin (*Turdus migratorius*), chipping sparrow (*Spizella passerina*), dark-eyed junco (*Junco hyemalis*), hermit thrush, mountain chickadee (*Poecile gambeli*), ruby-crowned kinglet (*Regulus calendula*), white-crowned sparrow (*Zonotrichia leucophrys*), and yellow-rumped warbler (*Setophaga coronata*). The density estimates (Table 4.10.4-2) represent baseline data for comparison with future monitoring results.

In this section of the assessment, we reported on the number and types of bird species that have been recorded, or that may occur, within Cedar Breaks NM. Because only one set of standardized surveys has been conducted to date, and those surveys are approximately 15 years old, we cannot assign a current condition for birds within the national monument. Therefore, we consider condition (and trends) unknown at this time. However, the lists of species observed from Manrodt et al. (2015) and Ormond (eBird 2017) data indicate that many of the species have been observed in recent

Table 4.10.4-1. Species with the greatest average abundance in USGS VCP point count surveys in two habitat types (and overall) at Cedar Breaks NM.

Average Abundance		
Mixed Conifer / Meadow	Mixed Conifer / Riparian	Total
American robin (0.85)	Cordilleran flycatcher (0.73)	American robin (0.67)
Dark-eyed junco (0.79)	Hermit thrush (0.70)	Dark-eyed junco (0.67)
White-crowned sparrow (0.73)	Mountain chickadee (0.54)	Hermit thrush (0.62)
Hermit thrush (0.58)	Dark-eyed junco (0.41)	White-crowned sparrow (0.53)
Chipping sparrow (0.55)	Broad-tailed hummingbird (0.35)	Mountain chickadee (0.50)
Yellow-rumped warbler (0.51)	American robin (0.27)	Yellow-rumped warbler (0.43)
Mountain chickadee (0.48)	Yellow-rumped warbler (0.24)	Chipping sparrow (0.40)
Ruby-crowned kinglet (0.44)	Western wood-pewee (0.24)	Ruby-crowned kinglet (0.36)
Western tanager (0.30)	Western tanager (0.22)	Cordilleran Flycatcher (0.29)
Clark's nutcracker (0.27)	Townsend's solitaire & Hammond's flycatcher (both 0.19)	Western tanager (0.27)

Source: Johnson et al. (2003).

years within the park. All but two of the 59 species recorded by Johnson et al. (2003) were listed by one or both sets of observations. Furthermore, of those (57) species, the vast majority (49) were reported within the last five years (2013-2017).

<u>Additional Information: Comparison to Species List for Dixie National Forest</u>

Because Cedar Breaks NM is surrounded by the Dixie National Forest, we thought it was of interest to compare the bird species list for the national monument to a checklist of birds for the national forest. Note that in our comparison we included all of the birds listed in the appendix table (Appendix G), which includes those recorded during eBird observations (not limited to Ormond's observations) and those noted as probably present and unconfirmed by NPS (2017). The 2004 checklist for the national forest contains 186 species, and the checklist covers not only the Cedar City District, which surrounds the monument,

Table 4.10.4-2. Estimated densities of bird species at Cedar Breaks NM based on USGS point count surveys (habitat types combined).

Species	Estimated Density (# per ha)	95% Confidence Interval
American robin	1.73	1.35 -2.22
Chipping sparrow	0.97	0.82-1.16
Dark-eyed junco	1.86	1.45-2.38
Hermit thrush	0.55	0.40-0.75
Mountain chickadee	3.25	2.22-4.76
Ruby-crowned kinglet	1.11	0.83-1.49
White-crowned sparrow	2.77	1.80-4.24
Yellow-rumped warbler	2.11	1.49-2.97

Source: Johnson et al. (2003).

but also the three more distant districts (Powell, Teasdale, and Pine Valley; U.S. Forest Service 2004). Our comparison indicated that of the 186 species on the national forest checklist, 137 species (74%) were on the Cedar Breaks NM list; approximately 26% of the 186 species were not on the monument list. The majority of the species not on the monument's list were ducks, grebes, wading birds, and gulls. Given the size of the national monument compared to the national forest, the two areas appear to share a substantial number of species in common. However, of the 71 species used to evaluate current condition, five species, California condor, evening grosbeak (*Coccothraustes vespertinus)*, Nashville warbler (*Oreothlypis ruficapilla)*, plumbeous vireo (*Vireo plumbeus)*, and spotted towhee (*Pipilo maculatus)*, are listed for Cedar Breaks NM but not included on the USFS checklist. Whereas, the American goldfinch and juniper titmouse are listed as common for USFS but have either not been recorded or only recorded via an eBird sighting for the monument, respectively.

<u>Additional Information: 1996-2002 Surveys for Three Bird Species</u>

It is also worth mentioning that some older data on three bird species that occur within Cedar Breaks NM are available for the national monument vicinity. A cooperative study was conducted in the Cedar City Ranger District of Dixie NF and Cedar Breaks NM within three study sites (Sugarloaf, Rattlesnake, and Radar Ridge) to assess the impact of spruce beetle infestation on spruce-fir communities (Boswell and Day

2004). Two of the sites monitored (the second two) are along the boundary or outside of but near the park. Various groups of animals were studied, including three birds- hermit thrush, western tanager (*Piranga ludoviciana*), and American three-toed woodpecker (*Picoides dorsalis*). Survey methods were described in Boswell and Day (2004). Bird surveys, conducted in June and July of each year, revealed no obvious trends (Boswell and Day 2004). Hermit thrushes were "well represented" on all of the three transects in all of the years. For the western tanager, researchers saw a general increase in detections over the limited three years of the study. Detections of American three-toed woodpeckers were more variable and lower than for the other two species. If national monument personnel had a future interest in monitoring any of these species, this dataset would represent a source of information. The American three-toed woodpecker is a wildlife species of concern with the State (see next section).

Presence of Species of Conservation Concern

Sixteen of the 71 species used for this evaluation are listed as species of conservation concern by at least one entity (Table 4.10.4-3). All but three (California condor, juniper titmouse, and Lewis' woodpecker) have been recorded by one or more survey efforts.

- USFWS / Listed Species: The California condor is federally listed as an endangered species, and in some areas it is listed as an experimental population, nonessential. USFWS (2017b) lists the species as within Iron County, Utah; however, the area surrounding the national monument is within the experimental population, nonessential region (USFWS 2017b). The California condor was not observed during the 2001-2003 USGS inventory (Johnson et al. 2003), but is noted by NPS (2017) as present. It was also reported on eBird (2017a) but wasn't observed by Ormond.
- UDWR: Three of the species are on the Utah Sensitive Species List, including the California condor noted above. Two of these are considered wildlife species of concern (American three-toed woodpecker and Lewis's woodpecker).
- USFWS / Birds of Conservation Concern: Eight of the species have been identified by USFWS as having the greatest conservation need at a USFWS Regional or BCR geographic scale (USFWS 2008). Seven of the species are listed for the region, and seven are listed for the BCR. Six of the species are listed for both.
- NABCI: There are eight species that are included on the NABCI 2014 Watch List. One species, California condor, is on the Red List; the other seven species are on the Yellow List.
- PIF: Eleven of the bird species are listed by PIF as either CC or RC (recall we did not include the stewardship categories). Five of the species were listed as CC species, with four of them also listed as RC species. A total of 10 species are listed as RC species.

In summary, Cedar Breaks NM provides habitat for a number of species considered species of conservation concern. Thirteen such species have been recorded within the monument by Johnson et al. (2003), Manrodt et al. (2015), and/or Ormond (eBird 2017).

Overall Condition, Trend, Confidence Level, and Key Uncertainties

For assessing the condition of the national monument's birds, we used one indicator with two measures, which are summarized in Table 4.10.4-4. Without additional standardized data to compare between years, the condition and overall trend of birds at Cedar Breaks NM is unknown.

While NCPN does not conduct bird monitoring at Cedar Breaks NM, they do at other NCPN parks and have reported on trend for 10 species recorded from 2005-2012. A brief description of this effort is included here. In 2012, McLaren and Blakesley (2013) estimated densities for 58 species detected throughout NCPN parks and then estimated population trends based on 24 species recorded from 2005-2012 that were of conservation or management concern. Trends were determined for 10 species, five of which occur at Cedar Breaks NM. Four of these, black-throated gray warbler (*Dendroica nigrescens)*, dusky flycatcher (*Empidonax oberholseri)*, mountain bluebird (*Sialia currucoides)*, and white-throated swift (*Aeronautes saxatalis*), with linear or log-linear trends, exhibited population declines. Two of these four species are listed as species of conservation concern in Table 4.10.4-3. The juniper titmouse and dusky flycatcher initially showed an increase in population density followed by a decrease in later years (McLaren and White 2016). According to McLaren and White (2012), "as additional years of data accumulate, trend analysis will become less sensitive to short-term fluctuations in

Table 4.10.4-3. Species of conservation concern at Cedar Breaks NM, according to one or more government agencies or organizations.

Common Name	Federal [1]	State [2]	U.S. Fish and Wildlife Service		NABCI [3]	Partners in Flight National Conservation Strategy [4]		NPS 2017a
	USFWS	UDWR	Region 6	BCR 16	2014 Watch List	BCR 16 CC	BCR 16 RC	Occurrence
American Three-toed Woodpecker	–	WSC	X	–	–	–	–	Present
Black-throated Gray Warbler	–	–	–	–	–	–	X	Present
California Condor	E (exp)	E (exp)	–	–	Red	X	X	Present
Cassin's Finch	–	–	X	X	Yellow	X	X	Present
Clark's Nutcracker	–	–	–	–	–	–	X	Present
Evening Grosbeak	–	–	–	–	Yellow	–	–	Present
Golden Eagle	–	–	X	X	–	–	X	Present
Juniper Titmouse	–	–	–	X	–	–	–	Present
Lewis's Woodpecker		WSC	X	X	Yellow	–	X	Present
Mountain Bluebird	–	–	–	–	–	–	X	Present
Olive-sided Flycatcher	–	–	–	–	Yellow	X	X	Present
Peregrine Falcon	–	–	X	X	–	–	–	Present
Pinyon Jay	–	–	X	X	Yellow	X	X	Present
Prairie Falcon	–	–	X	X	–	–	X	Present
Rufous Hummingbird	–	–	–	–	Yellow	–	–	Present
Virginia's Warbler	–	–	–	–	Yellow	X	–	Probably present

[1] Federally Listed Species Codes: T = Threatened; E = Endangered; E (exp.) = experimental population of Endangered species

[2] Utah Division of Wildlife Resources Codes: CAS = Conservation Agreement Species; WSC = Wildlife Species of Concern

[3] NABCI- 2014 Watch List: = Red List or Yellow List

[4] PIF NCS Categories: CC = Continental Concern; RC = Regional Concern

population density and long-term trends underlying annual fluctuations will be revealed." These results can help inform trends on selected species at Cedar Breaks NM as well.

The key uncertainties in this assessment are with the age of the data from Johnson et al. (2003), and the general lack of other studies. A substantial amount of information was available in association with the USGS/NCPN inventory surveys, including a map showing point count survey locations within the national monument, but such detailed information was not readily available from Maroldt et al. (2015).

Threats, Issues, and Data Gaps

No specific threats to birds within Cedar Breaks NM have been identified at this time. However, there are threats that are common to many bird species, including those that use the national monument. 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 2016b). As discussed previously, 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 2016b).

The largest data gaps concerning birds within the national monument are the lack of demographic data and the absence of an inventory with standardized surveys since the early 2000s. Although recent observations by Manrodt et al. (2015) and those obtained from Ormond (eBird 2017) provided some recent indications of species occurrence, it would have been desirable to have current standardized surveys

Table 4.10.4-4. Summary of birds indicators, measures, and condition rationale.

Indicator of Condition	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Species Occurrence	Presence/ Absence of Bird Species		Condition (and trend) under this measure is considered unknown due to the lack of recent standardized bird surveys and comparable datasets. However, a total of 71 bird species are on a list we compiled for the national monument from four main sources. The standardized surveys of Johnson et al. (2003) recorded a total of 60 species in two main habitat types within the monument. More recent observations by Manrodt et al. (2015) and by Ormond (eBird 2017) reported 27 and 23 species, respectively, although many were the same. We have low confidence in the measure.
	Presence of Species of Conservation Concern		Of the 71 species of birds on our list for the national monument, 16 are species of conservation concern. It is good that Cedar Breaks NM provides habitat for a number of species in particular need of conservation, but because we have few details on their current occurrence within the monument, we consider condition under this measure to be unknown (with an unknown trend). We have low confidence in the measure.
Overall Condition			We used one indicator, with two measures, to assess the condition of birds at Cedar Breaks NM. Although some information was available for each measure, we considered the condition of birds under each measure to be unknown. Therefore, overall condition is unknown, trend is unknown, and confidence level is low.

like those conducted by Johnson et al. 2003. To address the lack of bird demographic data, Cedar Breaks NM staff are starting a citizen's science project. They have identified particular bird species of interest and will provide standardized data sheets for volunteers to collect bird data annually. Staff will provide birders with a tablet from May to October to record information using iBird. Staff will confirm questionable sightings as a quality control measure. The information will be used to gather more consistent baseline data on the various species within the monument.

4.10.5. Sources of Expertise

This section was written by biologist and writer, Patty Valentine-Darby, and revised, based on reviewer comments, by Kim Struthers, writer and NRCA Coordinator for Utah State University.

Lucy Ormond (amateur birder and birding volunteer at Zion NP) provided her species lists from 2016 observations made within and outside of the park (also incorporated on eBird). Ms. Ormond, a retired RN, has been volunteering in Zion NP for eight years; she has been leading the weekly "What's Flyin' in Zion" birding walks during the spring for the past four years. Keith Day, Wildlife Biologist, Utah Division of Wildlife Resources, Cedar City, provided multiple reports on the ecological monitoring (including birds) of the Brian Head/Cedar Breaks area of Dixie National Forest.

4.11. Mammals

4.11.1. Background and Importance

The American Southwest has the highest species richness of native mammals (Figure 4.11.1-1) in the country due to its range of elevations and precipitation amounts, resulting in diverse habitats (Mac et al. 1998 as cited by Haymond et al. 2003, Brown 1978). The varied plant life within Cedar Breaks National Monument (NM) is largely a result of its range in elevation (Evenden et al. 2002), which in turn, supports a variety of wildlife species. A recent analysis for Cedar Breaks National Monument (NM) and 24 other national park units on the Colorado Plateau found that for the monument, surveyed native mammal richness was somewhat higher than predicted by historic range maps (Stegner et al. 2017).

One mammal of particular management interest at Cedar Breaks NM is the American pika (*Ochotona princeps*). This relative of the rabbit inhabits mountain peaks in the western U.S. and is disappearing from some previously occupied habitat due to climate change (Erb et al. 2011, Stewart et al. 2015, Beever et al. 2016, and Nichols et al. 2016). In fact, the American pika is considered a climate-sensitive sentinel species (Garrett et al. 2011). While the species is not listed as endangered or threatened under the Endangered Species Act (ESA), outside petitions were reviewed by the U.S. Fish and Wildlife Service (USFWS) as recently as 2016 (USFWS 2016c) and in 2009-2010 (USFWS 2010) to consider listing, although USFWS concluded that listing was not warranted.

4.11.2. Data and Methods

For Cedar Breaks NM mammals assessment, we used two indicators of condition, occurrence of mammals and occurrence of American pika, with a total of four measures. To assess the current condition for mammals as a group, we used three measures, presence/absence of species, absence of non-native species, and species of conservation concern. To evaluate the condition of American pika occurrence, we used presence/absence of this species in the monument.

<u>Presence/Absence of Species</u>

The most recent inventory of mammals was conducted by the U.S. Geological Survey (USGS) throughout Northern Colorado Plateau Network national parks (Haymond et al. 2003), including Cedar Breaks NM. The goal of the Haymond et al. (2003) work was to document the occurrence of at least 90% of the mammals expected within Cedar Breaks NM and other national parks during their two years of field sampling in 2001 and 2002. Additional objectives of the inventory included providing baseline information for

Figure 4.11.1-1. Bobcat is one of the native mammal species known to occur in Utah and at Cedar Breaks NM. Photo Credit: © Robert Shantz.

future monitoring and describing the distribution and abundance of species of management interest (e.g., endangered species, exotic species). The initial list of species developed was based on primary references that listed specimens previously "examined" (Haymond et al. 2003). In order to observe as many species as possible, especially small terrestrial mammals, bats, and carnivores, a variety of sampling methods was used: live-trapping, mist-netting, acoustic surveys, scat and track surveys, and opportunistic observations. Details of each method are included in Haymond et al. (2003). Voucher specimens were kept when animals were previously undocumented from the monument, as well as to verify identification in some cases. Survey efforts at Cedar Breaks NM in July and September 2001 included seven mist-net-nights and 1,885 trap-nights. Survey efforts in June and July 2002 included 458 trap-nights, nine mist-net-nights, 13 acoustic survey-hours, and a track-scat survey distance of 100 km (62 miles).

We also used the monument's NPSpecies list (NPS 2017a) and its animal sightings database (NPS 2016h) to determine whether additional species had been documented that were not recorded by Haymond et al. (2003). The NPSpecies list of mammals included a total of 63 species, 39 of which are considered present, 11 that are probably present, and 13 that are unconfirmed. To assess current condition of mammals, we eliminated the 'unconfirmed' species from the list, resulting in a total of 50 species. The monument's species sighting database included 10 mammals, all of which were either recorded by Haymond et al. (2003) and/or on the NPSpecies list (NPS 2017a). Additionally, although not used to assess condition, we reviewed a list of species recorded during 1995-2002 small mammal surveys in three spruce-fir forest sites near the park in Dixie National Forest (NF) (Boswell and Day 2004). Two of the sites monitored were along the national monument's boundary.

Absence of Non-native Species

The 50 mammal species considered present or probably present were evaluated to determine nativity using NPSpecies 'nativeness' designation (NPS 2017a). If present, a non-native species was evaluated for its impact(s) to native species, especially ones of conservation concern.

Species of Conservation Concern

We used the national monument's list of 50 mammal species and compared it to three lists of species of conservation concern. The Utah Division of Wildlife Resources (UDWR) maintains the Utah sensitive species list for vertebrate and invertebrate species, including ones that are federally listed, candidates for federal listing, and those for which a state conservation agreement exists (UDWR 2015). The list also includes "wildlife species of concern," which are species that have scientific evidence substantiating a threat to their continued population viability (UDWR 2015). The idea behind this last designation is that timely conservation actions taken for each species will avoid the need to list them under the federal ESA in the future. A similar goal underpins another list referenced titled "species of greatest conservation need," which is included in the Utah Wildlife Action Plan (UWAPJT 2015). And under the ESA, the U.S. Fish and Wildlife Service lists species as threatened, endangered, or candidates for listing (USFWS 2017c).

Presence/Absence of American pika in Cedar Breaks NM

To assess the condition of the American pika (Figure 4.11.2-1) within Cedar Breaks NM, we used surveys that were conducted in 2006 by Oliver (2007), in 2009-2012 by NPS (i.e., Waters 2010, Eberly 2011, NPS 2012b), and in 2014-2015 by Beever et al. (2016). We also included other miscellaneous sightings from other sources, such as the "animal sightings" database maintained by national monument personnel (NPS 2016h). Additionally, though not used to assess condition, we obtained data from the UDWR on general, reported locations of American pikas within and outside of the monument (Boswell and Day 2004).

The UDWR, in coordination with NPS, conducted work in 2006 at Cedar Breaks NM to try to verify occurrences of particular vertebrate species within the monument (Oliver 2007), with special attention given to the American pika. Oliver (2007) searched for pikas in one location where they had been observed in 1974, as well as other areas within the national monument with potential suitable habitat.

The Zion National Park (NP) wildlife crew conducted surveys for pikas at Cedar Breaks NM each year from 2009-2011 (Waters 2010, Eberly 2011) and in 2012, surveys were conducted by a Cedar Breaks NM employee (NPS 2012b). Surveys occurred in July or

August during morning hours, following a protocol developed by the Zion NP wildlife crew in 2009 (Waters 2010, Eberly 2011, NPS 2012b). In 2010, two digital audio recorders were placed in the area where a pika was observed in 2009 (Waters 2010). All surveys were conducted in talus areas near the monument's Alpine Pond Trail.

Beever et al. (2016) conducted the monument's most recent American pika surveys in 2014 and 2015. They focused their surveys in three geographic regions of the western U.S. (i.e., Great Basin, southern Utah, which included Cedar Breaks NM and areas around the national monument and Zion NP, and northeastern California). Areas surveyed were ones with recent and historical records of American pika occurrence. The goals of the surveys were to examine patterns of pika persistence or occupancy, and to ascertain whether certain variables could explain the patterns of persistence or occupancy (Beever et al. 2016). The study included sampling at more than 910 locations within the three regions.

The researchers surveyed 58 50-m (164-ft) transects on seven talus patches within Cedar Breaks NM, and 146 transects on 19 patches outside of the boundaries of the national monument. Beever et al. (2016) surveyed every patch within the national monument that was definitively talus (Erik Beever, Research Ecologist, USGS Northern Rocky Mountain Science Center, pers. comm.). There are a handful of locations within the breaks that have some rocks of appropriate rock diameter for pikas (i.e., 0.2-1.0 m; Tyser 1980), but these: a) are each extremely small in extent, b) appear from the high-resolution imagery in CalTopo.com to have few interstices, and c) all occur in what appear to be flow paths for water and eroded sediment (and thus a non-strategic locale for a central-place forager that is philopatric to choose as its 'home base'). These occur immediately below cliff faces, near the tops of Lavender, Columbine, and Labyrinth Canyons, plus the first unnamed canyon south of Columbine Canyon. Patches at which pikas had been previously reported but where the USGS team failed to detect pikas on the first visit were visited twice to increase confidence in the assertion of lack of current pika occupancy. Occurrence was based on direct sighting, vocalization, or evidence of fresh haypile(s).

Additional pika-related information reviewed for this assessment included, the Boswell and Day (2004) study of the Brian Head/Cedar Breaks area of Dixie NF, and the monument's animal sightings database (NPS 2016h) maintained by park personnel, which included recent sightings of pikas.

Figure 4.11.2-1. American pika is a species of conservation and management interest at Cedar Breaks NM. Photo Credit: NPS.

4.11.3. Reference Conditions

Reference conditions for the four measures are shown in Table 4.11.3-1 and are described for resources in good, moderate concern, and significant concern conditions.

4.11.4. Condition and Trend

<u>Presence/Absence of Species</u>

Table 4.11.4-1 lists the species that have been recorded within the national monument by Haymond et al. (2003) and NPS (2017), which includes species that are considered "probably present." In total, there are 50 species; 39 (78%) are considered present and 11 (22%) are considered to be probably present. Of the 50 species, there are: two ungulates, 12 carnivores, three lagomorphs, 10 bats, 19 rodents, and four shrews.

Thirty-two species (64%) were recorded by Haymond et al. (2003), 13 of which were documented during both field seasons. Twenty-five species were recorded in 2001 and 20 were recorded in 2002. NPS (2016) documented 10 species (20%) of the ones listed in Table 4.11.4-1. Seven of these were recorded during the 2001 and 2002 mammal surveys, and three were not (i.e., gray fox (*Urocyon cinereoargenteus)*, long-tailed weasel (*Mustela frenata)*, and American pika).

Table 4.11.3-1. Reference conditions used to assess mammals.

Indicator	Measure	Good	Moderate Concern	Significant Concern
Species Occurrence	Species Presence/ Absence	We considered condition good if all or nearly all of the species recorded during early surveys/observations in the monument were recorded during later surveys.	Condition is of moderate concern if several species recorded during early surveys were not recorded during later surveys (particularly if the species had previously been considered common at the monument).	Condition is of significant concern if a substantial number of species recorded during early surveys were not recorded during later surveys (particularly if the species had previously been considered common at the monument).
	Absence of Non-native Species	Non-native species are absent. If they are present, they are limited by habitat type and/or are not known to outcompete native species for resources.	Non-native species are present but are limited by habitat type and/or do not outcompete native species for resources.	Non-native species are widespread, indicating available habitat, and outcompete native species for resources.
	Presence of Species of Conservation Concern	A moderate to substantial number of species of conservation concern occur at the national monument, meaning there is habitat for these species that 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.
American Pika Occurrence	Presence/Absence in Monument	Occurrence of American pika in talus patches within the monument has remained stable or increased over time.	Occurrence of American pika in talus patches within the monument has decreased somewhat over time.	Occurrence of American pika in talus patches within the monument has decreased substantially over time.

In 2001, the most common species captured or observed by Haymond et al. (2003) included Uinta chipmunks (*Neotamias umbrinus*, 62 captured), least chipmunks (*Neotamias minimus*, 18), canyon mice (*Peromyscus crinitus*, 16), deer mice (*Peromyscus maniculatus*, 113), montane voles (*Microtus montanus*, 13), and long-tailed voles (*Microtus longicaudus*, 10). Several northern pocket gophers (*Thomomys talpoides*) were captured, as well as an ermine (*Mustela erminea*). A golden-mantled ground squirrel (*Spermophilus lateralis*) was also observed. In 2002, the deer mouse was the most frequently recorded species and accounted for 39% of all captures/observations. The next most common species in 2002 were Uinta chipmunk and long-legged myotis (*Myotis volans*), each accounting for- approximately 10% of individual mammals that were captured or observed.

In addition, Haymond et al. (2003) recorded a Brazilian free-tailed bat (*Tadarida brasiliensis*) during the 2001 field season, although it remains unconfirmed so was omitted from the list of species in Table 4.11.4-1. Haymond et al. (2003) also included raccoon (*Procyon lotor*) and bighorn sheep (*Ovis canadensis*) as probably present but NPSpecies showed these as unconfirmed as well.

A recent analysis for national park units on the Colorado Plateau found that for Cedar Breaks NM, surveyed native mammal richness was somewhat higher than predicted by historic range maps (Stegner et al. 2017). Although there were caveats and assumptions with the analysis (e.g., they included "probably present" species as occurring, and there were park differences in how data were collected in NPSpecies), this is a positive outcome for the national monument; the analysis showed the opposite situation for some of the other parks (i.e., lower richness than expected based on historic range maps). The species richness for each park was based on their respective NPSpecies lists, all of which were certified between 2005 and 2007 (Stegner et al. 2017). The historic range map data came from a 1959 mammals guide (i.e., Hall and Kelson 1959 as cited by Stegner et al. 2017) based on records from the late 1800s and early 1900s.

Boswell and Day (2004) recorded eight species and one additional group of small mammals during their

Table 4.11.4-1. Mammal species list for Cedar Breaks NM.

Group	Common Name	Scientific Name	Haymond et al. 2001 Field Season	Haymond et al. 2002 Field Season	Monument Dbase (NPS 2016h)	NPSpecies (2017a) Occurrence
Ungulates	Elk	*Cervus elaphus*	X	–	X	Present
	Mule deer	*Odocoileus hemionus*	X	X	–	Present
Carnivores	American badger	*Taxidea taxus*	X	–	X	Present
	American black bear	*Ursus americanus*	–	–	–	Probably Present
	Bobcat	*Lynx rufus*	X	X	–	Present
	Coyote	*Canis latrans*	–	X	X	Present
	Ermine	*Mustela erminea*	X	–	–	Present
	Gray fox	*Urocyon cinereoargenteus*	–	–	X	Present
	Long-tailed weasel	*Mustela frenata*	–	–	X	Present
	Mountain lion	*Puma concolor*	X	–	X	Present
	Red fox	*Vulpes vulpes*	–	X	X	Present
	Ringtail	*Bassariscus astutus*	–	–	–	Probably Present
	Striped skunk	*Mephitis mephitis*	–	X	–	Present
	Western spotted skunk	*Spilogale gracilis*	–	–	–	Probably Present
Lagomorphs	American pika	*Ochotona princeps*	–	Probably Present	X	Present
	Mountain (or Nuttall's) cottontail	*Sylvilagus nuttallii*	–	–	–	Probably Present
	White-tailed jackrabbit	*Lepus townsendii*	–	–	–	Probably Present
Bats	Big brown bat	*Eptesicus fuscus*	X	–	–	Present
	Fringed myotis	*Myotis thysanodes*	–	–	–	Probably Present
	Hoary bat	*Lasiurus cinereus*	–	X	–	Present
	Little brown myotis	*Myotis lucifugus*	X	X	–	Present
	Long-eared myotis	*Myotis evotis*	X	X	–	Present
	Long-legged myotis	*Myotis volans*	X	X	–	Present
	Silver-haired bat	*Lasionycteris noctivagans*	X	X	–	Present
	Spotted bat	*Euderma maculatum*	–	X	–	Present
	Townsend's big-eared bat	*Corynorhinus townsendii*	–	–	–	Probably Present
	Western small-footed myotis	*Myotis ciliolabrum*	X	–	–	Present
Rodents	Brush mouse	*Peromyscus boylii*	–	–	–	Probably Present
	Bushy-tailed woodrat	*Neotoma cinerea*	X	–	–	Present
	Canyon mouse	*Peromyscus crinitus*	X	Probably Present	–	Present

Note that Haymond et al. (2003) also included the gray wolf (*Canis lupus*) and grizzly bear (*Ursus arctos*) as unconfirmed species that probably occurred historically. They also included raccoon (*Procyon lotor*) and bighorn sheep (*Ovis canadensis*) as probably present but NPSpecies showed these as unconfirmed. Brazilian free-tailed bat (*Tadarida brasiliensis*) was documented as one capture during Haymon et al. 2001 field season, but NPSpecies listed it as unconfirmed.

Table 4.11.4-1 continued. Mammal species list for Cedar Breaks NM.

Group	Common Name	Scientific Name	Haymond et al. 2001 Field Season	Haymond et al. 2002 Field Season	Monument Dbase (NPS 2016h)	NPSpecies (2017a) Occurrence
Rodents *continued*	Cliff chipmunk	*Neotamias dorsalis*	–	Probably Present	–	Present
	Deer mouse	*Peromyscus maniculatus*	X	X	–	Present
	Golden-mantled ground squirrel	*Spermophilus lateralis*	X	X	–	Present
	Least chipmunk	*Neotamias minimus*	X	X	–	Present
	Long-tailed vole	*Microtus longicaudus*	X	X	–	Present
	Montane vole	*Microtus montanus*	X	–	–	Present
	North American porcupine	*Erethizon dorsatum*	X	–	X	Present
	Northern flying Squirrel	*Glaucomys sabrinus*	–	–	–	Present
	Northern pocket gopher	*Thomomys talpoides*	X	X	X	Present
	Pinon mouse	*Peromyscus truei*	–	X	–	Present
	Red squirrel	*Tamiasciurus hudsonicus*	X	X	–	Present
	Rock squirrel	*Spermophilus variegatus*	–	–	–	Probably Present
	Uinta chipmunk	*Neotamias umbrinus*	X	X	–	Present
	Western harvest mouse	*Reithrodontomys megalotis*	–	–	–	Probably Present
	Western jumping mouse	*Zapus princeps*	–	X	–	Present
	Yellow-bellied marmot	*Marmota flaviventris*	X	–	–	Present
Shrews	American water shrew	*Sorex palustris*	–	Probably Present	–	Present
	Masked shrew	*Sorex cinereus*	–	Probably Present	–	Present
	Merriam's shrew	*Sorex merriami*	–	–	–	Probably Present
	Montane shrew	*Sorex monticolus*	X	–	–	Present

Note that Haymond et al. (2003) also included the gray wolf (*Canis lupus*) and grizzly bear (*Ursus arctos*) as unconfirmed species that probably occurred historically. They also included raccoon (*Procyon lotor*) and bighorn sheep (*Ovis canadensis*) as probably present but NPSpecies showed these as unconfirmed. Brazilian free-tailed bat (*Tadarida brasiliensis*) was documented as one capture during Haymon et al. 2001 field season, but NPSpecies listed it as unconfirmed.

1995-2002 small mammal surveys in three spruce-fir forest sites near the monument in Dixie NF. Six of these species have been recorded in the monument including deer mouse, least chipmunk, northern flying squirrel (*Glaucomys sabrinus*), long-tailed vole, montane vole, and red squirrel (*Tamiasciurus hudsonicus*). The two species not recorded in the monument (meadow vole [*Microtus pennsylvanicus*] and Botta's pocket gopher [*Thomomys bottae]*) were captured only one time (i.e., one individual) by Boswell and Day (2004) over their eight years of sampling.

Boswell and Day (2004) also recorded shrews in Dixie NF but did not report species. Three species of shrews are considered to be present within the national monument, with a fourth species 'probably present,' according to the monument's NPSpecies (2017) list. In 2002, Haymond et al. (2003) changed the monument's occurrence status for the American water shrew (*Sorex palustris)* and masked shrew (*Sorex cinereus)* to 'probably present,' although both of these species are still recorded as 'present' in NPSpecies (2017). These two species of shrews, the cliff chipmunk (*Neotamias dorsalis*), and the northern flying squirrel are the only four species listed as present that have yet to be recorded during surveys in the monument. None of the 11 species with occurrence status of probably present have been recorded recently.

In summary, a greater number of small mammal species were recorded within the national monument during the 2001-2002 USGS surveys (Haymond et al. 2003) than what was recorded in the Dixie NF, but the monument's surveys were also conducted in a larger number of habitat types. While extensive, the Haymond et al. (2003) surveys are now 15-16 years old, with no subsequent surveys to compare the presence/absence of species. Due to the lack of comparison, we consider the condition and trend for the presence/absence of mammals to be unknown, with low confidence. Even though the Haymond et al. (2003) surveys are older, the information provides a good baseline for future monitoring and assessment of mammal species occurrence at the national monument. In addition, national monument personnel are actively recording mammal observations, providing some current information about presence, especially for the carnivore species.

Absence of Non-native Species

None of the species that are listed in Table 4.11.4-1 are non-native; therefore, this measure is in good condition, with high confidence. Trend is unknown without a current survey.

Species of Conservation Concern

Of the 50 mammal species shown in Table 4.11.4-1, five were identified as species of conservation concern, although none were listed on USFWS' (2017) list of threatened, endangered, or candidates for listing. All of the of the species, American pika, fringed myotis (*Myotis thysanodes)*, little brown myotis (*Myotis lucifugus)*, spotted bat (*Euderma maculatum)*, and Townsend's big-eared bat (*Corynorhinus townsendii)* were listed as species of greatest conservation need (UWAPJT 2015). Only fringed myotis, spotted bat, and Townsend's big-eared bat were listed on Utah's sensitive species list (UDWR 2015). Three of these species, American pika, little brown and spotted bats, were recorded during the monument's surveys.

Cedar Breaks NM provides undisturbed habitat for five species (10% of the mammals found at the monument) that are of conservation concern. In addition, the monument is surrounded by the Dixie NF providing even more protected habitat that can contribute to the continued conservation of these species. For these reasons, we consider the condition of this measure to be good. We have high confidence, although trend in condition is unknown, except for the American pika, which is addressed under its own measure.

Presence/Absence of American Pika in the Monument

To determine the occurrence of the American pika at Cedar Breaks NM, we examined results of surveys over the last approximately 10 years. The August 2006 survey made by Oliver (2007) occurred at a talus patch at the west end of the Alpine Pond trail where several pikas had been observed in 1974. No individuals were observed in 2006 even after a total of approximately nine hours of observations over three different days. Oliver (2007) concluded that the population was extirpated, but suggested that over time, the talus patch may go through periods of being occupied and unoccupied. Oliver (2007) also looked at habitat suggested as potentially suitable by monument personnel, but concluded the habitat was not suitable for pikas. However, Oliver (2007) did note that abundant suitable pika habitat existed to the north of the park (on Brian Head), to the east, along State Highway 143, and to the southeast, along State Highway 14 (with pikas occurring in at least some of the areas).

From 2009 through 2012, pika surveys were conducted by NPS personnel. In 2009 and 2010, Waters (2010) reported that one pika was observed at the talus patch/boulder field along the Alpine Pond Trail (likely the same patch that was surveyed by Oliver (2007)). One individual pika was sighted and heard making alarm calls, which were recorded in 2010. Nine days later, during the second survey in 2010, one pika was observed again. In 2009 and 2010, the pika was photographed and determined to be the same individual based on a notch in its ear. Also, the digital audio recordings that were collected in 2010 were determined to originate from one pika.

In 2011, pika surveys were conducted on one day, and only one individual was heard and observed at the same location as surveyed in 2009 and 2010 (Eberly 2011). During the 2012 survey, a Cedar Breaks NM employee observed two pikas in the Alpine Pond Trail area, but they were in a talus patch on the opposite side of the trail as compared to the individual detected in earlier years. Based on the 2009-2012 surveys, pikas appeared to occur in small numbers within the monument at two known talus patches.

In 2014 and 2015, Beever et al. (2016) surveyed a total of 58 transects on seven talus patches within the national monument. The patches included the vicinity of the Alpine Pond Trail, previously occupied by pikas, and five additional talus patches identified after Beever et al.'s 2014 surveys. Of the five additional patches, three were in the Alpine Pond Trail area, and two were in the northern part of the park. The researchers also surveyed 146 transects on 19 talus patches outside of the monument's boundary in the Dixie NF.

During the 2014 and 2015 surveys, no pikas were observed at the Alpine Pond talus patches that were previously occupied in 2012 (Beever et al. 2016). Additionally, no pikas have been observed in these areas since 2012. Of the five newly-identified talus patches in the national monument, a total of four pikas were observed in 2015: two individuals at two of the patches. The remaining three newly-identified patches (where no pikas were observed) contained old sign of pikas (e.g., old haypiles, fecal pellets, or both; Beever et al. 2016). According to Beever, "old signs of pikas can last from years to centuries, based on how arid a region and microsite are (with evidences lasting longer in more-arid locales), and how protected a site and microsite are (with evidences lasting longer in more-protected locales). At one site, our radiocarbon-dating results (combined with our field observations park-wide and my interpretation of what's going on in Cedar Breaks NM suggest that pikas were last occupying that patch around 1985-1988. At another site at higher elevation, the same results and process

suggest that pikas were last occupying that patch around 1995-1998. Finally, a bit counter-intuitively, at the lowest-elevation of the 3 patches, results suggest that pikas were last occupying that patch around 2004-2009 or perhaps more recently than 2009."

Within the national monument, the researchers estimated that pika density averaged 0.069 individuals per 50-m (164-ft) transect. From the two occupied talus patches within the national monument, straight-line distances to the nearest other pika-occupied patches were 0.51 km (0.32 mi) and 1.49 km (0.93 mi, which are within the maximum dispersal distance of individual pikas (E. Beever, Research Ecologist, pers. comm.). According to Beever, "distances longer than 300 m (984 ft) occur only rarely, so the key unknown is how frequently such dispersal events will happen." Dispersal distances are lower at hotter, drier locales, so it's likely that longer distance dispersal events will become even-less-frequent over time, given contemporary climate change (E. Beever, Research Ecologist, pers. comm.).

Of the 19 talus patches surveyed within Dixie NF, 12 (63%) were occupied by pikas. Pika density within the national forest averaged 0.363 individuals per 50-m (164-ft) transect. Like those within Cedar Breaks NM, each of the seven unoccupied talus patches contained old sign of pikas. Further, Beever et al. (2016) emphasized that all of the unoccupied patches observed (five from the national monument and seven from the national forest) appeared to have been occupied by pikas in the past, and not just used for exploratory purposes. Beever et al. (2016) acknowledged that, although quite unlikely, it was possible that pikas may occur in low densities at some of the sites they considered pika-extirpated in their overall study.

Beever et al. (2016) also reviewed high-resolution imagery in CalTopo.com concluding that there were very few unsurveyed patches of possible habitat for the American pika within the monument (Erik Beever, Research Ecologist, USGS Northern Rocky Mountain Science Center, pers. comm.). These sites included the broken-rock talus patches in the Breaks area (i.e., at the heads of Labyrinth, Columbine, and Lavender canyons), which have not been sampled to date due to safety and resource-protection concerns. Given their isolation from other pika-occupied patches, such as geographic distance and barriers, the erodible soils nearby (which could lead to infilling of talus interstices), and the apparent lack of extensive herbaceous-vegetation cover, these sites would seem to have low likelihood of pika occupancy (Erik Beever, Research Ecologist, USGS Northern Rocky Mountain Science Center, pers. comm.). However, given the dearth of pika-occupied patches in the national monument, a survey of these areas at periodic intervals may be worthwhile in the future.

Observation records of pikas in the general vicinity of Cedar Breaks NM were provided by UNHP from the UNHP Biodiversity Tracking and Conservation System (BIOTICS). Observation point localities were masked to within 2.6 km^2 (1 mi^2) of the actual location to comply with State law (UDWR 2017). The data contained 22 records, with all but one located outside of and more than 1.6 km (1 mi) from the national monument's boundary. Five of the records were more than 8.0 km (5 mi) from the park. The remaining locations were between these two distances, with the majority situated to the north, northeast of the monument. Note that the distances provided here are based on the masked point locations provided by UNHP. All of the records contained observation dates from the 1980s and 1990s. Five of the records contained two observation dates, with the first being in either 1908 or 1937. There were no observation records more recent than 1997. The one observation within the national monument was attributed to Oliver and indicated that several pikas were seen and heard around Alpine Pond in July 1997. It is possible that this is the same location where Oliver (2007) reported seeing pikas in 1974 and 2006.

Based on the fact that 71% of previously occupied patches (five of seven) within the national monument have experienced pika extirpations, we consider the current condition of pika occurrence to be of significant concern, with a declining trend but high confidence. Beever et al. (2016) used very-high-resolution aerial photography of the entire monument area to determine survey locations, and they also assessed current and past occupancy patterns for most of the patches in Cedar Breaks NM by radiocarbon dating old pellets. All of the radiocarbon dates have two date ranges. For the three patches containing old sign of pikas, the earlier dates were from 1956-1959. Given that pikas currently remain in two patches in Cedar Breaks NM, and how recently they were lost from the Alpine Pond Trail, it is highly unlikely that these patches (which are so close to the others) would have continuously had no pika occupancy for nearly 60 consecutive years (E. Beever, Research Ecologist, pers. comm.).

Overall Condition, Trend, Confidence Level, and Key Uncertainties

To assess the condition of mammals at the national monument, we used two indicators with four measures, which are summarized in Table 4.11.4-1. Recognizing the different conclusions under the different indicators and measures, we consider overall condition of mammals to be of moderate concern, with varying trends. Since a lot of exhaustive surveys have been conducted for the American pika, but only one comprehensive survey has been conducted for mammals as a group, our overall confidence level is medium.

One area of uncertainty is whether pikas will remain extirpated from the talus patches near the Alpine Pond Trail. Oliver (2007) suggested that, with abundant suitable pika habitat adjacent to the national monument (e.g., to the north, east, and southeast), and with pikas having been observed in some of these areas, over time talus patches may go through periods of occupation and unoccupation. He further suggested that the monument's pika colony may have been established by pikas that dispersed from Brian Head. Based on what is known about pika dispersal capability in other areas, reoccupation is a possibility (although an unquantifiable one; Erik Beever, Research Ecologist, USGS Northern Rocky Mountain Science Center, pers. comm.). It is also not impossible that pikas in low numbers may have been present in the patches considered pika-extirpated (Beever et al. 2016). National monument personnel plan to continue surveying for pikas in the Alpine Pond Trail area, including conducting a citizen science project to observe the talus patches for signs of pikas (Bryan Larsen, Resources Manager, Cedar Breaks NM, pers. comm.).

One final piece of information that is interesting in the context of mammal diversity across the Colorado Plateau comes from the Stegner et al. (2017) study mentioned previously. From their analysis, they concluded that the 25 national park units studied have generally the same diversity of mammals and biogeographic patterns that existed in the early 1900s (with a few exceptions). They noted that the question remains as to whether the mammalian diversity has been maintained due to effective park management, or because impacts from humans on the Colorado Plateau have been relatively light.

Threats, Issues, and Data Gaps

Potential climate change effects may be of most concern for the higher elevation species, such as the American pika (see Chapter 2 climate change discussion about increased temperatures over the last 40 years). Of at least four potential factors analyzed by the USFWS (2010; climate change, livestock grazing, invasive plant species, and fire suppression) that may affect the American pika's habitat or range, only

Table 4.11.4-1. Summary of mammal indicators, measures, and condition rationale.

Indicators of Condition	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Species Occurrence	Presence/ Absence of Species		Current condition of mammals under this measure is unknown because the last group-wide inventory of mammals was conducted approximately 15 years ago (2001-2002) and no recent surveys can be used to compare presence/absence. No information on trend is available, and our confidence level is low.
	Absence of Non-native Species		No non-native mammals have been documented at the national monument, therefore, we consider this measure to be in good condition with an unknown trend. Based on the intensive inventory conducted by Haymond et al. (2003), we have high confidence in the condition rating.
	Species of Conservation Concern		Five species are considered species of conservation concern, with three present and two probably present. The national monument provides important undisturbed habitat for these species resulting in good condition, high confidence, but an unknown trend.
American Pika Occurrence	Presence/ Absence in Monument		Based on surveys conducted in the national monument from 2006-2015, only two of seven talus patches, with sign of previous pika occurrence, were occupied during the most recent surveys in 2014-2015 (Beever et al. 2016). This is a 71% decrease in occurrence, warranting significant concern, with a high confidence level and deteriorating trend.
Overall Condition			Even though the occurrence of American pika is of significant concern, it is only one of 50 species included on the monument's mammals list. Additionally, it is uncertain whether pikas in low numbers may have been present in the patches considered pika-extirpated. While we don't have data to compare presence/absence of mammals as a group, the fact that no non-native species are present and there is undisturbed habitat throughout the monument to support species of conservation concern, we rate the overall condition of mammals to be of moderate concern, with medium confidence and an unknown trend.

climate change was considered a potential threat. Increased temperature has the potential to shift biomes northward and higher in elevation. Some already relatively high-elevation species, such as the American pika, may run out of higher-elevation areas in which to move (e.g., National Wildlife Federation 2017).

A vulnerability assessment conducted for the pika in Cedar Breaks NM and nearby parks considered it "high" in sensitivity (due to its specific habitat requirements and temperature sensitivity) and "low" in adaptive capacity (due to low migratory potential) (Shovic and Thoma 2011); the assessment estimated a rating of "high" for potential impacts to its habitat within the parks (i.e., both Cedar Breaks NM and Zion NP; due to its high extirpation potential and uncertain presence in some areas). Climate change can affect montane wildlife indirectly and/or directly, such as by influencing the amount and isolation of appropriate habitat, affecting forage plants or prey, and/or causing physiological stress, possibly resulting in extirpations (Beever et al. 2016).

As described in Cedar Breaks NM's foundation document, the combination of high elevation and a semiarid climate renders the national monument, and the entire Colorado Plateau, especially vulnerable to the effects of climate change (NPS 2015a). Based on climate models, the Southwest is expected to become warmer and more arid, with more-extreme droughts, over the next century (refer to Chapter 2 climate change discussion). USFWS (2010) noted some of the climate variables that can affect pika populations, such as extremely hot or cold days, average summer temperatures, and duration of snow cover. They also noted that temperatures below the surface of the habitat (e.g., in loose rock areas/crevices) are more representative of the conditions faced by pikas than surface temperatures, for longer periods of the day. This is because pikas use this subsurface habitat to avoid hotter summer daytime temperatures, as well as the colder winter periods. The USFWS ultimately concluded that even with the threats that climate change pose (including potential loss of populations in some areas), the species (across its range) did not warrant listing under the ESA.

Beever et al. (2016) statistical analyses suggested that variables related to temperature and water-balance strongly explained the persistence of pikas at sites in the Great Basin and in Utah, but not in northeastern California. The researchers did not find pikas at any of the 26 talus patches surveyed in Zion NP in 2014-2015, including in any of seven patches that last had pikas in 2011. Another important finding of the Beever et al. (2016) research was that climate change can result in losses in distribution even when the physical (talus) habitat remains intact and unaltered.

4.11.5. Sources of Expertise

This assessment was based on a past inventory for mammals and more recent surveys for the American pika (especially by Beever et al. 2016). Erik Beever, Research Ecologist, U.S. Geological Survey, Northern Rocky Mountain Science Center, also provided supporting information and input related to the Beever et al. publication and the research in the national monument. Patty Valentine-Darby, biologist and writer, with Utah State University, authored the first draft of the assessment. Kim Struthers, NRCA coordinator with Utah State University, authored the second draft of the assessment.

A panoramic view of the summer Milky Way from Cedar Breaks NM. Photo Credit: NPS / Zach Schierl.

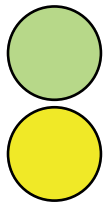
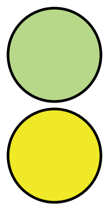
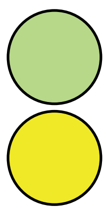
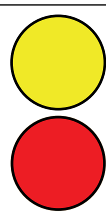
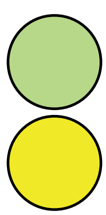
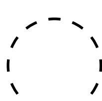
Chapter 5. Discussion

Of the 11 natural resources evaluated for Cedar Breaks NM's NRCA, both viewshed and geology are included in its purpose statement and are considered to be in good or good to moderate condition, respectively. Several of the remaining resources evaluated are also found in the monument's significance and/or fundamental resource statements, emphasizing the importance of maintaining or improving conditions and the underlying processes that are most important to the monument. The overall condition ratings for the 11 topics and their relationship to the monument's core components, as identified in its foundation document (NPS 2015a), are presented in Table 5.1.

While current conditions were evaluated separately for each of the 11 topics, we provide an alternative summary in this chapter, grouping resources into four broad categories. These categories include landscape-scale, geology and water, vegetation, and wildlife. Taken together as a whole, grouping resources provides a more practical, interconnected interpretation of data gaps for potential management actions or study proposals. From this perspective, an action or proposal is more likely to maintain or improve conditions for more than one resource. For each of the four groups, we summarize data gaps, proposal or project ideas, and identify the resource(s) addressed by each proposal or project idea.

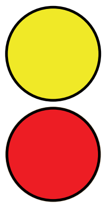
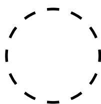
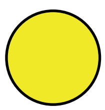
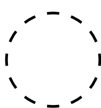
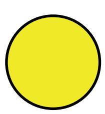
Colorado columbine at Cedar Breaks NM. Photo Credit: NPS.

Table 5-1. Natural resource condition summary for Cedar Breaks NM.

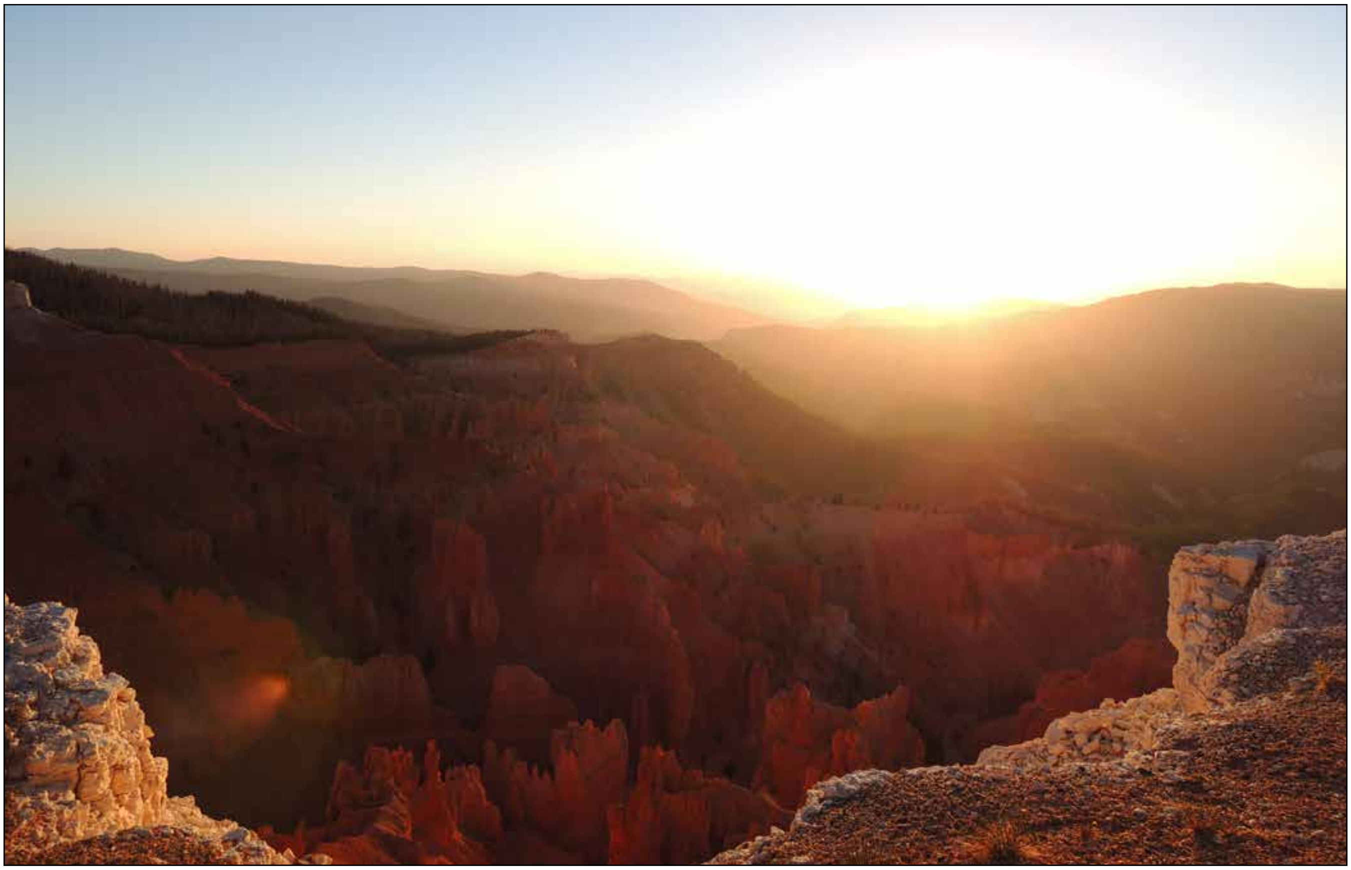
Core Component			Resource	Overall Condition	Overall Condition Discussion
Purpose	Significance	Fundamental			
X	X	X	Viewshed		Viewsheds are an important part of the visitor experience at national monuments and parks, and features on the visible landscape influence a visitor's enjoyment, appreciation, and understanding of a particular region. At Cedar Breaks NM, few non-contributing features are visible within the monument's viewshed and development is low, but the large amount of land within the viewshed that allows for extractive uses warrants moderate concern. Overall, however, the monument's current viewshed is good. Confidence is medium since the majority of data are modeled, and trend could not be determined at this time.
–	X	X	Night Sky		Maintaining a dark night sky is fundamental to protecting the wilderness character of Cedar Breaks NM and the monument was designated an International Dark Sky Park in 2017. All measures used to assess night sky condition are good or of moderate concern. Two measures are considered unknown due to lack of reference conditions. Confidence is medium since data are modeled and/or collected more than 10 years ago. Trend could not be determined. The overall current condition is good to moderate concern owing to its proximity to Cedar City and Saint George, Utah.
–	X	X	Soundscape		Opportunities to experience solitude and sounds of nature are becoming increasingly rare but still occur throughout the monument. The types and levels of sound not only impact visitor enjoyment but may also greatly influence wildlife behavior and survival. While sound levels and predicted sound level impact are considered to be in good condition, the percent reduction in listening area when sounds were recorded is of significant concern. This may have a far-reaching impact as the monument continues to receive higher visitation during both the summer and winter seasons.
–	–	X	Air Quality		Air quality impacts the sights we see, the air we breathe, and the health of vegetation, organisms, and water resources within a given airshed. The monument's airshed is influenced largely by activities located outside its boundary. Haze, ozone levels for human health and wet deposition of sulfur and nitrogen are of moderate concern. However, conditions deteriorated to significant concern for ozone levels for vegetation, wet mercury deposition, and the predicted methylmercury concentration in surface water.
X	–	X	Geology		The erosive forces of water and wind are responsible for the monument's unique geological features. Although there were few data with which to assess this resource, the data that were available suggested an overall condition of good to moderate concern. Anthropogenic damage to paleontological resources is low, largely due to the inaccessibility of the canyon. Rockfalls and slope failures, however, could be an issue along the rim. Social trails are also common in this area. Confidence is medium since data are limited. Trend could not be determined.
–	–	–	Springs and Seeps		Although springs and seeps occupy a limited area in Cedar Breaks NM, they provide critical habitat for birds, invertebrates, amphibians, and mammals. This habitat type is especially important given the monument's arid landscape. However, there were few current data with which to assess this resource, and virtually all measures revealed significant data gaps. Although historic data indicate good conditions for some measures, it is unknown whether these conditions have persisted. For this reason, current condition and trend could not be determined, confidence is low, and trend is unknown.

Note: Purpose, significance, and fundamental resources and values statements are listed in NPS (2015a).

Table 5.1 continued. ***Natural resource condition summary for Cedar Breaks NM.***

Core Component: Purpose	Core Component: Significance	Core Component: Fundamental	Resource	Overall Condition	Overall Condition Discussion
–	X	X	Upland Vegetation		The high elevations and short, cool summers and long, cold winters support the upland vegetation community at Cedar Breaks NM. Upland vegetation is regularly monitored to assess aspects of community composition and structure and forest health. Many of the measures' conditions are unknown but the assessment as a whole suggests moderate to significant concern, with medium confidence. The monument's forest has shifted from a mix of spruce-fir to a subalpine fir-dominated forest. Much of the standing Engelmann spruce has been killed by spruce beetles, and the vegetation condition class suggested a significant departure from historic conditions. Trend is unknown.
–	X	X	Unique and Distinctive Vegetation		Neither of the two studies used to assess condition reported recent data (i.e., < 5 yrs), and only one study focused on rare plants. This resulted in an unknown condition rating for this resource, although one of the two measures used suggests moderate concern. Given the age of the data and the fact that one study was not specifically targeted at surveying rare plants, confidence for both measures was low, which resulted in an overall low confidence. Trend could not be determined. These results suggest that the topic itself is a condition data gap.
–	–	–	Non-native Invasive Plants		Certain non-native plants can alter ecosystem structure and function wherever they occur. In Cedar Breaks NM most non-native plants are found along roadsides, in disturbed areas, and around buildings above the rim. Of the 20 non-native species known to occur in the monument, the most problematic and widespread is smooth brome. Smooth brome has invaded upland meadows and is spreading into areas that support rare plants. These results warrant moderate concern. However, confidence is medium because only uplands have been surveyed and some studies are >10 years old. Trend could not be determined.
–	X	X	Birds		Birds are a highly visible component of many ecosystems and are considered good indicators of ecosystem health because they can respond quickly to changes in environmental conditions and can be efficiently surveyed. The monument's comprehensive baseline bird inventory occurred 14 years ago, and while dedicated volunteers and employees record bird presence at the monument, it is due to the lack of recent standardized bird surveys and comparable datasets that we rated the condition of birds as unknown.
–	X	X	Mammals		Mammals are charismatic creatures that capture the interest and imaginations of visitors and researchers alike. The national monument provides habitat for a wide variety of mammals, including the declining American pika. While the condition of mammals as a group is unknown due to lack of repeatable surveys, the American pika has been extensively surveyed throughout the monument. Unfortunately, sightings have declined, with only two talus patches containing actual pikas in recent years, although signs of previous activity were observed. Overall, the condition of mammals is of moderate concern, with medium confidence and an unknown trend.

Note: Purpose, significance, and fundamental resources and values statements are listed in NPS (2015a).


A panoramic view of a sunset over Cedar Breaks. Photo Credit: NPS.

5.1. Landscape-scale resources

Most national park resources are not contained within legislated boundaries, which is especially true for landscape-scale resources, such as viewsheds, night sky, soundscapes, and air quality. While Cedar Breaks NM staff can influence some of these resource conditions directly, conditions are largely influenced by activities occurring outside its boundary. Because of this, partnerships for preservation are critical for maintaining or improving landscape-scale conditions. With the monument almost entirely surrounded by the Dixie National Forest, the largest forest in Utah, totaling almost 809,371 ha (2-million ac), opportunities for preserving landscape-scale resources abound. It's important that as visitation continues to increase, both within the monument and surrounding area, the resource conditions that initially attracted visitors remain intact and are incorporated into decision-making efforts.

The primary threats to the monument's landscape-scale resources include surrounding development and associated light, noise, and scenic pollution; rapidly increasing visitation, which now includes snowmobile and air traffic; and climate change-related atmospheric dust and smog, which impacts the visible, scenic landscape.

Proactive strategies to preserve the national monument's landscape-scale resources may include promoting community partnerships and local citizen education about these shared resources. Information, such as brochures or interpretive programs, can promote the benefits of working together to preserve the resources that make the surrounding area so desirable and unique. A toolkit has been developed by the NPS to aid parks with engaging in community conversation titled, *A Call to Action #13: Stop Talking and Listen* (NPS 2013). Monument staff have already committed to long-term monitoring of night skies in addition to working with city council members and planners to promote night-sky friendly lighting. Staff also offer educational programs that highlight the monument's nocturnal landscape. This effort could be expanded to include view, sound, and air quality resources. Completing the analysis of the 2012 acoustical monitoring would serve as an important baseline for the monument, especially as noise is expected to increase.

5.1.1. LANDSCAPE-SCALE RESOURCES— *viewshed, night sky, soundscape, and air quality*

Knowledge or data gaps:

A) Areas to Manage Landscape-scale Resources
A thorough inventory of where the most quiet, dark, and scenic areas exist in the monument is needed to identify areas for resource preservation, especially with increasing visitation.

B) Acoustic Data Analysis
Acoustic data were collected in 2012 but have yet to be analyzed. This information would likely help inform management actions.

C) Hazy Days and Scenic Resources
Haze affects a visitor's ability to see and is of moderate concern at the monument. Understanding the sources and origins of pollution is critical for resource protection.

Gaps: A, C

Landscape-scale Baseline Inventory
Identifying the most preserved areas in the monument for pristine views, dark sky, and solitude will provide information to guide future developments while maintaining good conditions. Modeled night sky and sound maps can provide a starting point for identifying areas.

Addresses Resources
- Viewshed
- Night Sky
- Soundscape
- Air Quality
- All remaining resources

Gap: A

Partnership Inventory
Inventorying existing partnership activities within an ecologically-relevant area would provide information from which monument resources could be managed cooperatively on a landscape-scale. With a small staff, working with partners is necessary for achieving conservation goals.

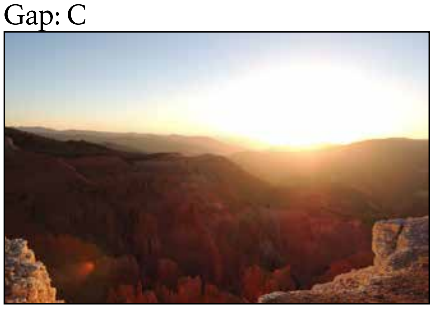
Addresses Resources
- Viewshed
- Night Sky
- Soundscape
- Air Quality

Gaps: A, B

Acoustic Data Analysis
A full analysis of the 2012 data would serve as an important baseline for potential future management action. Monitoring locations could be expanded using NPS IMR equipment and protocol. A STAR could be submitted for the data analyses.

Addresses Resources
- Soundscape

Gap: C



From top: Milky Way, Park entrance sign, raven, sunset, Photo Credits: NPS

Linking Scenic Views & Haze
Linking the monument's qualitative scenic vista Citizen Science project with quantitative haze index data would provide a framework that managers could use for educational and potential air pollution advocacy efforts, especially with the potential of oil-gas developments west of the park and increasing motorized traffic.

Addresses Resources
- Viewshed
- Air Quality

Cedar Breaks amphitheater. Photo Credit: NPS.

5.2. Geologic and water resources

The geologic features of Cedar Breaks NM are the defining resource of the monument, and the combination of geology, water, and elevation have created the spectacular views seen from within the monument. The viewing of this spectacular scenery is a popular visitor attraction, and as a result, the designated overlooks receive heavy use. Erosion at these viewpoints throughout the monument is of concern due to the potential impacts on facilities. Visitation along designated and undesignated trails also presents the risk of slope failure and/or rockfall.

With increasing visitation to the monument, an understanding of highly susceptible areas of erosion is imperative, especially if considering the siting of new developments to support the higher number of visitors.

Several data gaps and project ideas related to slope processes and water-related issues are listed in Thornberry-Ehrlich (2006). These inventory, monitoring, and research needs are still relevant to maintaining or improving present-day resource conditions. With some technical expertise to help develop study frameworks, several of the projects would lend themselves to volunteer scientists and/or student interns collecting data, which could be analyzed later by subject matter experts through technical assistance requests. A few of the data gaps and project ideas related to the geology and springs and seeps resource assessments are summarized on the following page.

5.2.1. GEOLOGIC and WATER RESOURCES— *geology and springs & seeps*

Knowledge or data gaps:

A) Erosion Locations & Processes
A thorough inventory with respect to the different rock formations and erosion potential is needed, especially to guide any future developments.

B) Social Trail Impacts
No data have been collected to comprehensively know locations and understand the impacts of social trails to soils, vegetation, and the potential slope/rockfall hazards.

C) Paleontologic Resources
A comprehensive survey for paleontological resources in the monument has not been conducted.

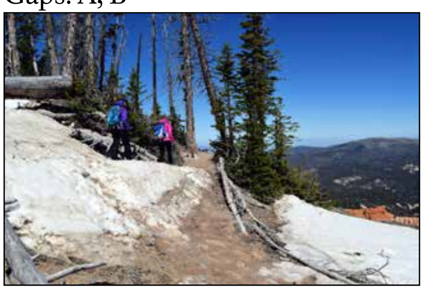
D) Springs & Seeps Data
No current data are available.

Gaps: A, B, C

Comprehensive Erosion Study
Create a rockfall susceptibility map using rock unit versus slope aspect in a GIS; use the map to plan future developments and aid current resource management of trails, buildings, and recreational use areas. Could also identify high priority areas for paleontologic resource survey(s).

Addresses Resources
- Geology
- Springs & Seeps

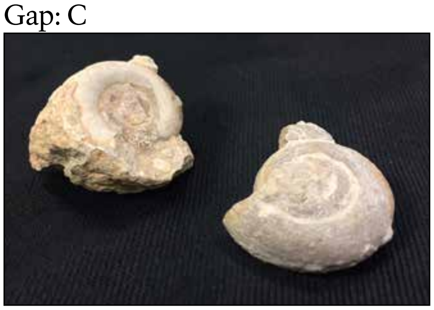
Gaps: A, B



Trail Stability Study
Develop a trail stability study to determine which trails are most at risk to slope or rockfalls and in need of further stabilization. An inventory of human impacts to soils and vegetation, including unique and distinctive vegetation, could be included to help guide visitor use management.

Addresses Resources
- Geology
- Vegetation & Soils

Gap: C



Paleontologic Resource Inventory
Comprehensively inventory paleontologic resources providing a baseline to develop appropriate resource monitoring strategies, which will facilitate scientific research, visitor interpretation, and resource management and protection of park fossils.

Addresses Resources
- Geology

Gap: D

From top: Scenic overlook, trail, fossil, spring. Photo Credits: NPS/D. Sharrow (top), Remaining: NPS.

Springs & Seeps Monitoring
There are no current data for springs and seeps in the monument even though they provide very important habitat for wildlife. Without data, problems can arise without any knowledge. NCPN has springs monitoring that could potentially be adopted by the monument with analysis and data management shared between Cedar Breaks NM and NCPN.

Addresses Resources
- Springs & Seeps

Wildflowers in Cedar Breaks NM. Photo Credit: NPS.

5.3. Vegetation

Vegetation is an expression of soils, topography, and climate, and it's likely that changes in temperature and precipitation, both amount and timing, will cause major changes to vegetation communities, especially in the Southwest— a climate change hotspot (NPS n.d., b). Impacts may result in vegetation shifts, altered fire regimes, and insect outbreaks, causing major ecological disruptions to vegetation communities. It's also likely that certain non-native invasive plants will thrive and rapidly spread due to the changing environmental conditions. Currently, smooth brome (*Bromus inermis*) is spreading into areas where the majority of rare and sensitive plant species are located. However, given its current limited abundance and distribution in the monument, there is an opportunity to reduce its threat by aggressively managing the infestations that exist. The endemic plants that are located at the higher elevations throughout Cedar Breaks NM are especially vulnerable to the changing climate conditions since they are unable to migrate to higher elevations and will need to adapt if they are to persist. The Intergovernmental Panel on Climate Change [IPCC] 2014) predicts that climate change will be most impactful to trees and herbaceous plants since they are less able to move (i.e., disperse) quickly enough to keep pace with the changing environmental conditions. A subset of Fertig and Reynolds (2009) plots could be identified that would represent all of the target species and could be monitored by park interns, Native Plant society volunteers, or students from Southern Utah University. Or the park could submit a proposal for a followup study.

NCPN regularly monitors the vegetation community structure and composition and forest health for the monument, providing data to routinely assess current conditions. In addition, the U.S. Forest Service monitors forested areas damaged or killed by bark beetles, which also includes areas throughout the monument. Finally, NCPN has developed a landscape-scale model linking vegetation response to climate variables, providing a means to potentially forecast future management issues of concern (Thoma et al. 2017). Determining appropriate reference conditions for these multiple monitoring efforts and associated data would help monument staff understand the effects of climate change on vegetation and identify management actions managers could implement.

5.3.1. VEGETATION— *uplands, unique and distinctive, and non-native invasive plants*

Knowledge or data gaps:

A) Lack of Reference Conditions for Vegetation Response to Climate Change
To effectively adapt to climate change, a framework is needed to understand the connection between multiple variables.

B) Unique & Distinctive Vegetation Data
No monitoring data are available.

C) Prioritize Non-native Invasive Plant Control Areas
Develop comprehensive location inventory.

D) Regular Monitoring for New Non-native Invasive Plants
Early detection is key to rapid control, especially with new, non-native species that are aggressive invaders.

Gaps: A, B, C

Linking Vegetation Data & Climate Metrics
Developing a framework to connect the multiple lines of evidence for the vegetation monitoring programs is crucial for understanding the role of climate change relative to vegetation health and management implications.

Addresses Resources
- Upland Vegetation
- Unique & Distinctive Vegetation
- Non-native Invasive Plants

Gaps: B, C

Unique & Distinctive Veg Monitoring
Monitor the unique and distinctive vegetation throughout the monument using Fertig and Reynolds (2009)baseline inventory as the foundation for repeat monitoring in the future. This will help identify management action(s) and potential research efforts.

Addresses Resources
- Unique & Distinctive Vegetation
- Non-native Invasive Plants

Gaps: B, C, D

From Top: Geologic breaks, spiked ipomopsis, invasive plant control. Photo Credits: NPS/D. Sharrow (top) and NPS for remaining photos.

Early Detection/Rapid Response
Early detection for implementing a rapid control response is critical to managing non-native invasive plants. NCPN's non-native plants lists for other parks may assist with targeting new introductions of non-native plants. NCPN has an invasive plants monitoring protocol that could potentially be adopted by the monument with analysis and data management shared between Cedar Breaks NM and NCPN.

In addition, knowing areas to prioritize, such as locations with sensitive and unique vegetation, will help staff identify management priorities.

Addresses Resources
- Upland Vegetation
- Unique & Distinctive Vegetation
- Non-native Invasive Plants

Red fox. Photo Credit: © Rob Whitmore.

5.4. Wildlife

The American Southwest has some of the highest species richness of native mammals in the country due to its range of elevations and precipitation amounts, which create diverse habitats (Mac et al. 1998 as cited by Haymond et al. 2003, Brown 1978). A recent analysis for Cedar Breaks NM found that the native mammal richness was somewhat higher than predicted by historic range maps (Stegner et al. 2017). One mammal of particular management focus at the monument is the American pika (*Ochotona princeps*), which is believed to be disappearing from previously occupied habitat likely due to climate change, specifically warming temperatures.

Research by U.S. Geological Survey has found that pika populations are now disappearing from numerous areas in the mountainous U.S., while other populations are migrating to higher elevations. Unfortunately, pikas are strongly dependent on rocky-talus habitat, which is limited. As a result, few within-site shift options are available as temperatures continue to rise.

The number of pikas at the monument has declined, with only two talus patches containing actual pika sightings in recent years. National monument personnel plan to continue surveying for pikas in the Alpine Pond Trail area, and could include the other patches identified by Beever et al. (2016) that contained pika or pika sign in their survey efforts. In addition, some remote locations could be included in the systematic survey, including the broken-rock talus patches in the Breaks area (i.e., at the heads of Labyrinth, Columbine, and Lavender canyons), although safety and resource protection precautions would need to be considered.

In addition, given contemporary climate change, a potential management priority may be to try to record new (lower-elevation-associated) species, both mammals and birds coming into the monument for the first time. This would provide information to monument staff from which they can evaluate adaptive conservation goals and strategies.

5.4.1. WILDLIFE— *birds and mammals*

Knowledge or data gaps:

A) Comprehensive American Pika Survey
Consistent and thorough monitoring of American pika is needed to monitor potential population changes.

B) Climate Change Species
Documenting the presence of new or shifting species will provide climate-change related science.

C) QA/QC Data Collections
Need to ensure quality assurance and quality control for all data collection.

Gaps: A, B, C

American Pika Monitoring
American pikas may serve as the "canary in the coal mine" at Cedar Breaks. Systematic and comprehensive surveys will provide staff with information for implementing adaptive management strategies.

Addresses Resources
- Mammals

Gaps: B, C

Record New Species
With climate change, it's expected that species shifts will occur. Knowing which species and where these changes are occurring is critical for proactively managing resources.

Addresses Resources
- Mammals
- Birds

Gaps: A, B, C

From Top: American pika, Yellow-rumped warbler, California condor. Photo Credits: NPS/J. LeVasseur (top), and NPS for remaining photos.

Develop Systematic Methodologies for New Data Collection Efforts
Developing and documenting systematic data collection methodologies and implementing data quality assurance and quality control protocols for all collection efforts is necessary. This will ensure data usefulness and applicability to management efforts, especially when comparing data sources from various efforts.

Addresses Resources
- Mammals
- Birds

5.5. Climate Change

Natural resources and associated processes are highly dynamic and require a range of variability paradigm to understand and appropriately frame management goals. When a fundamental driver such as climate begins to rapidly change, changes to resource conditions are inevitable. Identifying near-term priorities, in addition to embracing new challenges and opportunities, is necessary for an effective adaptive management strategy.

> *"Today's rapid climate change challenges national parks in ways we've never seen before."*
>
> *— Climate Change Response Program, National Park Service*

As the NPS *Climate Change Action Plan 2012-2014* suggests, developing robust partnerships, strengthening communication strategies, and providing climate change science to parks are a few ways to take action. Because of the high elevation at Cedar Breaks NM, it is likely that both vegetation and wildlife species occupying habitats at the highest elevations will be most affected by climate change. In general, it's expected that an increase in annual mean temperature, a decrease in the average number of days below freezing, and an earlier average peak spring runoff will occur. NPS (2015a) cites the following as the most likely changes with the highest degree of certainty:

- a longer growing season and similarly longer fire seasons
- earlier snow melt and more winter precipitation falling as rain rather than snow
- more evaporation from plants, resulting in less groundwater recharge and reduced spring and stream flow
- greater year-to-year variability may also be experienced

Alpine forest in the winter at Cedar Breaks NM. Photo Credit: NPS.

- a warmer and drier landscape will mean a decrease in water resources, both surface and groundwater.

What is unclear, and represents a significant data gap and uncertainty, is how intensely resources will respond to these expected changes. The IPCC (2014) states that "many species will be unable to track suitable climates under mid- and high-range rates of climate change during the 21st century ([with] medium confidence). Lower rates of change will pose fewer problems. Some species will adapt to new climates. Those that cannot adapt sufficiently fast will decrease in abundance or go extinct in part or all of their ranges." Figure 5.5.1 shows climate change impacts, adaptation, and vulnerability for eight groups of organisms. The maximum speed at which organisms can move relative to changing environmental conditions will be a significant factor in determining their ability to persist.

As managers try to formulate conservation goals in the midst of these rapidly changing conditions, access to scientifically-credible information that helps inform decisions will be extremely beneficial. As shown in Figure 5.5-1, trees are the most vulnerable group to changing temperature and precipitation patterns due

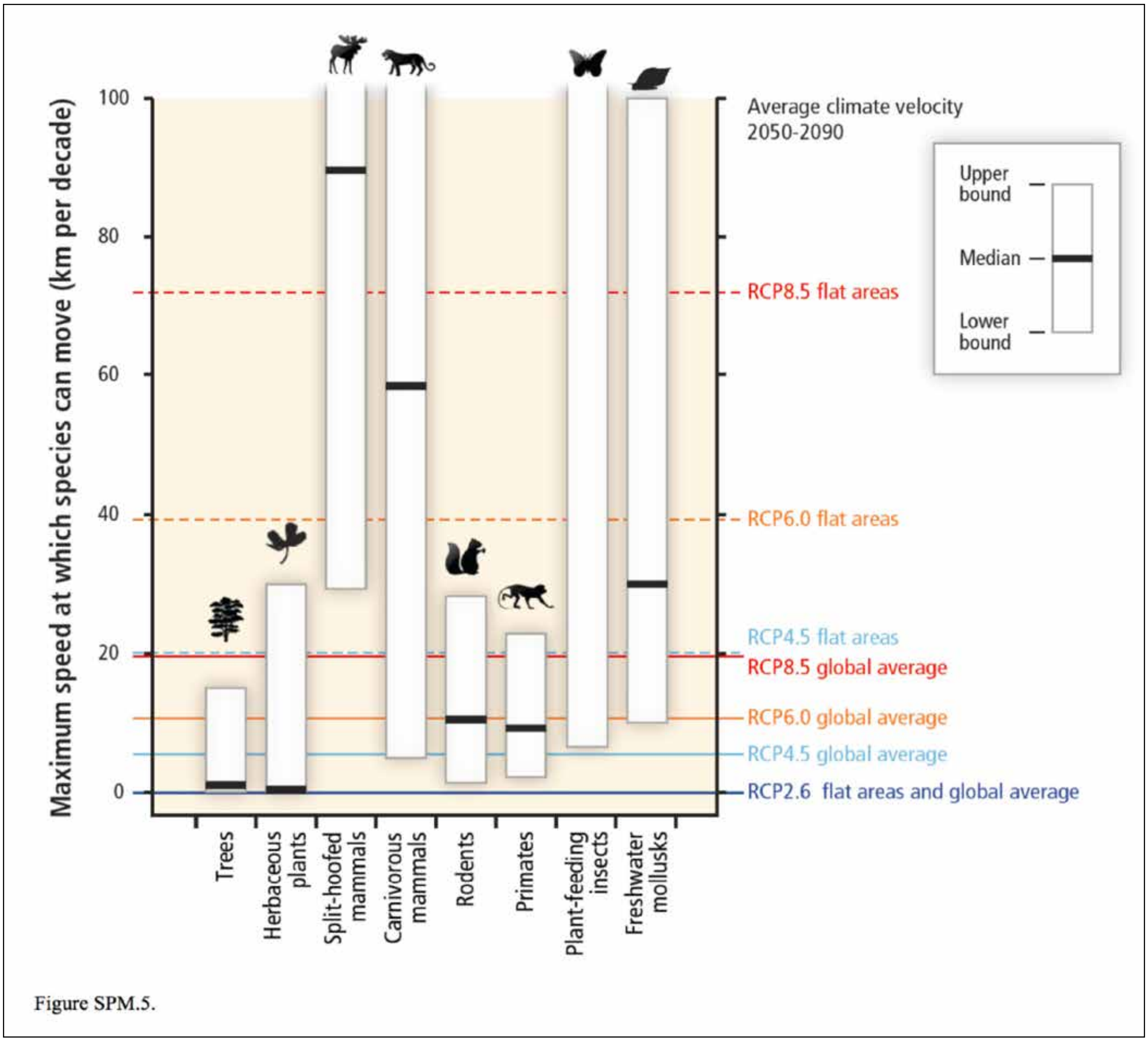


Figure 5.5-1. Graph of climate change impacts, adaptation, and vulnerability for eight groups of organisms based on the maximum speed at which the organism can move. Figure Credit: IPCC (2014).

to their inability to move (disperse) quickly, especially for species inhabiting alpine environments, such as those found at Cedar Breaks NM.

The NCPN has developed a landscape-scale model linking vegetation response to climate variables using satellite imagery and weather data (Thoma et al. 2017). The information derived from the model provides park managers with climate change science that may inform future adaptive management strategies.

NCPN completed a Normalized Difference Vegetation Index (NDVI) assessment for Cedar Breaks NM in 2017 for the Upland Vegetation condition assessment (which is included in this report). Much of the NDVI results are presented in the actual assessment, but additional information pertaining to vegetation productivity within the five forest types assessed is presented here to emphasize the connection between climate, specifically temperature and precipitation, and resource response.

Results showed that annual vegetation production was most strongly correlated with, and sensitive to, average annual temperature (Figure 5.5-2, left graph) versus precipitation (Figure 5.5-2, right graph). Long-term trends (1980-2016) indicated that the average annual temperature was variable with a significant ($p < 0.10$) positive trend in all of the forest types assessed. In other words, as temperatures continue to increase as they have at Cedar Breaks NM, with the last decade representing the warmest on record for years 1901-2012 (Monahan and Fisichelli 2014), changes associated with these increasing temperatures are likely inevitable, especially for vegetation. For example, the severity and scale of the bark beetle outbreak in forests, in and surrounding the monument, was likely greater than it otherwise would have been due to increasing winter minimum temperatures, increasing summer maximum temperatures, drought, and wide-scale host tree suitability (DeRose and Long 2007, DeRose and Long 2012, USEPA 2016d).

Even though this type of information may not initially result in immediate management action(s) that can be implemented, resource managers will be better informed about climate change science. This, in turn, will provide staff with evidence-based information to communicate projected consequences of climate change to the public effectively and with credibility. Metrics that can continue to synthesize the complex changes as a result of the rapidly changing environmental conditions is essential, especially since it's predicted that climate change will increasingly affect all aspects of the monument's resources, operations, and visitor experiences (Monahan and Fisichelli 2014).

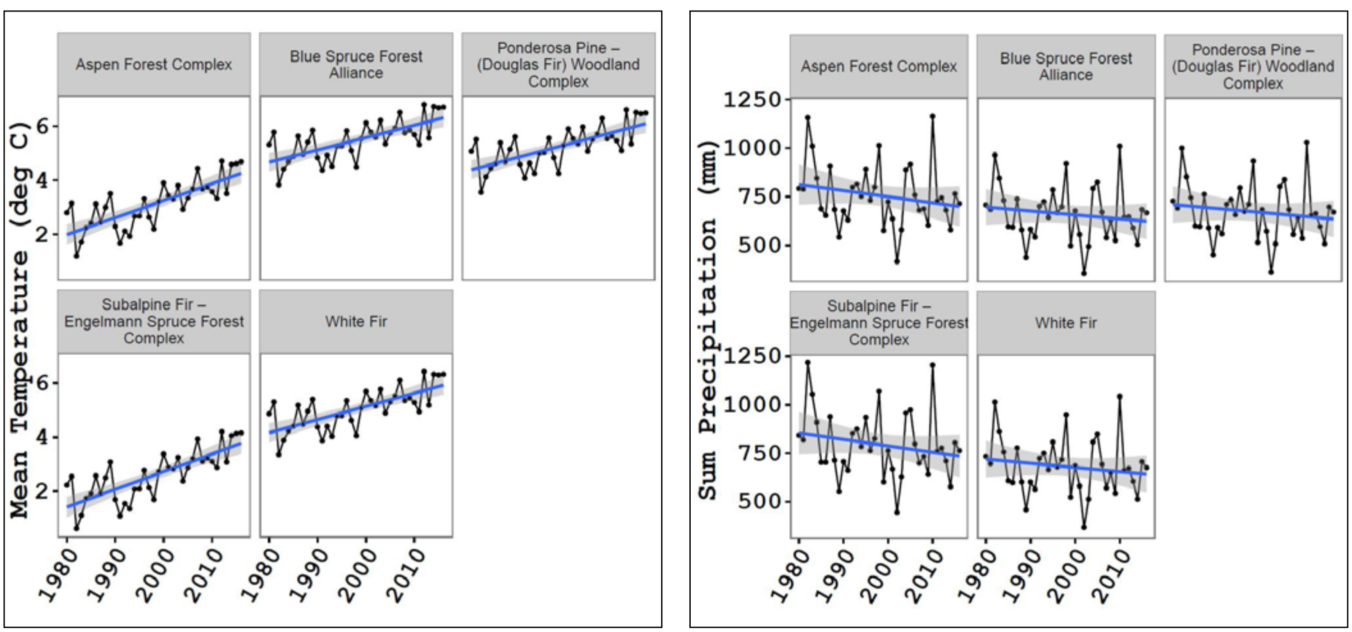


Figure 5.5-2. Trends in mean annual temperature (left) and cumulative annual precipitation (right) in five forest types in Cedar Breaks NM. Blue lines represent significant trends (p<0.1) and gray bands represent 90% confidence intervals. Figure Credit: NPS NCPN/Dave Thoma. Data Sources: MODIS 250 m vegetation products and 500 m snow cover products.

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Appendix A. Cedar Breaks NM Herpetofauna Species List

Listed below are the reptile and amphibian species that have been listed for Cedar Breaks National Monument (NM). Sources used for the list were the Certified NPSpecies list for the national monument (NPS 2017a, dated 23 March 2017) and Platenberg and Graham (2003). Species listed by Platenberg and Graham (2003) were those recorded during field work in 2001-2002, a review and evaluation of others' past observations, and museum specimens. A total of 12 species are listed for the monument, but only one is confirmed as occurring within the monument and another presents conflicting data. The list of species was compared with lists of federally threatened and endangered species (U.S. Fish and Wildlife Service 2017) and those listed as sensitive by the state of Utah (Utah Division of Wildlife Resources 2015). None of the 12 species listed below are considered endangered, threatened, or sensitive. All species are native to the region.

Table A-1. Herpetofauna species list for Cedar Breaks NM.

Group	Common Name	Scientific Name	Occurrence[1]
Reptiles	Arizona (Sonoran) mountain kingsnake[3]	*Lampropeltis pyromelana*	May Occur
	Common sagebrush lizard[2,3]	*Sceloporus graciosus*	Unconfirmed, May Occur
	Gopher snake[3]	*Pituophis catenifer*	May Occur
	Milk snake[3]	*Lampropeltis triangulum*	May Occur
	Mountain (Greater) short-horned lizard[2,3]	*Phrynosoma hernandesi*	Present, May Occur
	Terrestrial gartersnake[2]	*Thamnophis elegans*	Unconfirmed
	Western rattlesnake[3]	*Crotalus oreganus*	May Occur
	Western skink[3]	*Eumeces skiltonianus*	May Occur
Amphibians	Boreal chorus frog[3]	*Pseudacris maculata*	Present
	Northern leopard frog[3]	*Rana pipiens*	May Occur
	Western chorus frog[2]	*Pseudacris triseriata*	Probably Present
	Western tiger salamander[3]	*Ambystoma mavortium*	May Occur

Note: Occurrence is based on the most recent information available.

[1] Species with differing occurrence designations are listed by NPSpecies (NPS 2017a) then Platenberg and Graham (2003).

[2] Occurrence from NPSpecies (NPS 2017a).

[3] Occurrence from Platenberg and Graham (2003).

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
Phyllis Pineda Bovin	National Park Service Intermountain Region Office, Natural Resource Condition Assessment Coordinator
Cassity Bromley	National Park Service Zion National Park, Chief of Resources Management and Research
Dr. Mark Brunson	Utah State University, Professor and Principal Investigator
Bryan Larsen	National Park Service Cedar Breaks National Monument, Resource Management Technician
Dusty Perkins	National Park Service Northern Colorado Plateau Inventory and Monitoring Network, Program Manager
Paul Roelandt	National Park Service Cedar Breaks National Monument, Superintendent
Zachary Schierl	National Park Service Cedar Breaks National Monument, Education Specialist
Dave Sharrow	National Park Service Zion National Park, Hydrologist
Kim Struthers	Utah State University, NRCA Project Coordinator and Writer/Editor

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
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
Dusty Perkins	National Park Service Northern Colorado Plateau Inventory and Monitoring Network, Program Manager	Air Quality, Birds, Mammals, Night Sky, Soundscape, Springs & Seeps, Non-native Invasive Plants, and Geology, Assessments
Bryan Larsen	National Park Service Cedar Breaks National Monument, Resource Management Technician	Park Resource Expert Reviewer
Cassity Bromley	National Park Service Zion National Park, Chief of Resources Management and Research	Chapters 1 & 3
Dave Thoma	National Park Service Northern Colorado Plateau and Greater Yellowstone Networks Inventory and Monitoring Network Hydrologist	Upland Vegetation Assessment
Rebecca Weissinger	National Park Service Northern Colorado Plateau Inventory and Monitoring Network, Aquatic Ecologist	Springs & Seeps Assessment
Dana Witwicki	National Park Service Northern Colorado Plateau Inventory and Monitoring Network, Ecologist	Unique & Distinctive Vegetation, Upland Vegetation Assessments
Dave Sharrow	National Park Service Zion National Park, Hydrologist	Springs & Seeps, Geology Assessments
Laura Schrage	National Park Service Zion National Park, Vegetation Program Manager	Non-native Invasive Plants, Upland Vegetation, and Unique & Distinctive Vegetation Assessments
Kathryn Mandrodt	National Park Service Cedar Breaks National Monument, Interpretive Park Ranger	Birds Assessment
Carl Hallows	National Park Service Cedar Breaks National Monument, Resource Management Technician	Birds Assessment

Table B.2 continued. ***Report reviewers.***

Name	Affiliation and Position Title	Section(s) Reviewed or Other Role
Ethan Hammer	National Park Service Cedar Breaks National Monument, Resource Management Technician	Birds Assessment
Zachary Schierl	National Park Service Cedar Breaks National Monument, Education Specialist	Night Sky Assessment
Adrienne Fitzgerald	National Park Service Cedar Breaks National Monument, Interpretive Park Ranger	Night Sky Assessment
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, Night Sky 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
Jim Cheatham	National Park Service Air Resources Division, Policy, Planning, and Permit Review Branch, Environmental Protection Specialist	Air Quality Data
Tim Connors	National Park Service Geologic Resources Division, Geologist	Geology Assessment
Erik Beever	USGS Northern Rocky Mountain Science Center, Research Ecologist	Mammals Assessment
Amy Tendick	National Park Service Southeast Utah Group, Environmental Protection Specialist	Unique and Distinctive Vegetation Assessment
Doug Reynolds, Ph.D.	Professor Emeritus of Botany and Ecology	Unique and Distinctive Vegetation Assessment
Walter Fertig, Ph.D.	Washington Natural Heritage Program, State Botanist	Unique and Distinctive Vegetation Assessment
Jeff Conn	National Park Service Southwest Exotic Plant Management Team, Liason	Non-native Invasive Plants Assessment
Todd Chaudhry, Ph.D.	National Park Service- Intermountain Region Colorado Plateau Cooperative Ecosystem Studies Unit, Research Coordinator	Provided a cursory review of full report

Appendix C. Viewshed Analysis Steps

The process used to complete Cedar Breaks National Monument's 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"). ESRI (2016a) provides a useful overview of the visibility analysis.

Ran Viewshed Analysis using the Viewshed Tool in ESRI's ArcGIS 10.2, Spatial Analyst Toolbox, ran viewsheds using the following inputs.

- Input raster = 1/3 arc second NED
- Input point observer feature = obs_point.shp.

The rasters were reclassified into visible areas only to create the maps. The 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 park, reprojected into the Albers Equal Area Conic USGS projection, then used as the AOA for the NPS NPScape's housing, road, and conservation status tools as described in NPS 2014a,b,c. A text attribute field was added to the AOA for the area of analysis identifier.

Housing (CONUS, Density, SERGoM, 1970 - 2100, Metric Data (ESRI (2016) 9.3 File Geodatabase) (Theobald 2005), U.S. Census Bureau 2016a TIGER/Line Shapefiles: Roads) (U.S. Census Bureau 2016a), and conservation status (NPS 2014c, USGS GAP 2016) GIS datasets were downloaded from NPScape (NPS 2016i) and the USGS GAP (USGS GAP 2016) websites. Standard Operating Procedures for all three tools were followed based on NPScape instructions (NPS 2014a,b,c).

The following panoramic image was taken at Sunset Point Overlook in June 2017 but was not included in the viewshed analysis described in the assessment.

Figure C-1. The viewshed from Sunset Point Overlook in Cedar Breaks NM.

Appendix D. Geospatial Sound Model Maps

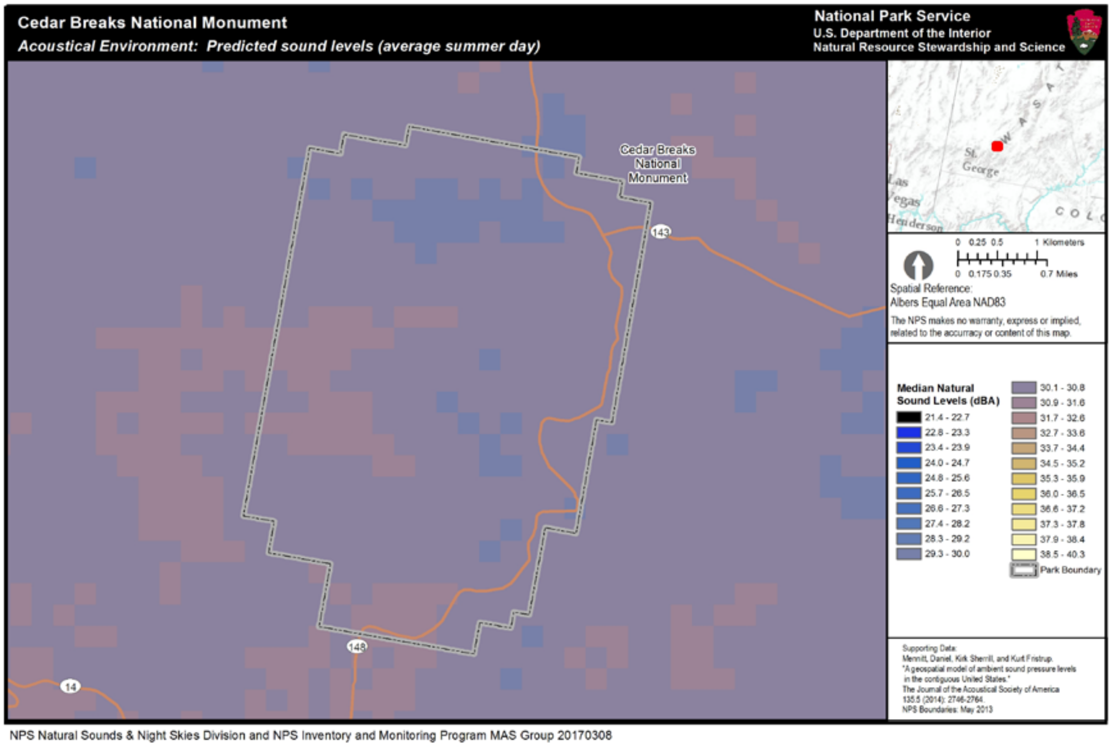

Figure D-1. **Natural CONUS soundscape model zoomed to Cedar Breaks NM. Figure Credit: NPS Natural Sounds and Night Skies Division.**

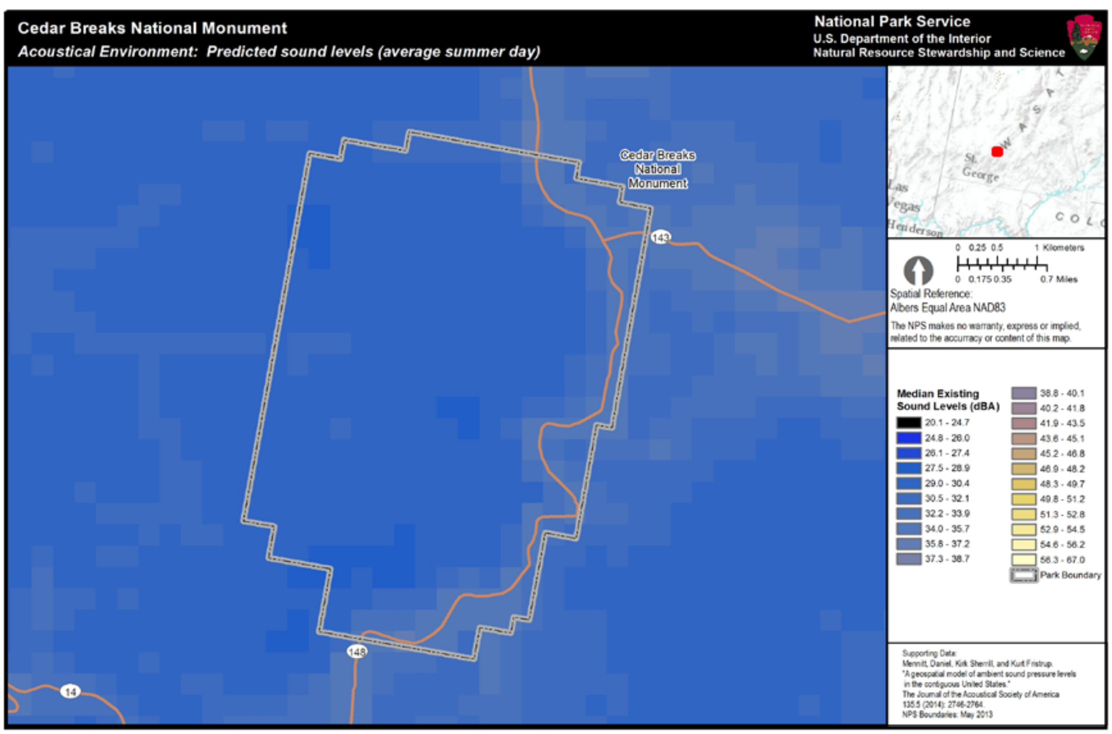

Figure D-2. **Existing CONUS soundscape model zoomed to Cedar Breaks NM. Figure Credit: NPS Natural Sounds and Night Skies Division.**

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 Cedar Breaks NM had a natural L_{50} dBA average of 30.4 (Figure D-1) and an existing L_{50} dBA average of 30.5(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 0.8 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. Upland Vegetation NDVI Results

The following figure shows trends in NDVI (Normalized Difference Vegetation Index) anomaly from 2000 to 2016 for the five forest types analyzed at Cedar Breaks National Monument (see the Uplands Vegetation assessment for a description of methods). NDVI anomaly is the difference from the long-term average where the average value is scaled to zero. Only quaking aspen (*Populus tremuloides*) forest and subalpine fir-Engelmann spruce (*Abies lasiocarpa-Picea engelmannii*) forest complex showed significant ($p < 0.10$) and positive trends over time.

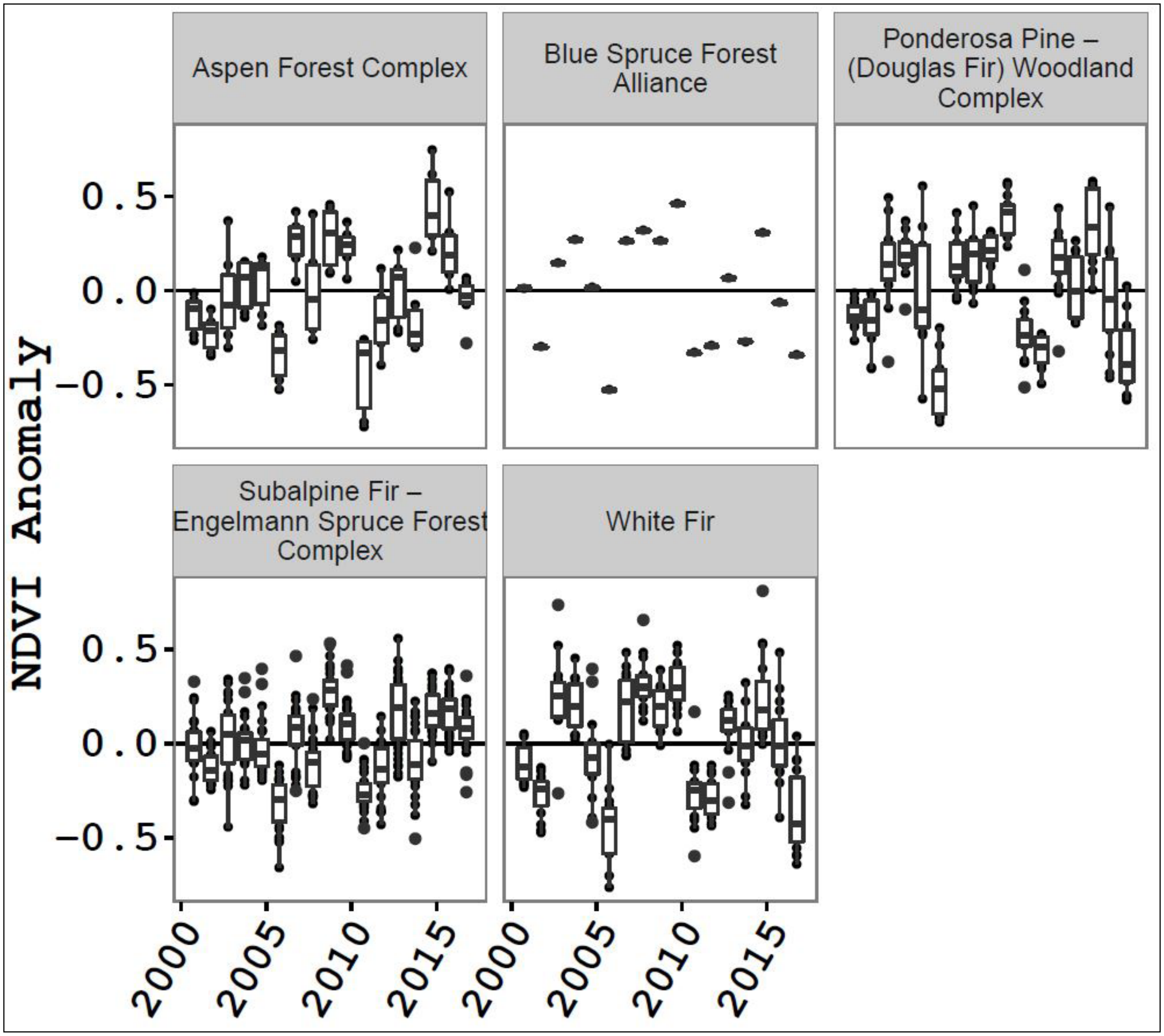

Figure E-1. Anomaly trends for five forest types. All trends shown are statistically significant (p < 0.10).

Appendix F. 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. The information presented here supports the Data and Methods section of the birds assessment. This appendix contains some of the same, but additional, information as that section of the report.

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 Cedar Breaks 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) (North American Bird Conservation Initiative 2016). 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.

F.1. 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 2016a). 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 2016a). 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.

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 2008). 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.

Utah Division of Wildlife Resources

The Utah Division of Wildlife Resources (UDWR) prepared and maintains the Utah Sensitive Species List for vertebrate and invertebrate species. The list includes species for which a State conservation agreement exists, wildlife species of concern, and species that are federally listed and candidates for federal listing (UDWR 2015). Wildlife species of concern are species for which there is scientific evidence substantiating a threat to their continued population viability (UDWR 2015). The idea behind the designation is that timely conservation actions taken for each species will avoid the need to list them under the federal ESA in the future.

Appendix G. Cedar Breaks NM Bird List

Listed in the table below are the bird species that are considered present, probably present, and unconfirmed in Cedar Breaks National Monument (NM) according to the current NPSpecies list for the park (NPS 2017a). The last column of the table indicates into which category (i.e., present, probably present, unconfirmed) each species falls. The third column indicates which species were recorded during the 2001-2003 U.S. Geological Survey / Northern Colorado Plateau Network surveys in the national monument (Johnson et al. 2003). Recent observations made by Manrodt et al. (2015) in July 2015, and cumulative observations from multiple observers obtained from eBird (2017), are also included in the table, although e-Bird observations recorded by Ormond only were used in the condition assessment. The eBird observations span 1991-April 2017 (according to "last seen" date), the majority of the listings (84% of them) are from the last 10 years (with 66% from the last four years). Only the Johnson et al. (2003) survey results were obtained using standardized bird sampling methods. Note that the Johnson et al. (2003) surveys were conducted primarily during the breeding season, but the eBird and NPSpecies (NPS 2017a) listings include birds recorded outside of the breeding season. A total of 147 species are contained in the table. Of these, 121 species occur on the current NPSpecies list (NPS 2017); this number includes those noted as present, probably present, and unconfirmed. Of the species in the table, a total of 60 were recorded during the 2001-2003 surveys of Johnson et al. (2003). One hundred and twenty-eight species appear on the eBird list, including some not listed by NPS (2017a). All of the species observed by Manrodt et al. (2015) were on the NPSpecies (NPS 2017a) list. The 71 species used to assess current condition at Cedar Breaks NM were compared to the USFWS' Migratory Bird Treaty Act list. Only one of the species, dusky grouse (*Dendragapus obscurus*) was not on the list.

Table G-1. Bird species list for Cedar Breaks NM.

Common Name	Scientific Name	Johnson et al. (2003)	Manrodt et al. (2015)	eBird (2017)	NPSPecies (NPS 2017a)	Used in assessment
American coot	*Fulica americana*	–	–	X	–	–
American crow	*Corvus brachyrhynchos*	–	–	X	Unconfirmed	–
American dipper	*Cinclus mexicanus*	X	–	X	Present	X
American goldfinch	*Spinus tristis*	–	–	–	Present	X
American kestrel	*Falco sparverius*	–	–	X	Probably Present	–
American pipit	*Anthus rubescens*	–	–	X	Probably Present	–
American robin	*Turdus migratorius*	X	X	X	Present	X
American three-toed woodpecker	*Picoides dorsalis*	X	–	X	Present	X
American white pelican	*Pelecanus erythrorhynchos*	–	–	X	–	–
Bald eagle	*Haliaeetus leucocephalus*	–	–	X	Probably Present	–
Band-tailed pigeon	*Patagioenas fasciata*	–	–	–	Probably Present	–
Bank Swallow	*Riparia riparia*	–	–	X	–	–
Barn swallow	*Hirundo rustica*	–	–	–	Probably Present	–
Black phoebe	*Sayornis nigricans*	–	–	–	Probably Present	–
Black rosy-finch	*Leucosticte atrata*	–	–	–	Probably Present	–
Black-billed magpie	*Pica hudsonia*	–	–	X	–	–
Black-capped chickadee	*Poecile atricapillus*	X	–	X	Present	X

[1] The genus name shown is current in accordance with the 57th AOU (American Ornithologist's Union) Supplement (dated 2016). The genus name shown in the NPSpecies list (NPS 2017a) was out of date. This species was listed in Johnson et al. (2003) Appendix 1 for Cedar Breaks NM but not listed in the park-specific summary so was recorded as detected during the survey in this list.

[2] Species is non-native.

[3] This species was listed in Johnson et al. (2003) summary for Cedar Breaks NM but not listed in the Appendix 1. It was recorded as detected during the survey in this list and in the birds condition assessment.

[4] The eBird list obtained on 17 April 2017 contained a total of 128 species, 102 of which were on the NPSpecies list (NPS 2017a).

[5] There are a total of 121 species on the NPSpecies list; 69 are "present," 38 are "probably present," and 14 are "unconfirmed" on the list.

Table G-1 continued. Bird species list for Cedar Breaks NM.

Common Name	Scientific Name	Johnson et al. (2003)	Manrodt et al. (2015)	eBird (2017)	NPSPecies (NPS 2017a)	Used in assessment
Black-chinned hummingbird	*Archilochus alexandri*	X	–	X	Present	X
Black-crowned night-heron	*Nycticorax nycticorax*	–	–	X	–	–
Black-headed grosbeak	*Pheucticus melanocephalus*	–	–	X	Probably Present	–
Black-throated gray warbler	*Dendroica nigrescens*	X	–	X	Present	X
Black-throated sparrow	*Amphispiza bilineata*	–	–	X	–	–
Blue-gray gnatcatcher	*Polioptila caerulea*	–	–	–	Unconfirmed	–
Brewer's blackbird	*Euphagus cyanocephalus*	–	–	X	Probably Present	–
Brewer's sparrow	*Spizella breweri*	–	–	X	–	–
Broad-tailed hummingbird	*Selasphorus platycercus*	X	X	X	Present	X
Brown creeper	*Certhia americana*	X	X	X	Present	X
Brown-headed cowbird	*Molothrus ater*	–	–	–	Unconfirmed	–
Bullock's oriole	*Icterus bullockii*	–	–	X	Probably Present	–
Bushtit	*Psaltriparus minimus*	–	–	X	Unconfirmed	–
California condor	*Gymnogyps californianus*	–	–	X	Present	X
Calliope hummingbird	*Selasphorus calliope*	–	–	X	–	–
Canada goose	*Branta canadensis*	–	–	X	–	–
Canyon wren	*Catherpes mexicanus*	–	–	–	Probably Present	–
Cassin's finch	*Haemorhous cassinii* [1]	X	X	X	Present	X
Chipping sparrow	*Spizella passerina*	X	X	X	Present	X
Clark's nutcracker	*Nucifraga columbiana*	X	X	X	Present	X
Cliff swallow	*Petrochelidon pyrrhonota*	X	–	X	Present	X
Common nighthawk	*Chordeiles minor*	–	–	–	Probably Present	–
Common poorwill	*Phalaenoptilus nuttallii*	–	–	X	Unconfirmed	–
Common raven	*Corvus corax*	X	–	X	Present	X
Cooper's hawk	*Accipiter cooperii*	–	–	X	Probably Present	–
Cordilleran flycatcher	*Empidonax occidentalis*	X	–	X	Present	X
Dark-eyed junco	*Junco hyemalis*	X	X	X	Present	X
Downy woodpecker	*Picoides pubescens*	–	–	X	Present	X
Dusky flycatcher	*Empidonax oberholseri*	X	X	X	Present	X
Dusky (Blue) grouse	*Dendragapus obscurus*	–	–	X	Present	X
Eurasian collared-dove	*Streptopelia decaocto* [2]	–	–	X	–	–
European starling	*Sturnus vulgaris* [2]	–	–	X	Unconfirmed	–
Evening grosbeak	*Coccothraustes vespertinus*	X	–	X	Present	X
Ferruginous hawk	*Buteo regalis*	–	–	–	Probably Present	–
Flammulated owl	*Psiloscops flammeolus* [1]	–	–	–	Unconfirmed	–
Fox sparrow	*Passerella iliaca*	–	–	X	Probably Present	–
Franklin's gull	*Leucophaeus pipixcan*	–	–	X	–	–
Gadwall	*Anas strepera*	–	–	X	–	–

[1] The genus name shown is current in accordance with the 57th AOU (American Ornithologist's Union) Supplement (dated 2016). The genus name shown in the NPSpecies list (NPS 2017a) was out of date. This species was listed in Johnson et al. (2003) Appendix 1 for Cedar Breaks NM but not listed in the park-specific summary so was recorded as detected during the survey in this list.

[2] Species is non-native.

[3] This species was listed in Johnson et al. (2003) summary for Cedar Breaks NM but not listed in the Appendix 1. It was recorded as detected during the survey in this list and in the birds condition assessment.

[4] The eBird list obtained on 17 April 2017 contained a total of 128 species, 102 of which were on the NPSpecies list (NPS 2017a).

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Table G-1 continued. Bird species list for Cedar Breaks NM.

Common Name	Scientific Name	Johnson et al. (2003)	Manrodt et al. (2015)	eBird (2017)	NPSPecies (NPS 2017a)	Used in assessment
Golden eagle	*Aquila chrysaetos*	X	–	X	Present	X
Golden-crowned kinglet	*Regulus satrapa*	–	–	X	Probably Present	–
Grace's warbler	*Setophaga graciae* [1]	–	–	X	Probably Present	–
Gray flycatcher	*Empidonax wrightii*	–	–	X	Unconfirmed	–
Gray jay	*Perisoreus canadensis*	–	–	X	Present	X
Gray-crowned rosy-finch	*Leucosticte tephrocotis*	–	–	–	Probably Present	–
Great horned owl	*Bubo virginianus* [3]	X	–	–	Present	X
Green-tailed towhee	*Pipilo chlorurus*	–	–	X	Probably Present	–
Green-winged teal	*Anas crecca*	–	–	X	–	–
Hairy woodpecker	*Picoides villosus*	X	X	X	Present	X
Hammond's flycatcher	*Empidonax hammondii*	X	–	–	Present	X
Hermit thrush	*Catharus guttatus*	X	–	X	Present	X
Hermit warbler	*Setophaga occidentalis*	–	–	X	–	–
Horned lark	*Eremophila alpestris*	–	–	X	Probably Present	–
House finch	*Haemorhous mexicanus* [1]	–	–	X	Present	X
House wren	*Troglodytes aedon*	X	–	X	Present	X
Juniper titmouse	*Baeolophus ridgwayi*	–	–	X	Present	X
Killdeer	*Charadrius vociferus*	–	–	X	Probably Present	–
Lazuli bunting	*Passerina amoena*	–	–	–	Probably Present	–
Lesser goldfinch	*Spinus psaltria* [1]	–	–	X	Unconfirmed	–
Lesser scaup	*Aythya affinis*	–	–	X	–	–
Lewis's woodpecker	*Melanerpes lewis*	–	–	X	Present	X
Lincoln's sparrow	*Melospiza lincolnii*	X	X	X	Present	X
Loggerhead shrike	*Lanius ludovicianus*	–	–	X	–	–
Long-eared owl	*Asio otus*	–	–	–	Unconfirmed	–
MacGillivray's warbler	*Geothlypis tolmiei* [1]	X	X	X	Present	X
Mallard	*Anas platyrhynchos*	–	–	X	Unconfirmed	–
Merlin	*Falco columbarius*	–	–	X	Probably Present	–
Mountain bluebird	*Sialia currucoides*	X	–	X	Present	X
Mountain chickadee	*Poecile gambeli*	X	X	X	Present	X
Mourning dove	*Zenaida macroura*	–	–	X	Probably Present	–
Nashville warbler	*Oreothlypis ruficapilla* [1]	X	–	X	Present	X
Northern flicker	*Colaptes auratus*	X	X	X	Present	X
Northern goshawk	*Accipiter gentilis*	–	–	X	Probably Present	–
Northern harrier	*Circus cyaneus*	–	–	X	–	–
Northern pygmy-owl	*Glaucidium gnoma*	X	–	X	Present	X
Northern rough-winged swallow	*Stelgidopteryx serripennis*	X	–	–	Present	X

[1] The genus name shown is current in accordance with the 57th AOU (American Ornithologist's Union) Supplement (dated 2016). The genus name shown in the NPSpecies list (NPS 2017a) was out of date. This species was listed in Johnson et al. (2003) Appendix 1 for Cedar Breaks NM but not listed in the park-specific summary so was recorded as detected during the survey in this list.

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Table G-1 continued. Bird species list for Cedar Breaks NM.

Common Name	Scientific Name	Johnson et al. (2003)	Manrodt et al. (2015)	eBird (2017)	NPSPecies (NPS 2017a)	Used in assessment
Northern saw-whet owl	*Aegolius acadicus*	–	–	–	Probably Present	–
Northern shrike	*Lanius excubitor*	–	–	–	Probably Present	–
Olive-sided flycatcher	*Contopus cooperi*	X	–	X	Present	X
Orange-crowned warbler	*Vermivora celata*	–	X	X	Probably Present	–
Osprey	*Pandion haliaetus*	–	–	X	–	–
Peregrine falcon	*Falco peregrinus*	X	–	X	Present	X
Pine grosbeak	*Pinicola enucleator*	–	–	X	Probably Present	–
Pine siskin	*Spinus pinus* [1]	X	X	X	Present	X
Pinyon jay	*Gymnorhinus cyanocephalus*	X	–	X	Present	X
Plumbeous vireo	*Vireo plumbeus*	X	–	X	Present	X
Prairie falcon	*Falco mexicanus*	X	–	X	Present	X
Pygmy nuthatch	*Sitta pygmaea*	X	X	X	Present	X
Red crossbill	*Loxia curvirostra*	X	–	X	Present	X
Red-breasted nuthatch	*Sitta canadensis*	X	X	X	Present	X
Red-breasted merganser	*Mergus serrator*	–	–	X	–	–
Red-naped sapsucker	*Sphyrapicus nuchalis*	–	–	X	Present	X
Red-tailed hawk	*Buteo jamaicensis*	X	–	X	Present	X
Red-winged blackbird	*Agelaius phoeniceus*	–	–	X	–	–
Ring-necked duck	*Aythya collaris*	–	–	X	–	–
Rock wren	*Salpinctes obsoletus*	X	–	X	Present	X
Ruby-crowned kinglet	*Regulus calendula*	X	X	X	Present	X
Rufous hummingbird	*Selasphorus rufus*	X	X	X	Present	X
Sage thrasher	*Oreoscoptes montanus*	–	–	X	–	–
Savannah sparrow	*Passerculus sandwichensis*	–	–	X	–	–
Say’s phoebe	*Sayornis saya*	–	–	X	–	–
Sharp-shinned hawk	*Accipiter striatus*	–	–	X	Unconfirmed	–
Song sparrow	*Melospiza melodia*	–	–	X	Unconfirmed	–
Spotted sandpiper	*Actitis macularius*	X	–	X	Present	X
Spotted towhee	*Pipilo maculatus*	X	–	X	Present	X
Steller's jay	*Cyanocitta stelleri*	X	–	X	Present	X
Swainson's hawk	*Buteo swainsoni*	–	–	X	Probably Present	–
Swainson's thrush	*Catharus ustulatus*	–	–	X	Probably Present	–
Townsend's solitaire	*Myadestes townsendi*	–	–	X	Present	X
Townsend's warbler	*Setophaga townsendi* [1]	–	–	X	Present	X
Tree swallow	*Tachycineta bicolor*	–	–	X	Probably Present	–
Turkey vulture	*Cathartes aura*	–	–	X	Probably Present	–
Vesper sparrow	*Pooecetes gramineus*	X	–	X	Present	X

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Table G-1 continued. Bird species list for Cedar Breaks NM.

Common Name	Scientific Name	Johnson et al. (2003)	Manrodt et al. (2015)	eBird (2017)	NPSPecies (NPS 2017a)	Used in assessment
Violet-green swallow	*Tachycineta thalassina*	X	X	X	Present	X
Virginia's warbler	*Oreothlypis virginiae* [1]	X	–	X	Probably Present	X
Warbling vireo	*Vireo gilvus*	X	X	X	Present	X
Western bluebird	*Sialia mexicana*	X	–	X	Present	X
Western kingbird	*Tyrannus verticalis*	–	–	X	Probably Present	–
Western meadowlark	*Sturnella neglecta*	–	–	X	Probably Present	–
Western tanager	*Piranga ludoviciana*	X	X	X	Present	X
Western wood-pewee	*Contopus sordidulus*	X	X	X	Present	X
White-breasted nuthatch	*Sitta carolinensis*	X	X	X	Present	X
White-crowned sparrow	*Zonotrichia leucophrys*	X	X	X	Present	X
White-throated swift	*Aeronautes saxatalis*	X	–	X	Present	X
Wild turkey	*Meleagris gallopavo*	–	–	X	Probably Present	–
Williamson's sapsucker	*Sphyrapicus thyroideus*	–	–	X	Unconfirmed	–
Wilson's warbler	*Cardellina pusilla* [1]	–	–	X	Probably Present	–
Woodhouse's scrub-jay	*Aphelocoma woodhouseii*	–	–	X	–	–
Yellow warbler	*Setophaga petechia* [1]	X	–	X	Present	X
Yellow-breasted chat	*Icteria virens*	–	–	X	–	–
Yellow-rumped warbler	*Setophaga coronata* [1]	X	X	X	Present	X
TOTAL NUMBER	147 species	60	27	128 [4]	121 (69, 38, 14) [5]	71

[1] The genus name shown is current in accordance with the 57th AOU (American Ornithologist's Union) Supplement (dated 2016). The genus name shown in the NPSpecies list (NPS 2017a) was out of date. This species was listed in Johnson et al. (2003) Appendix 1 for Cedar Breaks NM but not listed in the park-specific summary so was recorded as detected during the survey in this list.

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The Department of the Interior protects and manages the nation’s natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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