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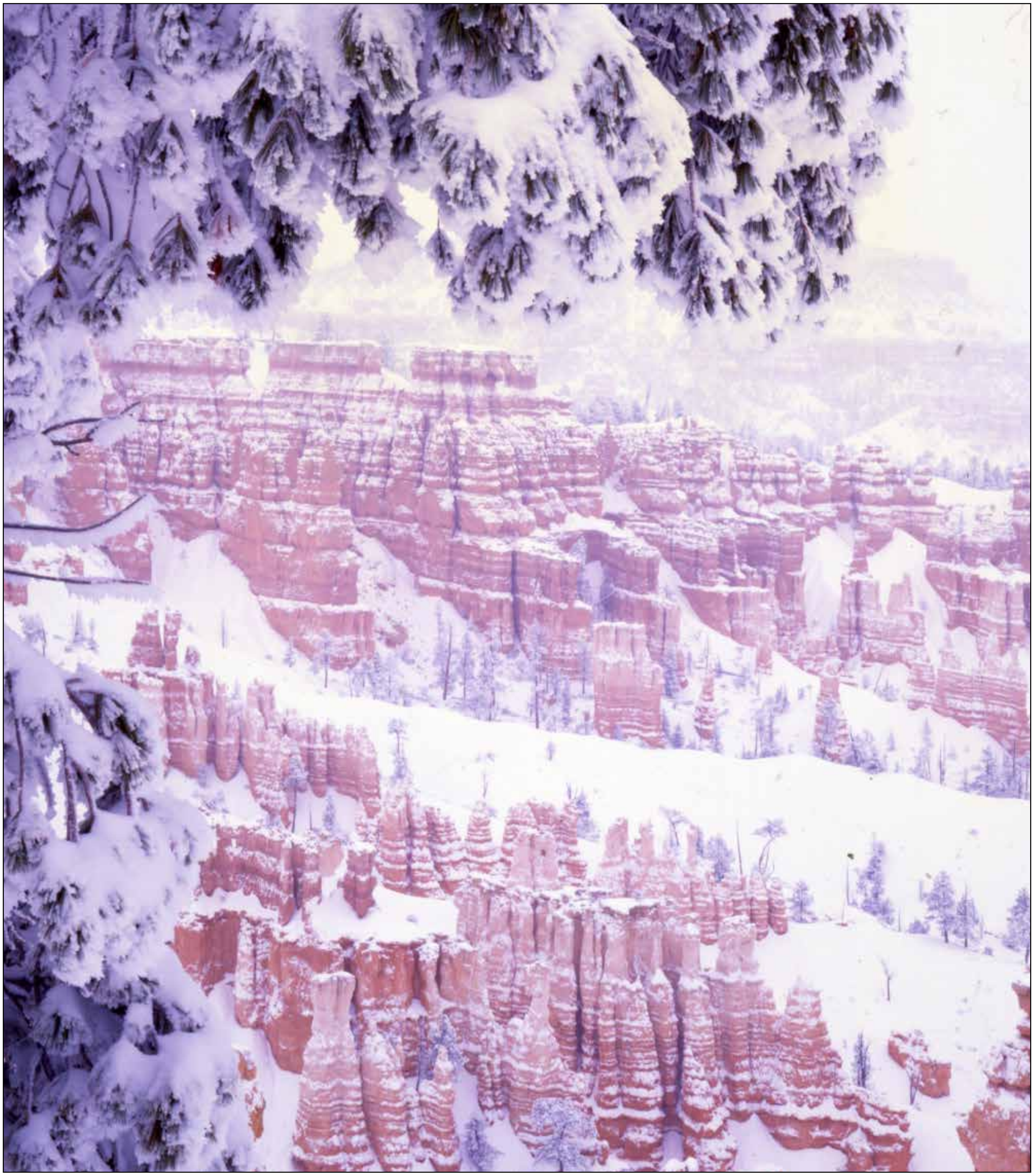
Bryce Canyon National Park

Natural Resource Condition Assessment

Natural Resource Report NPS/NCPN/NRR—2018/1690



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Snow covered hoodoos. Photo Credit: NPS

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Sheep Creek in Bryce Canyon National Park. Photo Credit: NPS NCPN

Bryce Canyon National Park

Natural Resource Condition Assessment

Natural Resource Report NPS/NCPN/NRR—2018/1690

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Executive Summary

The Natural Resource Condition Assessment (NRCA) Program, administered by the National Park Service's (NPS) Water Resources Division, provides a multidisciplinary synthesis of existing scientific data and knowledge about current conditions of important national park natural resources through the development of a park-specific report. The NRCA process for Bryce Canyon National Park (NP) began with a meeting that was held on April 6, 2017 with staff from the park, NPS Intermountain Region Office, NPS Northern Colorado Plateau Inventory and Monitoring Network (NCPN), and Utah State University.

Bryce Canyon NP was established in 1923 as a national monument then later named a national park in 1928 (NPS 2014a). Its purpose is to "protect and conserve resources integral to a landscape of unusual scenic beauty exemplified by highly colored and fantastically eroded geological features, including rock fins and spires, for the benefit and enjoyment of the people" (NPS 2014a). Eleven of the park'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 a subset of the park's wildlife and vegetation resources.

The park's viewshed, night sky, water quality, and wildlife topics, birds and Utah prairie dog (*Cynomys parvidens*), were considered to be in good condition. Air quality, upland vegetation, and non-native invasive plants were of moderate concern. And while none of the resources were rated as of significant concern exclusively, conditions for the park's soundscape, geology, and unique vegetation were of moderate to significant concern.

Like many other national parks, resources at Bryce Canyon NP face many threats, such as increasing temperatures due to climate change, ever-increasing visitation to the park, conflicting management mandates between resources and human health safety, etc. Fostering effective partnerships will become even more important in maintaining or influencing the park's natural resource conditions and identifying necessary adaptations in a rapidly changing environment.

Acknowledgements

We thank Bryce Canyon NP and NCPN staffs for assistance in providing data; establishing indicators, measures, and reference conditions; and for reviewing drafts of the assessments and chapters. NCPN's inventory and monitoring data for the upland vegetation, non-native invasive plants, water quality, and birds informed conditions for the park's resources.

Phyllis Pineda-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 Bryce Canyon NP's NRCA report.

Bryce 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).


Sunrise at Bryce Point, Bryce Canyon NP. Photo Credit: © Brian B. Roanhorse.

Chapter 2. Introduction and Resource Setting

2.1. Introduction

2.1.1. Enabling Legislation/Executive Orders

Bryce Canyon National Park (NP) was established in 1923 as a national monument then later named a national park in 1928 (NPS 2014a). Its purpose is to "protect and conserve resources integral to a landscape of unusual scenic beauty exemplified by highly colored and fantastically eroded geological features, including rock fins and spires, for the benefit and enjoyment of the people" (NPS 2014a). The park's unique resources and values are further described in its five significance statements as follows (text excerpted from NPS (2014a)):

1. Bryce Canyon National Park showcases one of the largest and most colorful concentrations of erosional geologic features in the world, including hoodoos, fins, windows, fluted cliffs, bridges, arches, and grottoes. This unusual landscape within the Claron Formation is created by a unique combination of natural processes, location, rock properties, and climate.

2. The location of the park at the summit of the Grand Staircase, surrounded by a system of nationally protected lands, and combined with the exceptional clarity of the air and natural quiet, provides a multisensory experience. The outstanding views often extend more than 100 miles and begin with the colorful and intricately carved Claron Formation and include panoramic vistas of cliffs, canyons, and forested landscapes.

3. With a nearly pristine night sky, thousands of stars shine brightly at Bryce Canyon National Park. As one of the darkest publicly accessible places in North America, the Milky Way Galaxy can be viewed from horizon to horizon. The clear, clean air and a lack of artificial light in the park and the region are essential to this unparalleled nighttime experience. The darkness is also an important resource for nocturnal wildlife.

4. Cultural resources encompassing thousands of years of human use and

experience are found throughout Bryce Canyon National Park. These resources are important to the identity of indigenous people of the Colorado Plateau and the living descendants of 19th-century pioneers. In addition, many of the historical resources of the park are associated with the emergence of tourism in the early 20th century, and are linked to the regional development of other "Grand Circle" national parks.

5. Bryce Canyon National Park is a scientist's laboratory. Its geophysical setting, range in elevation through three climatic zones, and dynamic terrain provide for study of diverse biological and physical processes and resources important to the understanding and management of Colorado Plateau environments of the past, present, and future.

Additional fundamental and other important resources and values are identified for the park in its Foundation Document (NPS 2014a), which further expand on the themes related to its purpose and significance statements.

2.1.2. Geographic Setting

Bryce Canyon NP is located in southwest Utah (Figure 2.1.2-1), approximately 129 km (80 mi) northeast of Cedar City, Utah, with its northern portion located in Garfield County and its southern portion in Kane County. The park preserves a 14,502 ha (35,835 ac) area that is surrounded by the Dixie National Forest (NF) and Bureau of Land Management (BLM) managed lands (NPS 2014a; Figure 2.1.2-2a,b). Forty-six percent of Bryce Canyon NP was recommended for wilderness in 1975 (NPS 2014a). Designated wilderness areas are afforded the highest level of protection from resource extraction and development, providing additional protection for the park's resources.

<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, 2017, the population estimate for Kane County was 7,567 and 5,078 in Garfield County. The population percent change from April 1, 2010 to July 1, 2017 represents an increase of 6.2% in Kane County and a population decrease of 1.8% in Garfield County (U.S. Census Bureau no date).

<u>Climate</u>

There are four weather stations at Bryce Canyon NP: a Remote Automated Weather Station (RAWS) at 2,394 m (7,854 ft) 2003-2018 and National Weather Service Cooperative Observer (COOP) Network station ID: 421008 at 2,413 m (7,916 ft) from 1959-2018 in the northern portion of the park, and a Natural Resources Conservation Service (NRCS) Snow-Telemetry (SNOTEL) station at 3,033 m (9,950 ft) from 1994-2018 and RAWS station at 2,710 m (8,891 ft) from 1990-1996 and 1998-2018 (Climate Analyzer 2018) in the southern portion of the park. The COOP station's long-term (1959-2017) temperature and precipitation graphs are shown in Figures 2.1.2-3 and 2.1.2-4. The average daily minimum temperatures are steadily rising, and annual precipitation averages 381 mm (15 in), with an average annual snowfall of 254 cm (100 in) at park headquarters (NPS NCPN 2016a).

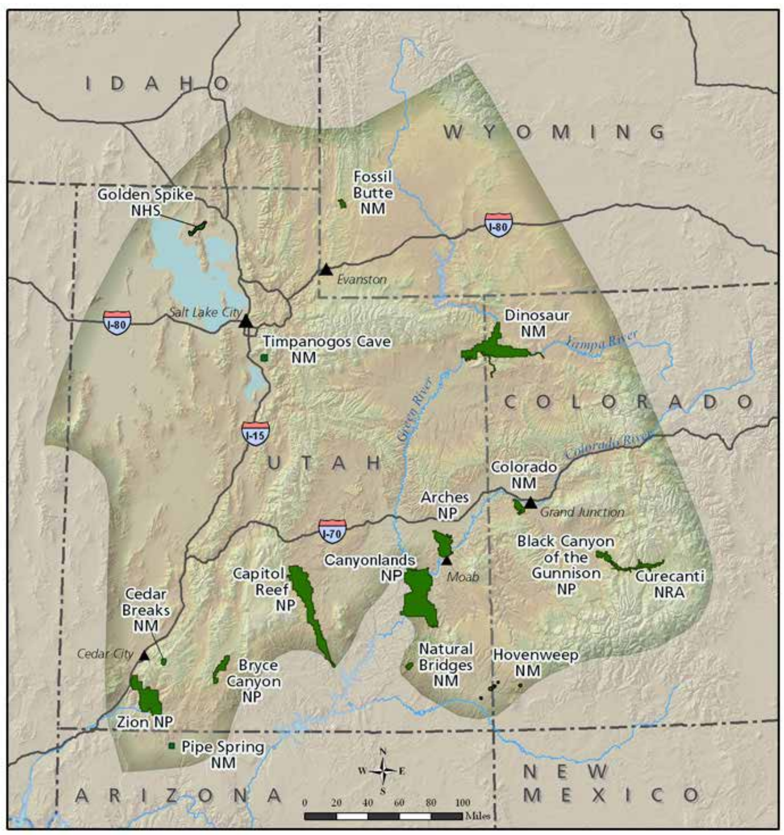


Figure 2.1.2-1. Bryce Canyon NP is located in southwest Utah and is one of 16 park units within the NPS Northern Colorado Plateau Inventory and Monitoring Network. Figure Credit: NPS NCPN.

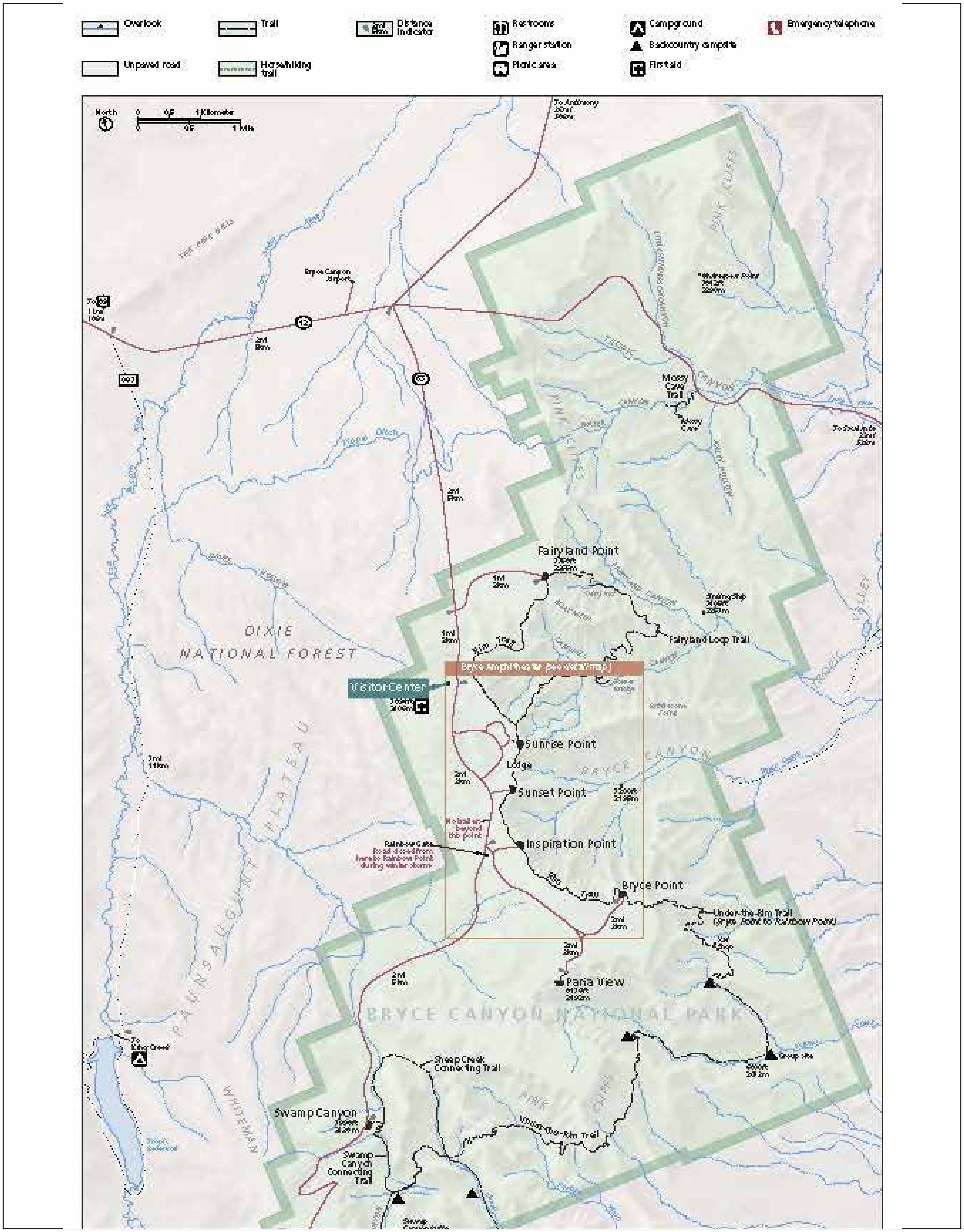


Figure 2.1.2-2a. Northern portion of Bryce Canyon NP. Figure Credit: NPS.

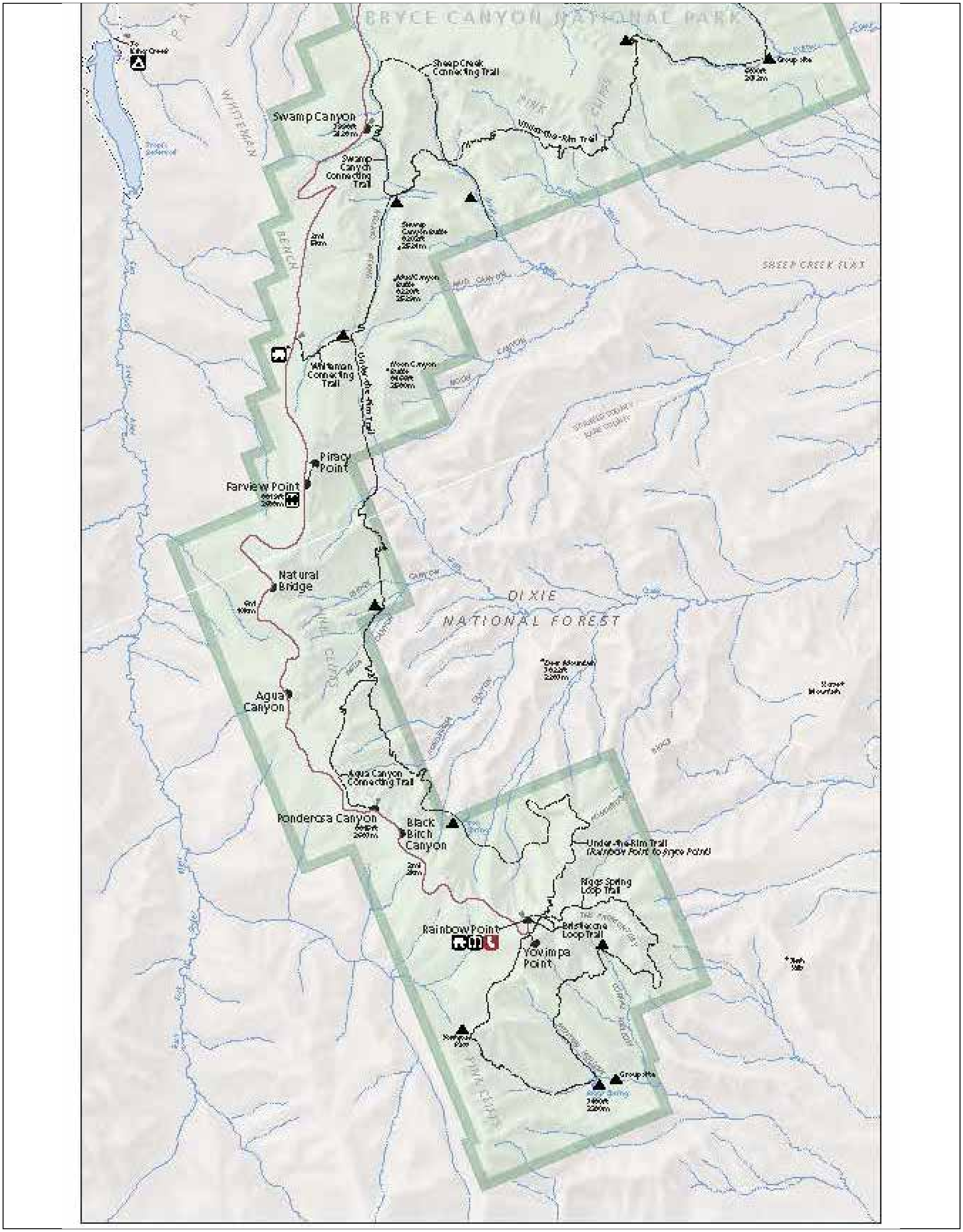


Figure 2.1.2-2b. Southern portion of Bryce Canyon NP. Figure Credit: NPS.

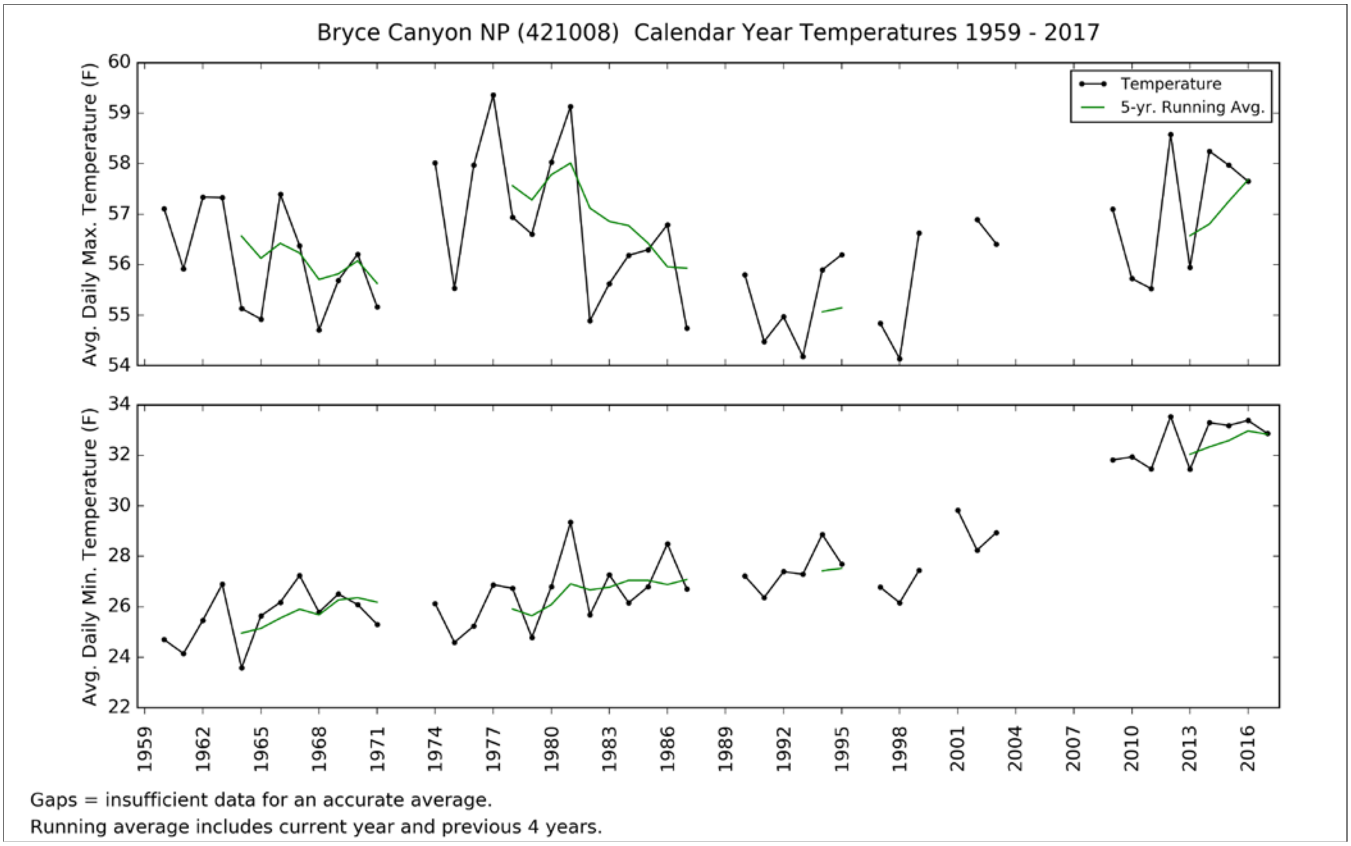


Figure 2.1.2-3. Average daily temperatures (1959-2017) at COOP station 421008. Figure Credit: Climate Analyzer 2018.

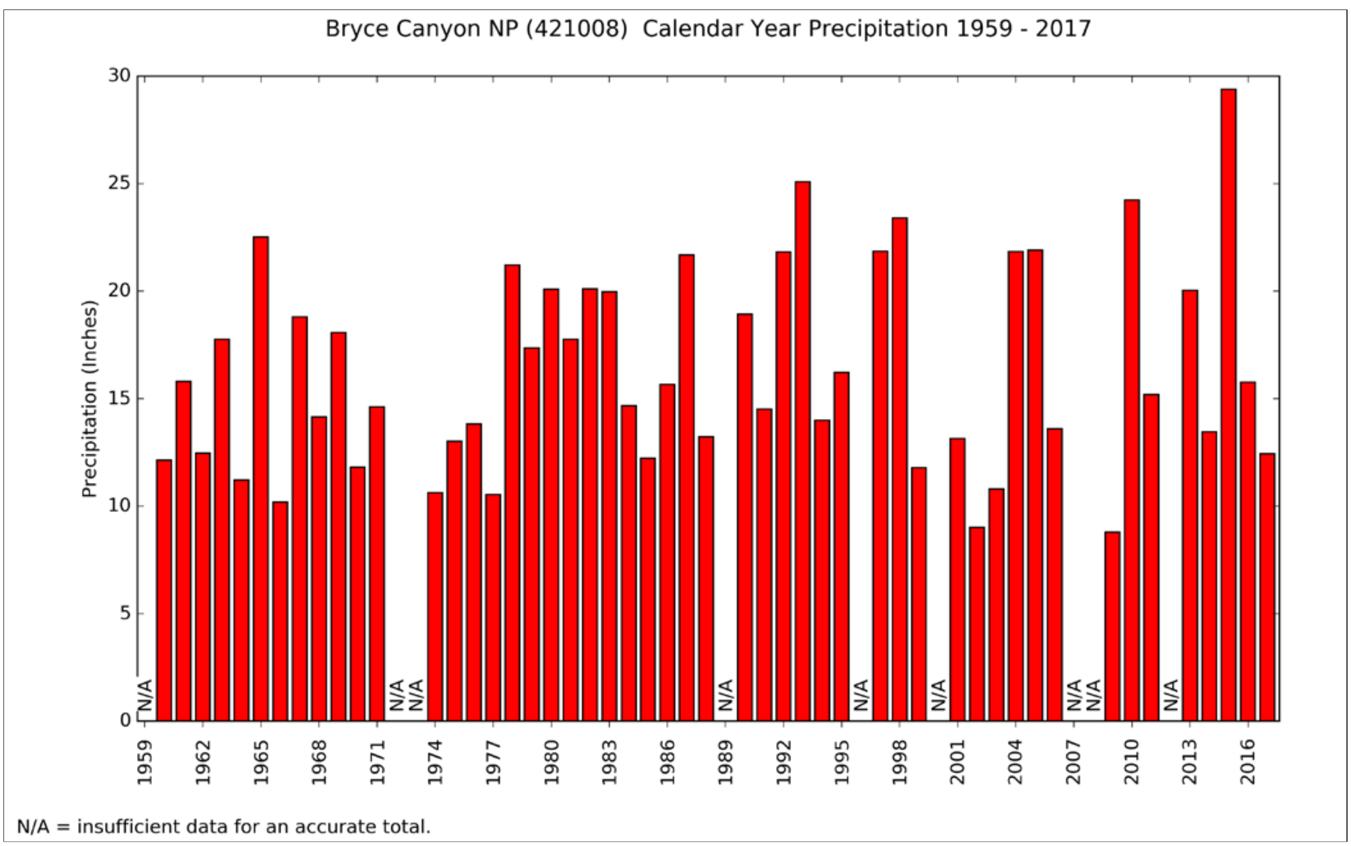


Figure 2.1.2-4. Calendar year precipitation totals (1959-2017) at COOP station 421008. Figure Credit: Climate Analyzer 2018.

2.1.3. Visitation Statistics

Visitation data for Bryce Canyon NP are available from 1929-2017 (NPS Public Use Statistics Office 2018). The total number of visitors each year has been steadily increasing, with the highest number of visitors, 2,571,684, occurring in 2017 (Figure 2.1.3-1). The months with the highest average number of visitors between 1979-2017 were June-September (NPS Public Use Statistics Office 2018).

2.2. Natural Resources

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

Ecological Units

Bryce Canyon NP is located in the Utah High Plateaus and Mountains Section within the Northern Colorado Plateau Inventory and Monitoring Network (NCPN). The park is situated along the eastern rim of Paunsaugunt Plateau and its elevation ranges from approximately 1,859 m (6,100 ft) in the eastern lowlands, 2,438 m (8,000 ft) at headquarters, and 2,774 m (9,100 ft) at the park's southern end. (Evenden et al. 2002).

Watershed Units

Bryce Canyon NP is located within 13 different watersheds, with Bryce Creek, Yellow Creek, Upper Sheep Creek, and Mud Spring Creek-East Fork Sevier River watersheds accounting for the majority of watershed area in the park (U.S. Geological Survey [USGS 2014], Figure 2.2.1-1).

NPScape Landscape-scale

Most of Bryce Canyon NP's natural resources (e.g., viewshed, night sky, soundscape, geology, water quality, 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 park. 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

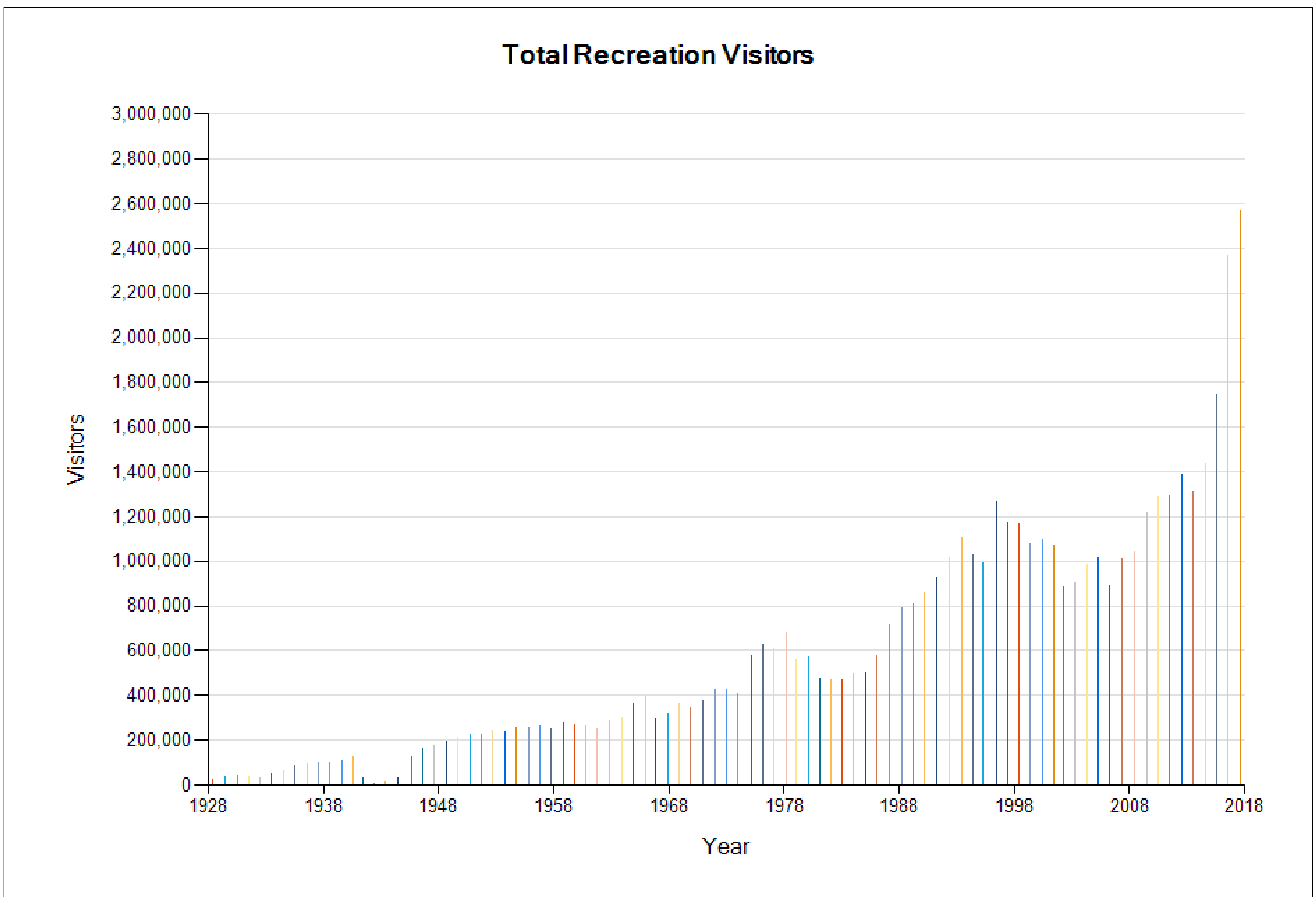


Figure 2.1.3-1. Total number of annual visitors to Bryce Canyon NP from 1929-2017. Figure Credit: NPS Public Use Statistics Office 2018.

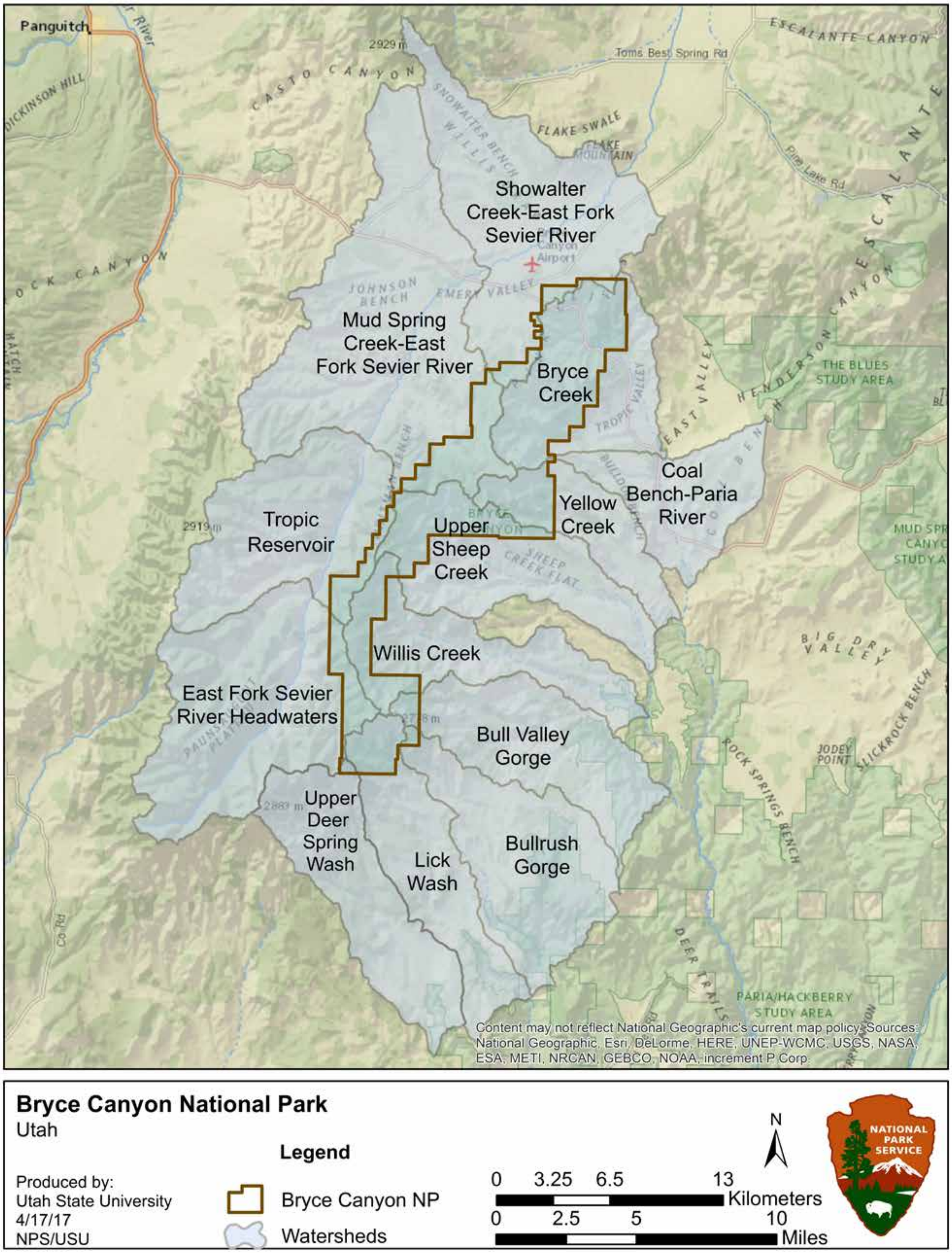


Figure 2.2.1-1. Bryce Canyon NP is located in 13 watersheds.

enough to encompass self-contained ecosystems for the resources found within their boundaries. When feasible, landscape-scale indicators and measures were included in the park's condition assessments to provide an ecologically relevant, landscape-scale context for reporting resource conditions. NPS NPScape metrics were used to report on the landscape-scale measures, providing a framework for conceptualizing human effects (e.g., housing densities, road densities, etc.) on landscapes surrounding the park (NPS 2014b,c).

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. In Senate Report No. 294, Secretary of the Interior, Hubert Work, described Bryce Canyon as "one of the three outstanding scenic exhibits of southwestern Utah..." (as cited in NPS 1980). Bryce Canyon NP offers outstanding scenic views to its visitors with many developed and accessible overlooks. Most of the surrounding landscape is undeveloped, with the Dixie NF and BLM helping to maintain the views in a primarily natural state.

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 resource conditions (Moore et al. 2013). Maintaining a dark night sky was identified in Bryce Canyon National Park's (NP) Foundation Document as fundamental to protecting the wilderness setting and biodiversity of the park (NPS 2014a) and is one of the best places on the Colorado Plateau to experience dark night skies. To protect and further promote dark night skies in the park, NPS staff are applying for Dark Sky Park status from the International Dark Sky Association (NPS 2014a).

Soundscape

The natural soundscape at Bryce Canyon NP is important to the park's natural resources and to the visitor experience. Bryce Canyon NP's backcountry and wilderness areas provide an increasingly rare opportunity for visitors to experience solitude and quiet. Several acoustical monitoring efforts have occurred at Bryce Canyon NP, including a park-initiated monitoring program. These efforts are summarized in the soundscape condition assessment.

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)). Bryce Canyon NP is designated as a Class I airshed, with visibility and wet deposition air quality monitoring stations located within the park. Bryce Canyon NP has a robust visibility monitoring dataset of day and nighttime images that record visual conditions and pollution (e.g., haze-inducing particles, nighttime light pollution, etc.). These monitoring efforts are summarized in the air quality condition assessment.

Geology and Water

Bryce Canyon NP was established in 1923 to preserve the distinctive geologic formations found in the breaks (NPS 2014a). 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. The same processes that created the breaks are at work today as unstable hoodoos.

Water is the primary erosive force responsible for these unusual geologic formations. With more than 200 days of frost per year, water seeping into cracks in the rock freezes and expands, exerting extreme pressure that splits apart rock. Chemical weathering from acidic rain and slope failures caused by intense rainstorms also sculpt the landscape (Thornberry-Ehrlich 2005).

The park is located on the divide between two major river drainages — the Paria River, which drains areas below the rim, and the East Fork of the Sevier River, which drains the Paunsaugunt Plateau above the rim (Thornberry-Ehrlich 2005). Only three perennial streams occur in the park: Yellow Creek, Willis Creek, and Sheep Creek (NPS 1996). All other streams flow intermittently or are ephemeral (NPS 1996). With an average of 2 m (8 ft) of snow annually (NPS 2014a), snowmelt is the principal source of groundwater recharge in the park (NPS 1996). Summer monsoonal rains also contribute to groundwater recharge but to a lesser extent (NPS 1996).

Vegetation

The park's plant communities have been broadly classified into three vegetation belts (Buchanan

1992 as cited in Tendick et al. 2011). From highest to lowest elevations the vegetation belts are as follows: mixed coniferous forests in the montane forest belt, ponderosa pine (*Pinus ponderosa*) woodlands interspersed with sagebrush shrublands (*Artemisia* spp.) in the submontane forest belt, and sparse woodlands in the lowest vegetation belt (Tendick et al. 2011). Sparse woodlands are further divided into pinyon pine-Utah juniper (*Pinus edulis-Juniperus osteosperma*) woodlands on mesic north-facing slopes and bristlecone pine (*Pinus longaeva*) woodlands on xeric south-facing slopes (Tendick et al. 2011).

The lowest vegetation belt is characterized by some of the harshest environmental conditions in the park—soils are poorly developed, erosion is rapid and continuous, and multiple freeze-thaw cycles occur during winter (Tendick et al. 2011) but supports many of the park's rare plants.

<u>Wildlife</u>

Inventories have been conducted throughout the national park to record the presence of birds, herpetofauna, and mammals. Birds and the Utah prairie dog (UPD) (*Cynomys parvidens*) were selected as condition assessment topics. A summary of the remaining mammals, including bats, and the park's amphibians and reptiles (herpetofauna) is provided in Appendix A.

Birds

Birds have been identified as an important vital sign of ecosystem health and a long-term monitoring program is administered by the NPS NCPN at Bryce Canyon NP (McLaren and White 2016). Over the span of 44 years, a total of 116 birds have been confirmed at Bryce Canyon NP. In addition to NCPN's monitoring program, Bryce Canyon NP staff have been monitoring the peregrine falcon (*Falco peregrinus*) as a species of management concern (Flower 2011). Areas within Bryce Canyon NP provide high quality nesting and foraging habitat for the peregrine (Burman 2016).

Mammals

A total of 55 mammal species has been confirmed at the park. House mouse (*Mus musculus)* is the only non-native species that has been recorded. An additional 20 species are either probably present or are unconfirmed (NPS 2017a). The UPD is the only federally threatened species at Bryce Canyon. The park's UPD recovery program includes annual spring colony counts, vegetation management within the park's meadow habitat, plague management, and traffic control efforts along roads that are adjacent to UPD colonies.

Bats

Fifteen bats (or 79% of Utah's comprehensive bat list) have been observed in Bryce Canyon NP, accounting for almost one quarter (22.4%) of the mammals in the park (NPS 2017a). Park staff routinely monitor bats, especially at the historic Bryce Lodge, where certain types of bat species, particularly little brown myotis (*Myotis lucifugus*), select roosts within old structures. Park staff have implemented a variety of actions to manage human-bat interactions within the park's historic structures.

Herpetofauna

During field work in 2001-2002, Platenberg and Graham (2003) conducted an inventory of Bryce Canyon NP's reptiles and amphibians. A total of 20 species is listed for the park, 12 of which are confirmed. All recorded species are native.

2.2.3. Resource Issues Overview

<u>Climate Change</u>

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 °C (34 °F) (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 Bryce Canyon NP. 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 Bryce Canyon NP were reported as follows:

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

Results for the temperature of each year between 1901-2012, the averaged temperatures over progressive 10-year intervals, and the average temperature of 2003-2012 (the most recent interval) are shown in Figure 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 park.

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). Monahan and Fisichelli (2014) state that "climate change will manifest itself not only as changes in average conditions, as summarized here, but also as changes in particular climate events (e.g., more intense storms, floods, or drought). Extreme climate events can cause widespread and fundamental shifts in conditions of park resources."

Other Threats

In 2017, Bryce Canyon NP received the highest number of annual visitors on record, with more than 2.5 million (NPS Public Use Statistics Office 2018). While the majority of visitors are concentrated along road corridors, at pullouts, visitor centers, and interpretive exhibits rather than dispersed across the backcountry, off-trail travel is a concern in some areas (NPS 2014a). Visitation has also increased in the form of air tours. In 2016, 455 air tours were reported for the park (Natural Sounds and Night Skies Division, E. Brown, acoustical resource specialist, unpublished report, 27 March 2017). Air tours are not only visually disruptive, but they also create noise pollution in the park (NPS 2011a), which is a threat to wildlife species, such as nesting peregrine falcons.

Most anthropogenic sounds in the frontcountry are associated with noise produced inside the park (i.e., vehicles), while noise in the backcountry is largely produced outside the park (i.e., jets and fixed-wind aircraft). Helicopters flying low over the park have been described as being of particular concern for nesting

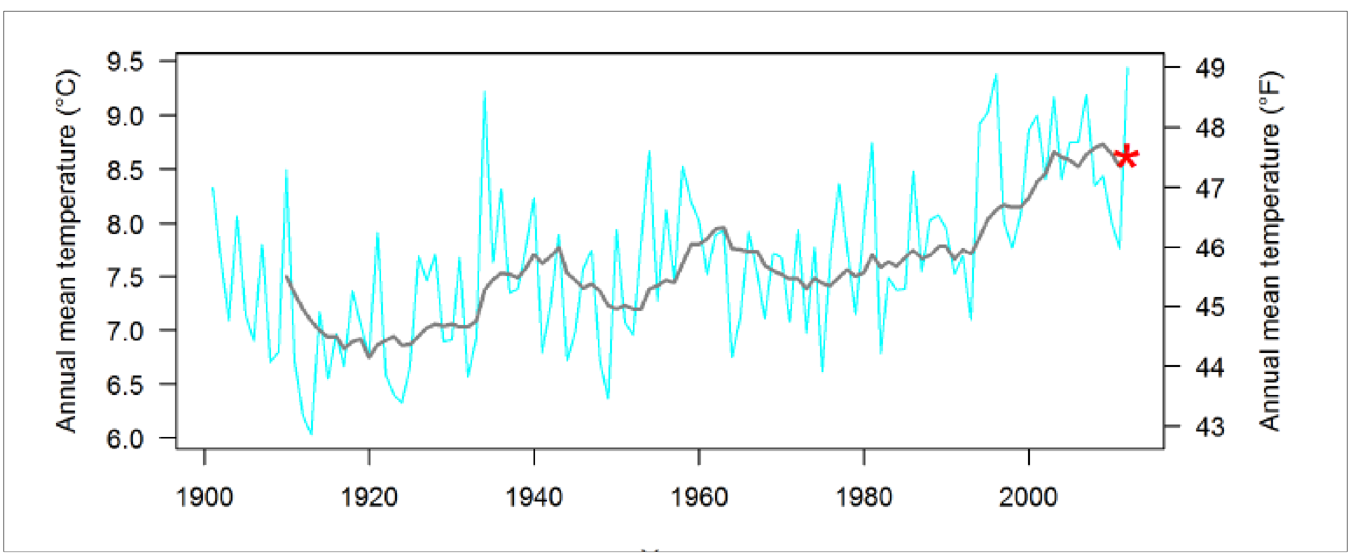


Figure 2.2.3-1. Time series used to characterize the historical range of variability and most recent percentile for annual mean temperature at Bryce Canyon NP (including areas within 30-km [18.6-mi] of the park's boundary). Figure Credit: Monahan and Fisichelli (2014).

peregrines (Flower 2011). Additionally, the park's 2015 and 2016 annual monitoring reports mention potential human disturbance to nesting falcons from the construction of guest facilities, roadways, and parking lots within the park (Salganek and Anderson 2015, Burman 2016). While such disturbances are of concern to this species, these disturbances can affect other wildlife species as well.

Vehicle traffic is a major threat to the federally threatened UPD. Many of the park's UPD colonies are bisected by very busy park roads where they are struck and killed. Another threat to UPDs is the quality of vegetation within their meadow habitat, and the functional connectivity between colonies for dispersion. UPDs will avoid areas where shrub species dominate and will eventually decline or disappear in areas invaded by brush (Collier 1975, Player and Urness 1982). Open habitats are important for foraging, visual surveillance to escape predators, and intraspecific interactions (Player and Urness 1982). Bryce Canyon NP has habitat and size limitations that will likely prevent them from having standalone large colonies, which is why maintaining high quality meadow habitat by managing for non-native invasive plants and shrub reduction within existing colonies is important. A potential management tool is prescribed fire, which can also be used within Bryce Canyon NP forests.

The park's prescribed fire program was initiated in 1990, but by that time most changes to tree density, species composition, and understory cover had already occurred (Ironside et al. 2008). However, some forest stands have shown improving trends as a result of prescribed fire, especially at lower elevations. Prescribed fire may not be possible in dense mixed coniferous forests due to the risk of escaped fires as a result of high fuel loads and ladder fuels (Fulé et al. 2004). High tree density and ladder fuels provided by saplings have increased the potential for stand-replacing fire in mixed coniferous forests, which may be undesirable (Ironside et al. 2008).

Another threat to the park's forests, especially in the pinyon-juniper woodlands, is the introduction and spread of non-native species, and once established, these plants can be extremely difficult to control and most will never be completely eradicated (Mack et al. 2000). Additionally, how non-native invasive plant infestations change over time with treatment is not clear but critical for determining the success of management efforts. Measuring success is difficult because of the multiple treatments required for some species, restrictions placed on treating prairie dog meadows, and the constant threat of re-dispersal via roads, foot traffic, horses and mules, and other disturbances. NCPN staff working on upland and water quality protocols have often observed stray cattle and downed fencing and reported these instances to park staff. While the majority of non-native plants are not problematic at the park, most infestations are located in upland meadows where UPDs reside.

Many of the park's rare plants occur near areas of high visitor use (i.e., in the amphitheater and along cliff edges near the rim), which may transport non-native invasive plant seeds into these areas, especially as visitation increases. The park's increasing visitation contributes to the establishment of social trails, which leads to soil compaction, increased runoff, and trampling of native vegetation. From 1994 to 1998, a study on visitor impacts at high use areas showed that social trails were common, and that the area of bare ground as a result of foot traffic had increased over time (Ames-Curtis 1997, Mitton 1999). Although boundary fences and barriers have been erected in some areas to discourage the use of social trails and to protect native vegetation, visitors sometimes ignore them, but once social trails have become established they can be difficult to rehabilitate. Although erosion is a natural and important geologic process reflective of the region's dynamic landscape, erosion due to anthropogenic causes may alter the park's geology beyond what is natural. This is of particular concern since many of the park's rare plant species occur in the breaks.

In addition to social trail development and associated erosion and soil compaction, rockfalls and slope failures are potential hazards along all established roads and trails (Thornberry-Ehrlich 2005), potentially threatening visitor safety. The Wall Street portion of the Navajo Loop Trail is of particular concern with a decades-long history of rockfall. However, there is no comprehensive study of the erosion processes at the park with respect to the different rock formations associated with administrative features, including buildings, roads, and trails (Thornberry-Ehrlich 2005).

And finally, as described in the park's Foundation Document (NPS 2014a), trends in CO_2 emissions have increased (U.S. Energy Information Agency data) in southwestern states from 1980 through 2010. The temperature has increased (statistically significant) from 1901-2002 in the immediate area surrounding Bryce Canyon NP (NPS 2014a). the protection of air quality in Bryce Canyon NP plays a role in meeting a key park purpose mentioned in the park's enabling legislation: "preserving in their natural state the outstanding scenic features" (NPS 2014a). The majority of threats to air quality within Bryce Canyon NP originate from outside the park and local surroundings (NPS 2014a). In general, sources of air quality threats may include forest fires (natural or prescribed), dust created from mineral and rock mines and quarries, and carbon emissions. Potential increases in commercial or industrial development around the park could lead to air quality effects (NPS 2014a). Details pertaining to these and additional resource threats, concerns, and data gaps are included 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 park's purpose, significance, and fundamental resources and values, and other potential resources/ecological drivers of interest, the NPS Washington (WASO) level programs guided the selection of key natural resources for this condition assessment. This included the NCPN, I&M NPScape Program for landscape-scale measures, Geologic Resources Division for geology, Air Resources Division for air quality, and the Natural Sounds and Night Skies Program for the soundscape and night sky assessments.

<u>NCPN I&M Program</u>

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 2011b). 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 2011b).

To facilitate this effort, 270 parks with significant natural resources were organized into 32 regional networks. Bryce Canyon NP 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, birds, springs and seeps, water quality, and upland vegetation were selected for monitoring at Bryce Canyon NP by park staff and NCPN (NPS NCPN 2016a).

<u>Park Planning Reports</u>

Natural Resource Condition Assessment

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 Bryce Canyon NP in

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

2014 (NPS 2014a) and was used to identify some of the primary natural features throughout the park 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, with an overall summary by topic presented in Chapter 5.

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 park.

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 park's condition assessments.

Bryce Canyon National Park's NRCA scoping meeting was held on April 6, 2017. Photo Credit: NPS.

Chapter 3. Study Scoping and Design

The Natural Resource Condition Assessment (NRCA) for Bryce Canyon National Park (NP) 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 Bryce Canyon NP and NPS Northern Colorado Plateau Inventory and Monitoring Network (NCPN), the NPS IMRO NRCA Coordinator, and USU's NRCA team.

3.1. Preliminary Scoping

Preliminary scoping for Bryce Canyon's NRCA began on June 29, 2016 with a conference call. Prior to the call, USU staff reviewed Bryce Canyon NP's Foundation Document (NPS 2014), the park's and Northern Colorado Plateau Inventory and Monitoring Network's websites (NPS 2016a, NPS NCPN 2016b, respectively), and the NPS integrated resource management applications: IRMA portal (NPS 2016b). The NPS Natural Resource Stewardship and Science Directorate (NRSS) divisions provided data for night sky, soundscape, air quality, and geology (NPS 2016c). Based on the information gathered from these sources, an initial list of potential focal resources for the park's NRCA was developed and discussed during the June conference call. Bryce Canyon's natural resources staff, Dr. Mark Graham and Eric Vasquez, further reviewed, discussed, refined, and prioritized the list of resources.

USU NRCA writers reviewed reports and data sets to determine logical arrangement of the prioritized resources. For example, park staff selected meadows as a focal resource, but given the limited data for that topic and that the meadow habitat is primarily occupied by the Utah prairie dog (*Cynomys parvidens)*, (a separate focal resource also selected for the NRCA), information related to meadows was included as an indicator/measure for the Utah prairie dog assessment instead of a stand-alone topic. USU NRCA writers developed the Phase I draft indicators, measures, and reference conditions for the 10 preliminary focal resources selected by park staff. These tables served as the primary discussion guide during Bryce Canyon NP's on-site NRCA scoping workshop.

The NRCA workshop was held over a three day period from April 6-8, 2017 at Bryce Canyon NP's headquarters (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 park's NRCA report. An additional focal resource, water quality, was added to the park's list of priority topics. Additional data sets and reports were identified for the selected focal resources, and USU, IMRO, and Bryce Canyon NP staffs gathered and scanned needed information on April 8, 2017. Park staff also identified threats, issues, and data gaps for each natural resource topic, which are discussed in each Chapter 4 condition assessment.

3.2. Study Design

3.2.1. 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 Bryce Canyon NP's NRCA, 11 focal resources were selected for assessment, which are listed in Tables 3.2.1-1 - 3.2.1-5. Due to USU's timeline and budget constraints, this list of resources *does not*

Table 3.2-1-1. Bryce Canyon NP 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
	Audibility of Anthropogenic Sounds	% Time Audible
	Geospatial Model	L_{50} Impact

Table 3.2.1-2. Bryce Canyon NP 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 3.2.1-3. Bryce Canyon NP natural resource condition assessment framework based on the NPS Inventory & Monitoring Program's Ecological Monitoring Framework for geology and soils.

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

Table 3.2.1-4. Bryce Canyon NP natural resource condition assessment framework based on the NPS Inventory & Monitoring Program's Ecological Monitoring Framework for water.

Resource	Indicators	Measures
Water Quality	Water Quality	Core Parameters
	Water Quality	Major Ions
	Water Quality	Nutrients
	Water Quality	Trace Elements
	Water Quality	Fecal Indicator Bacteria
	Contaminants of Emerging Concern	Pesticides
	Contaminants of Emerging Concern	Wastewater Indicators
	Contaminants of Emerging Concern	Pharmaceutical and Personal Care Products

Table 3.2.1-5. Bryce Canyon NP natural resource condition assessment framework based on the NPS Inventory & Monitoring Program's Ecological Monitoring Framework for biological integrity.

Resource	Indicators	Measures
Upland Plants (*reported by community type*)	Forest Community Changes (1957-2007)	Relative Importance of Trees (RI)
	Forest Community Changes (1957-2007)	Understory Cover
	Community Composition and Structure	Tree Density (#/ha)
	Community Composition and Structure	Crown Health
	Soil Stability	Soil Aggregate Stability (class)
	Forest Health	Fuels Volume (tons/ha)
	Forest Health	Bark Beetle Infestation (ha)
	Forest Health	Vegetation Condition Class
Unique Vegetation	Prevalence	Change in Density
	Prevalence	Frequency (%)
	Reproduction	% Flowered
Non-native 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
	Status of Peregrine Falcon within the Park	Occupancy of Territories
	Status of Peregrine Falcon within the Park	No. of Young Fledged per Year
Utah Prairie Dog (UPD)	Population Status	Spring Count/Estimated UPD Population
	Population Status	Roadkill Mortality Rate
	Colony Persistence	Colony Counts
Utah Prairie Dog (UPD) *continued*	Colony Persistence	Plague Presence/ Absence
	Condition of Occupied Meadows	Percent Vegetation Cover
	Condition of Occupied Meadows	Plant Species Diversity

Table 3.2.1-5 continued. Bryce Canyon NP natural resource condition assessment framework based on the NPS Inventory & Monitoring Program's Ecological Monitoring Framework for biological integrity.

include every natural resource of interest to park staff, rather the list is comprised of the natural resources and processes that were of greatest interest/concern to park staff at the time of this effort.

Bryce Canyon's 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 2004a) are all organized similarly to the I&M framework.

3.2.2. Reporting Areas

The primary focus of the reporting area was within Bryce Canyon NP's legislative boundary; however, some of the analyses encompassed areas beyond the park's boundary. Natural resources assessed at the landscape level included viewshed and night sky. The NPS NRSS Natural Sounds and Night Skies Division provided the data and reports for the night sky assessment. USU and IMRO staff completed the GigaPan panoramas for the park's viewshed assessment during the April 2017 visit.

3.2.3. General Approach and Methods

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

1. The background and importance section of each condition assessment provided information regarding the relevance of the resource to the park.

2. The data and methods section described the existing datasets and methodologies used for evaluating the indicators/measures for current conditions.

3. The reference conditions section described the good, moderate concern, and significant concern thresholds used to evaluate the condition of each measure.

4. The condition and trend section provided a discussion 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 2012) and served as visual representations of condition/trend/level of confidence for each measure. Table 3.2.3-1 shows the condition/trend/confidence level scorecard used to describe the condition for each assessment. Table 3.2.3-2 provides examples of conditions and associated interpretations, and Table 3.2.3-3 shows the criteria USU writers used to assign condition, confidence level, and trend. The level of confidence in the assessment ranges from high to low and is symbolized by the border around the condition circle. Key uncertainties and resource threats were also discussed in the condition and trend section for each resource topic.

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

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

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

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

Table 3.2.3-1. Indicator symbols used to indicate condition, trend, and confidence in the assessment.

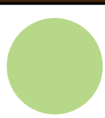
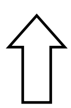
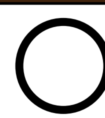
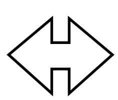
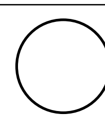
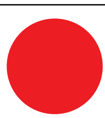
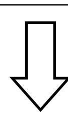
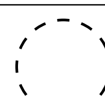
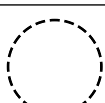
Condition Status		Trend in Condition		Confidence in Assessment	
	Resource is in good condition.		Condition is Improving.		High
	Resource warrants moderate concern.		Condition is unchanging.		Medium
	Resource warrants significant concern.		Condition is deteriorating.		Low
	An open (uncolored) circle indicates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

Table 3.2.3-2. Example indicator symbols and descriptions of how to interpret them.

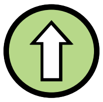
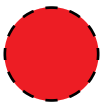
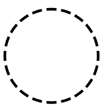
Symbol Example	Description of Symbol
	Resource is in good condition; its condition is improving; high confidence in the assessment.
	Condition of resource warrants moderate concern; condition is unchanging; medium confidence in the assessment.
	Condition of resource warrants significant concern; trend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

Table 3.2.3-3. Factors affecting the assignment of overall condition, trend, and confidence levels.

Condition Rating	Trend in Condition	Confidence in Assessment
• Conditions across all measures coupled with confidence levels determine condition status (i.e., circle color)	• Cumulative trend(s) across all measures • Length of dataset(s) • Confidence levels	• Age of data • Field data vs. modeled data • Data quality and uncertainties

Chapter 4. Natural Resource Conditions

Chapter 4 delivers current condition reporting for the 11 important natural resources and indicators selected for Bryce Canyon NP'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.

Northern Colorado Plateau Inventory and Monitoring hydrologist with weir along the Sheep Creek in Bryce Canyon National Park. Photo Credit: NPS.

4.1. Viewshed

4.1.1. Background and Importance

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

Bryce Canyon National Park (NP) preserves a 14,502 ha (35,835 ac) area that is surrounded by the Dixie National Forest and Bureau of Land Management (BLM) lands (NPS 2014a). Much of the surrounding landscape is undeveloped and provides habitat for many species of wildlife and plants (NPS 2014a). Bryce Canyon NP was established to preserve the unique and scenic geologic features found throughout the park (Figure 4.1.1-1) In Senate Report No. 294, Secretary of the Interior, Hubert Work, describes Bryce Canyon as "one of the three outstanding scenic exhibits of southwestern Utah..." (as cited in NPS 1980). In 1931, additional land was added to Bryce Canyon (46 Stat. 1166) and in 1942, an Act was passed to correct the description of the previously added land (56 Stat. 141), with the following statement from Secretary of the Interior, Harold Ickes, "From a scenic standpoint, the lands in question are vital to the national park. They contain portions of the rim of the canyon, large sections of the famous Pink Cliff formation, and many highly colored and fantastically carved erosional forms" (as cited in NPS 1980). Undoubtedly Bryce Canyon NP's scenic and inspiring vistas were important in its establishment as a national park.

<u>Visitor Experience</u>

Viewsheds are considered an important part of the visitor experience at Bryce Canyon NP, and features on the visible landscape influence a visitor's enjoyment, appreciation, and understanding of the park. These views represent much more than just scenery; they represent a way to better understand the connection between self and nature. Visitors to the park are provided opportunities to immerse themselves in the

Figure 4.1.1-1. Sunrise at Bryce Point. Photo Credit: © James Marvin Phelps.

wilderness where experiences become more remote from anthropogenic sights and sounds, offering an opportunity to literally "visualize" their connection to nature. In 1975, nearly half (46%) of Bryce Canyon NP was recommended for inclusion in the National Wilderness Preservation System (NPS 2014a).

Inherent in virtually every aspect of this assessment is how features on the visible landscape influence the enjoyment, appreciation, and understanding of the park by visitors. The indicators we use for condition of the viewshed are based on studies related to perceptions people hold toward various features and attributes of the viewsheds.

4.1.2. Data and Methods

The indicator and measures used for assessing the condition of Bryce Canyon NP's viewshed are based on studies related to perceptions people hold toward various features and attributes of scenic landscapes. In general, there is a wealth of research demonstrating that people tend to prefer natural landscapes over human-modified landscapes (Zube et al. 1982, Kaplan and Kaplan 1989, Sheppard 2001, Kearny et al. 2008, Han 2010). Human-altered components of the landscape (e.g., roads, buildings, power lines, and other features) that do not contribute to the natural scene are often perceived as detracting from the scenic character of a viewshed. Despite this generalization for natural landscape preferences, studies have also shown that not all human-made structures or features have the same impact on visitor preferences. Historic structures in Bryce Canyon NP for example, are considered to contribute to, rather than detract from, the park's viewshed. Visitor preferences can be influenced by a variety of factors including cultural background, familiarity with the landscape, and their environmental values (Kaplan and Kaplan 1989, Virden and Walker 1999, Kaltenborn and Bjerke 2002, Kearney et al. 2008).

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

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

<u>Key Observation Points</u>

Six key observation points were selected by park staff (Figure 4.1.2-1). These locations were used to qualitatively evaluate viewshed condition using GigaPan panoramas and to quantitatively evaluate condition using viewshed analysis overlaid with NPScape housing density, road density, and protected area status. The six locations chosen were based on viewsheds that are accessible to the public and those that are inclusive of natural resources and scenic vistas.

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

GigaPan Images

We used a series of panoramic images to portray the viewshed from an observer's perspective. These images were taken from each key observation point using a Canon PowerShot digital camera and the GigaPan Epic 100 system, a robotic camera mount coupled with stitching software (Figure 4.1.2-2). GigaPan images were collected from the six key observation locations during 7-9 April 2017. We collected panoramas only in the direction of the scenic vista since these areas are most likely to influence the visitor experience.

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

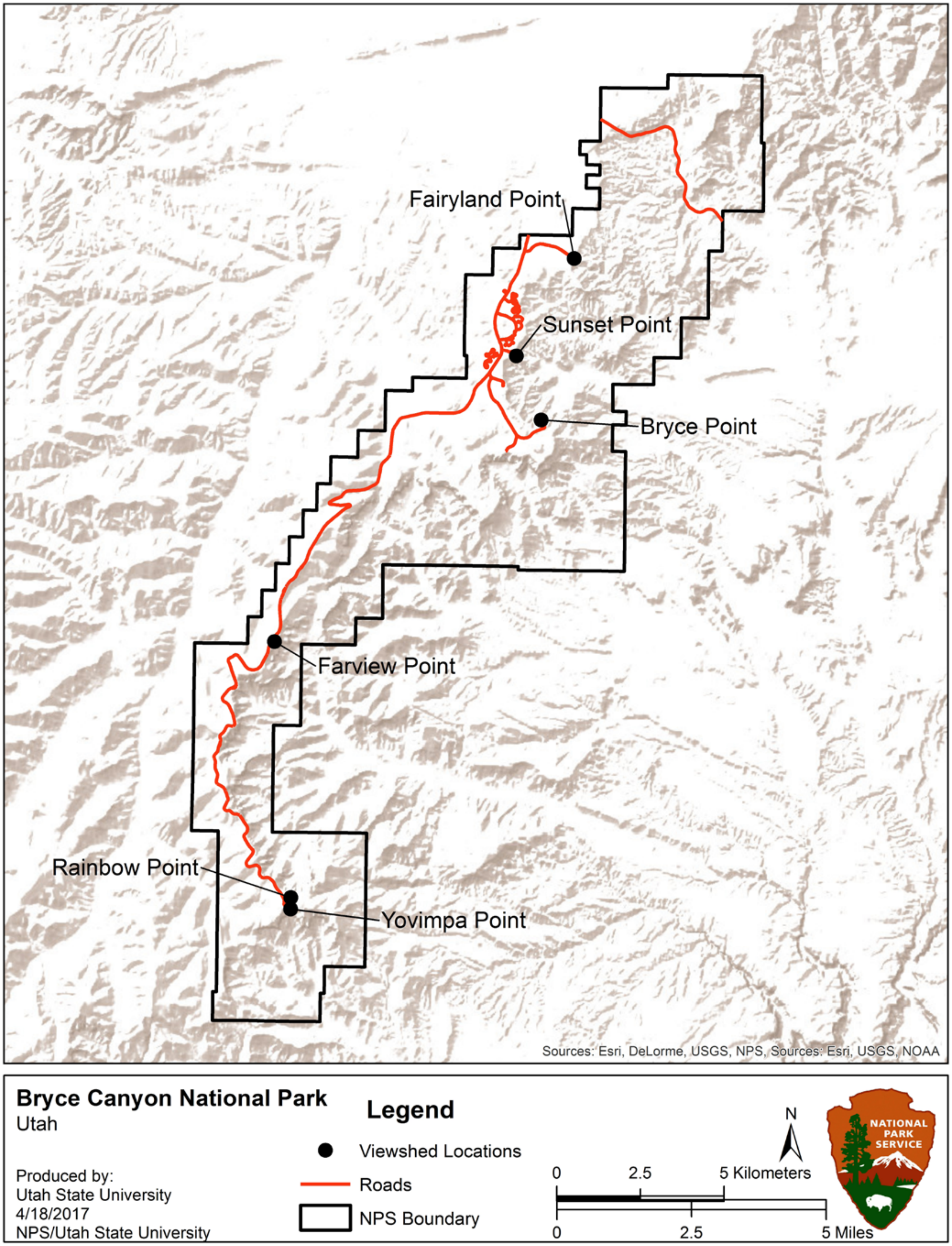


Figure 4.1.2-1. **Locations of 2017 viewshed monitoring locations at Bryce Canyon NP.**

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

characteristics and their influence on conspicuousness is 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* = 0-½ mile from key observation point
- *Middle ground* = ½-3 miles from key observation point
- *Background* = 3-60 miles from key observation point.

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

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

The foreground is the zone where visitors should be able to distinguish variation in texture and color, such as the relatively subtle variation among vegetation patches, or some level of distinguishing clusters of tree boughs. Large birds and mammals would likely be visible throughout this distance class, as would small or medium-sized animals at the closer end of this distance class (USFS 1995). Within the middle ground there is often sufficient texture or color to distinguish individual trees or other large plants (USFS 1995). It is also possible to still distinguish larger patches within major plant community types (such as riparian areas), provided there is sufficient difference in color shades at the farther distance. Within the closer portion of this distance class, it still may be possible to see large birds when contrasted against the sky, but other wildlife would be difficult to see without the aid of binoculars

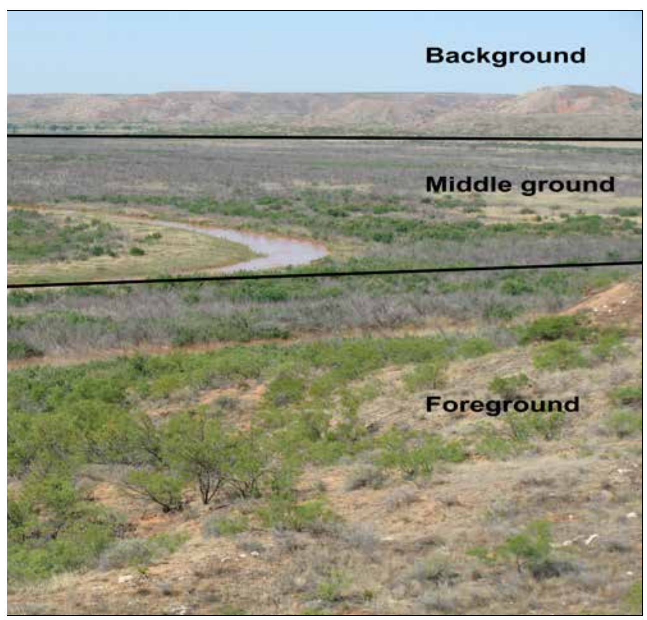


Figure 4.1.2-3. An example of foreground, middle ground, and background distance classes.

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, and Palmer (1979) found that farms tended to be viewed more favorably than views of towns or industrial sites, which ranked very low on visual preference. This is consistent with other studies that have reported rural family dwellings, such as farms or ranches, as quaint and contributing to rural character (Schauman 1979, Sheppard 2001, Ryan 2006), or as symbolizing good stewardship (Sheppard 2001).

We considered the features on the landscape surrounding Bryce Canyon NP as belonging to one of six size classes (Table 4.1.2-2), which reflect the preference groups reported by studies. Using some categories of perhaps mixed measures, we considered size classes within the context of height, volume, and length.

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

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

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

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

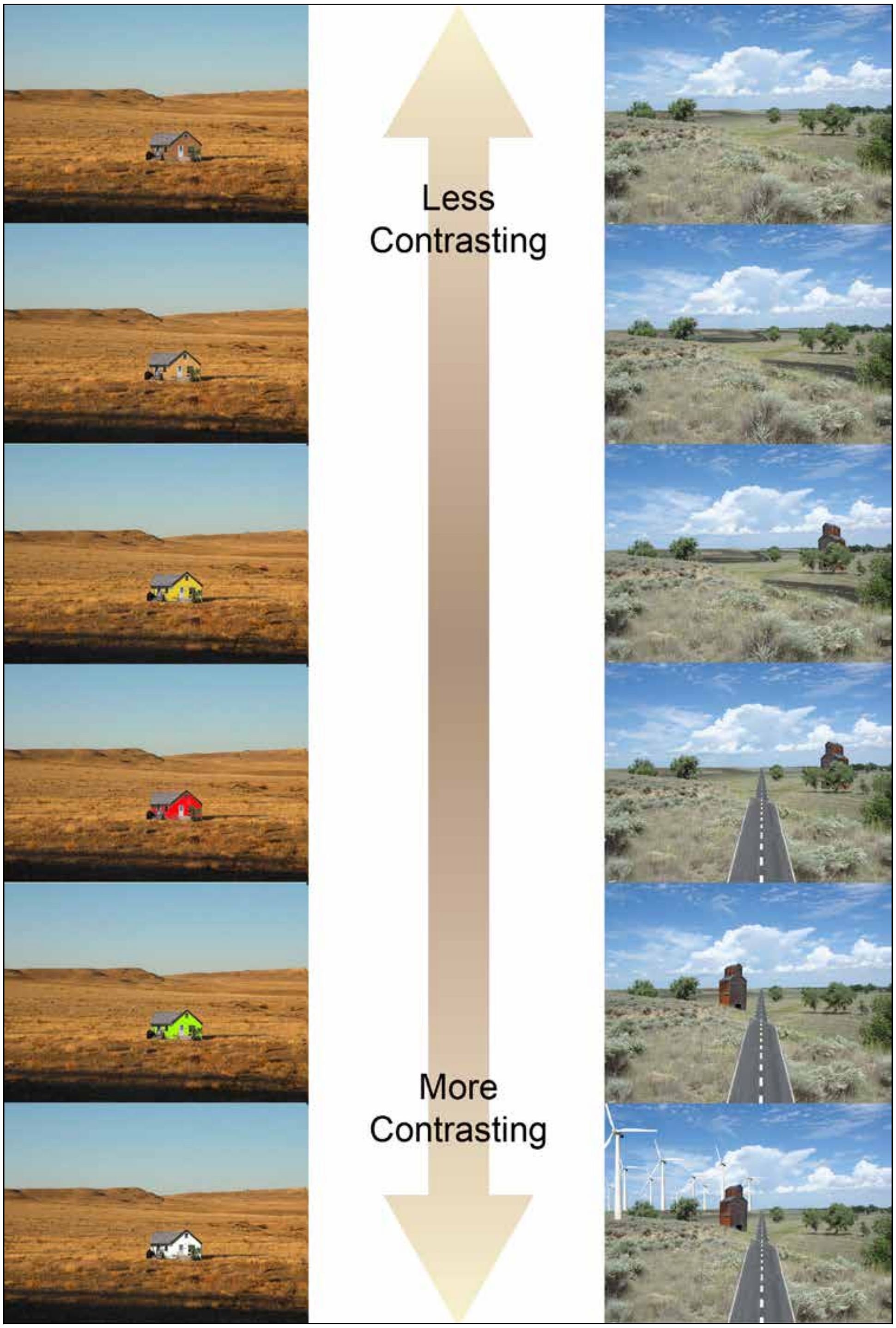


Figure 4.1.2-4. Graphic illustration of how color (left) and shape (right) can influence whether features are in harmony with the environment, or are in contrast.

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 Spatial Analyst Viewshed tool. USGS' National Elevation Datasets (NED) at 1/3 arc-second resolution (approximately 10 m / 32.8 ft resolution) (USGS 2016) were used to create the viewshed area of analysis (AOA), which we identified as a 97 km (60 mi) area surrounding the park from each of the six key observation points. The viewshed analysis for each location was used to support the GigaPan images. The AOAs were then combined to create a composite viewshed based on all six points. Composite viewsheds are a way to show multiple viewsheds as one, providing an overview of the visible/non-visible areas across all observation points. 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 individual viewshed analyses were used to support the GigaPan images and the composite viewshed analysis was used to support the following two measures (i.e., extent of development and conservation status).

<u>Extent of Development</u>

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

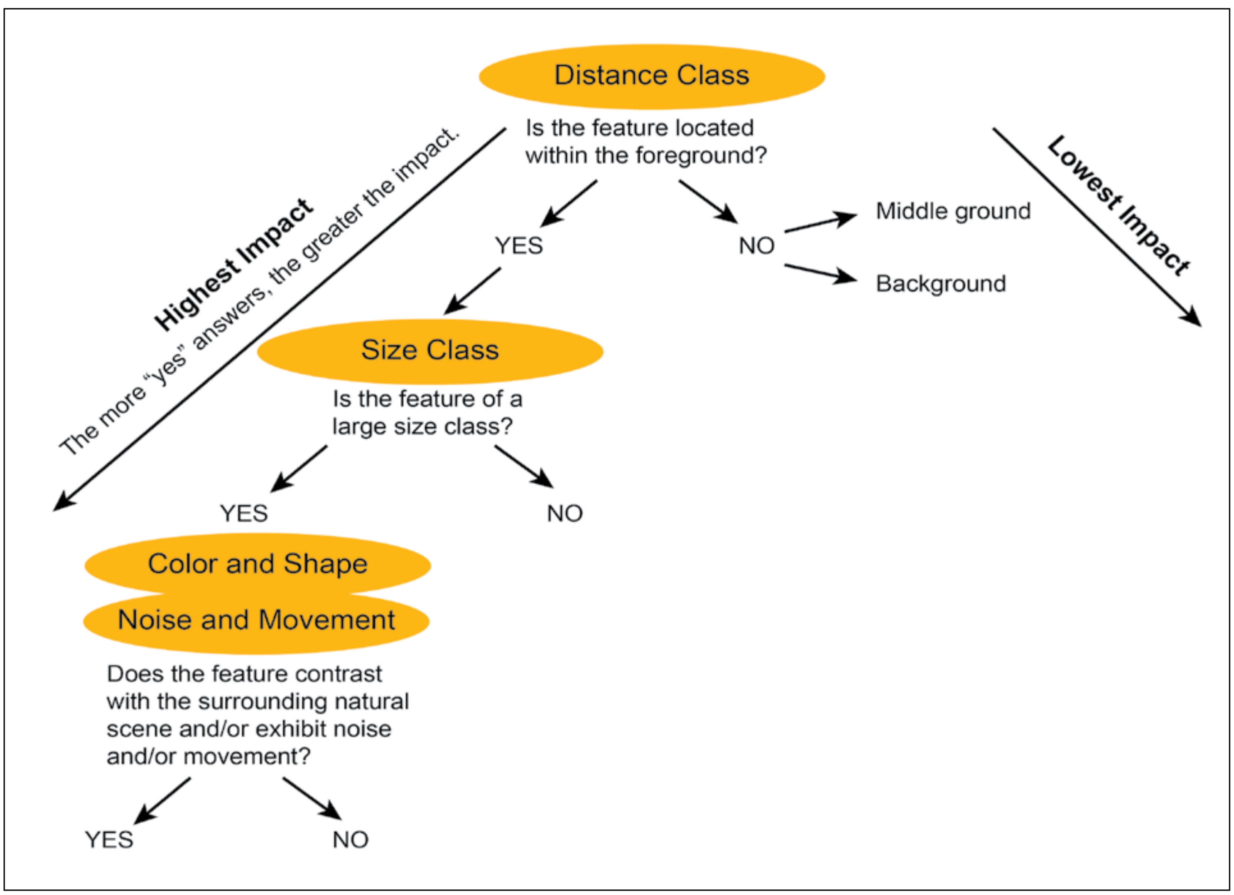


Figure 4.1.2-5. Conceptual framework for hierarchical relationship of characteristics that influence the conspicuousness of features within a viewshed.

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 (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 Bryce Canyon NP. NPScape data are consistent, standardized, and collected in a repeatable fashion over time, and yet are flexible enough to provide analyses at many spatial and temporal scales. The NPScape datasets used in this analysis are described in the sections that follow.

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 - 1,234
	146 - 495
Exurban	50 - 145
	25 - 49
	13 - 24
	7 - 12
Rural	4 - 6
	1.5 - 3
	<1.5
	Private undeveloped

Housing Density
The NPScape 2010 housing density metrics are derived from Theobald's (2005) Spatially Explicit Regional Growth Model, SERGoM 100 m (328 ft) resolution housing density rasters. SERGoM forecasts changes on a decadal basis using county specific population estimates and variable growth rates that are location-specific. The SERGoM housing densities are grouped into six classes as shown in Table 4.1.2-3. NPScape's housing density standard operating procedure (NPS 2014b) and toolset were used to clip the raster to the park's AOA then to recalculate the housing densities. Using the output from this analysis, we also calculated the percent change in housing density from 1970 to 2010 using ArcGIS Spatial Analyst's Raster Calculator tool to determine trend in this measure.

Road Density
ESRI's Utah Roads (Statewide) features (ESRI 2016a) and the U.S. Census Bureau's TIGER/Line Shapefiles (U.S. Census Bureau 2016b) were used to calculate the road density within the park's AOA. The Feature Class Code values in the dataset are used to identify road types. According to NPScape's road density standard operating procedure (NPS 2014c), "highways are defined as interstates (FCC: A10-A19) or major roads (FCC: A20-A38, excluding ferry routes). All roads include all road features from the source data regardless of FCC value (excluding ferry routes). New road density rasters, feature classes, and statistics were generated from these data.

<u>Conservation Status</u>
The U.S. Geological Survey (USGS) (Gap Analysis Program (GAP) Protected Areas Database (PAD)-US version 1.4 conservation status metric was used to calculate the percent area protected and the percent area in broad ownership categories (e.g., federal, state, tribal, etc.) within a 97 km (60 mi) area surrounding the park (USGS GAP 2016). According to Monahan et al. (2012), "the percentage of land area protected provides an indication of conservation status and offers insight into potential threats (e.g., how much land is available for conversion and where it is located in relation to the park boundary) as well as opportunities (e.g., connectivity and networking of protected areas)." NPScape's conservation status operating procedure (NPS 2014d) and toolset were used to clip the geodatabase to the park's AOA then to recalculate the GAP Status and broad ownership categories.

There are four GAP categories that vary based on degree of protection and management mandates. Bryce Canyon NP is within the 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.

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).

Finally, the housing density, road density, and conservation status outputs described above were overlaid with the composite viewshed from the six key observation locations in order to determine where roads, houses, and land management units are most likely to be visible from the park.

4.1.3. Reference Conditions

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

4.1.4. Condition and Trend

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

From the Fairyland vantage point, views to the north were unobstructed with no visible human-made features other than the Fairyland trail in the foreground (Figure 4.1.4-1). From east to south the Fairyland trailhead, stone retaining wall, fencing, and trail sign were visible in the foreground, along with a temporary yellow caution sign for visitor safety. Although these features are considered non-contributing features, they do not interfere with the viewshed at this location since the focus of the viewshed is the canyon and rock pinnacles that Bryce Canyon NP is known for. Furthermore, the size, shape, and color of the non-contributing features (except for the caution sign) blend well with the natural landscape.

Sunset Point offered one of the widest viewsheds in the park (Figure 4.1.4-2). Unfortunately, portions of two images were unfocused. The unfocused areas, however, do not inhibit an evaluation of the viewshed from this location. In all directions, the viewshed was intact with minimal man-made structures. A wooden fence was visible along the canyon rim to the north and west, an interpretive sign was visible to the east, and a chain link fence was visible to the south. All of these non-contributing features were in the foreground. The middle ground, which is directed into the amphitheater, and the background, which is directed toward the Escalante Mountains and Sevier Plateau, were intact with no visible non-contributing features.

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

Figure 4.1.4-1. Panoramic views from the Fairyland Point key observation point in Bryce Canyon NP (from top: north to east and east to south).

At Bryce Point, views in all directions were unobstructed (Figure 4.1.4-3). A low chain-link fence is visible in the foreground toward the northeast, but its low height does not interfere with the viewshed. The park border town of Tropic, Utah was visible in the background to the east. While these features do not contribute to the viewshed, their distance minimizes their impact.

From the Farview vantage point the main viewshed was located from north to south (Figure 4.1.4-4). Toward the north, a paved footpath and fencing is visible in the foreground. The middle ground and background becomes visible as one pans to the south. At the far southern end of the viewshed and in the foreground a stone wall and wooden fencing become visible again. These non-contributing features do not degrade the quality of the viewshed since the color and materials blend well with the natural landscape. The middle ground and background of these images were uninterrupted; however, agricultural land was visible in the background to the east.

The viewshed from Rainbow Point was good (Figure 4.1.4-5). Other than a stone wall and railing visible in the foreground, no other non-contributing features were present. In the background toward the east a large agricultural field could be seen, but its distance minimized its visibility. The viewshed at Yovimpa Point was also good (Figure 4.1.4-6). As with the other viewpoints, a railing was visible in the foreground and in the background a road was visible.

Figure 4.1.4-7 shows the area and extent that should be visible from each key observation location. The analysis revealed that Yovimpa Point has the largest viewshed while Bryce Point and Fairyland Point have the smallest viewshed. For all six locations, the western viewsheds were the most obscured while views to the north and east were generally good. Yovimpa Point was the only location with views to the south. The viewshed analyses, however, appeared to show a smaller visible area that what was actually seen during ground-truthing. This could be due to the highly variable terrain and resolution of the DEM used in the analysis. Therefore, we relied more heavily on the GigaPan images to determine condition for

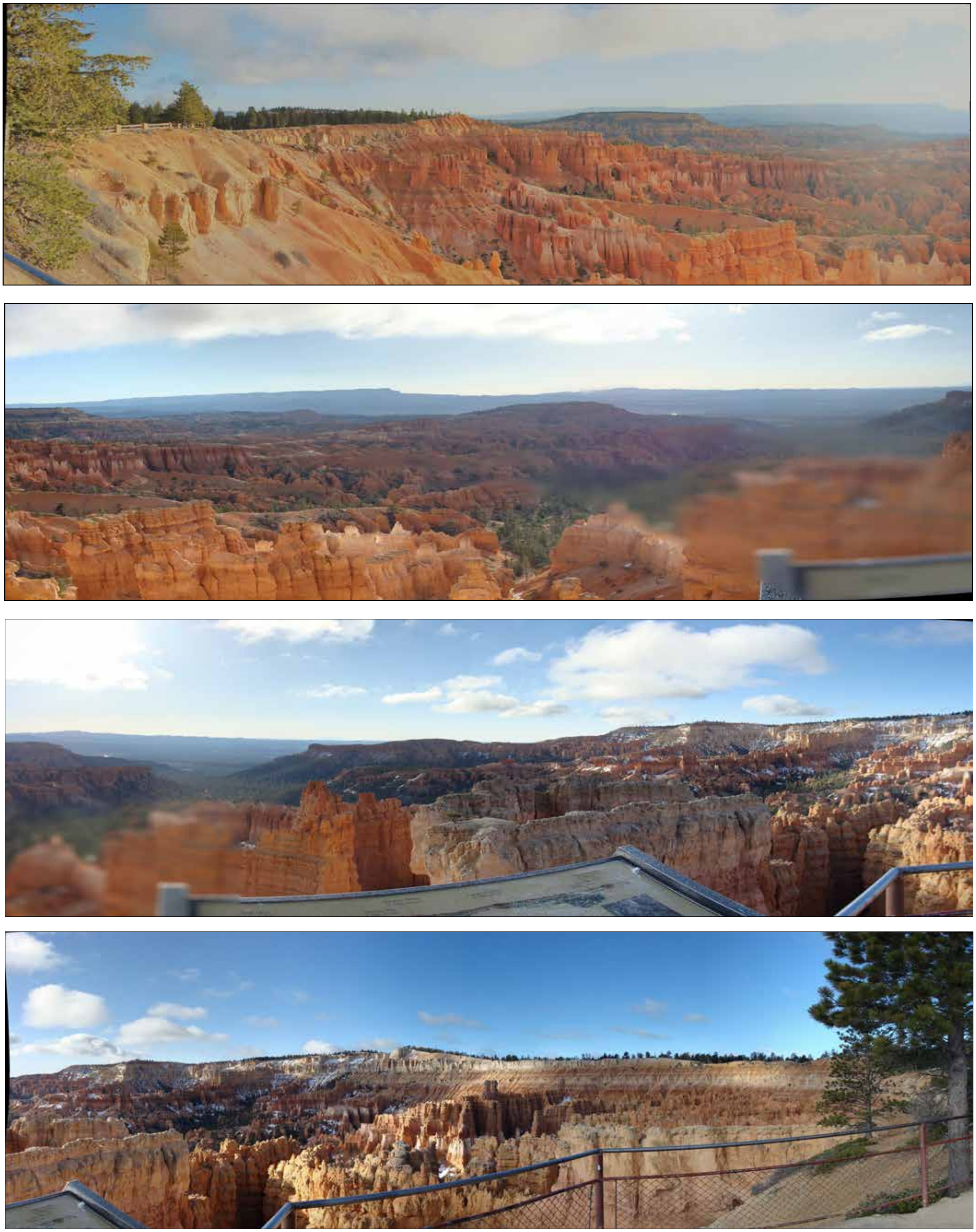


Figure 4.1.4-2. Panoramic views in each direction from the Sunset Point key observation point in Bryce Canyon NP (from top: north to east, east, southeast, and south).

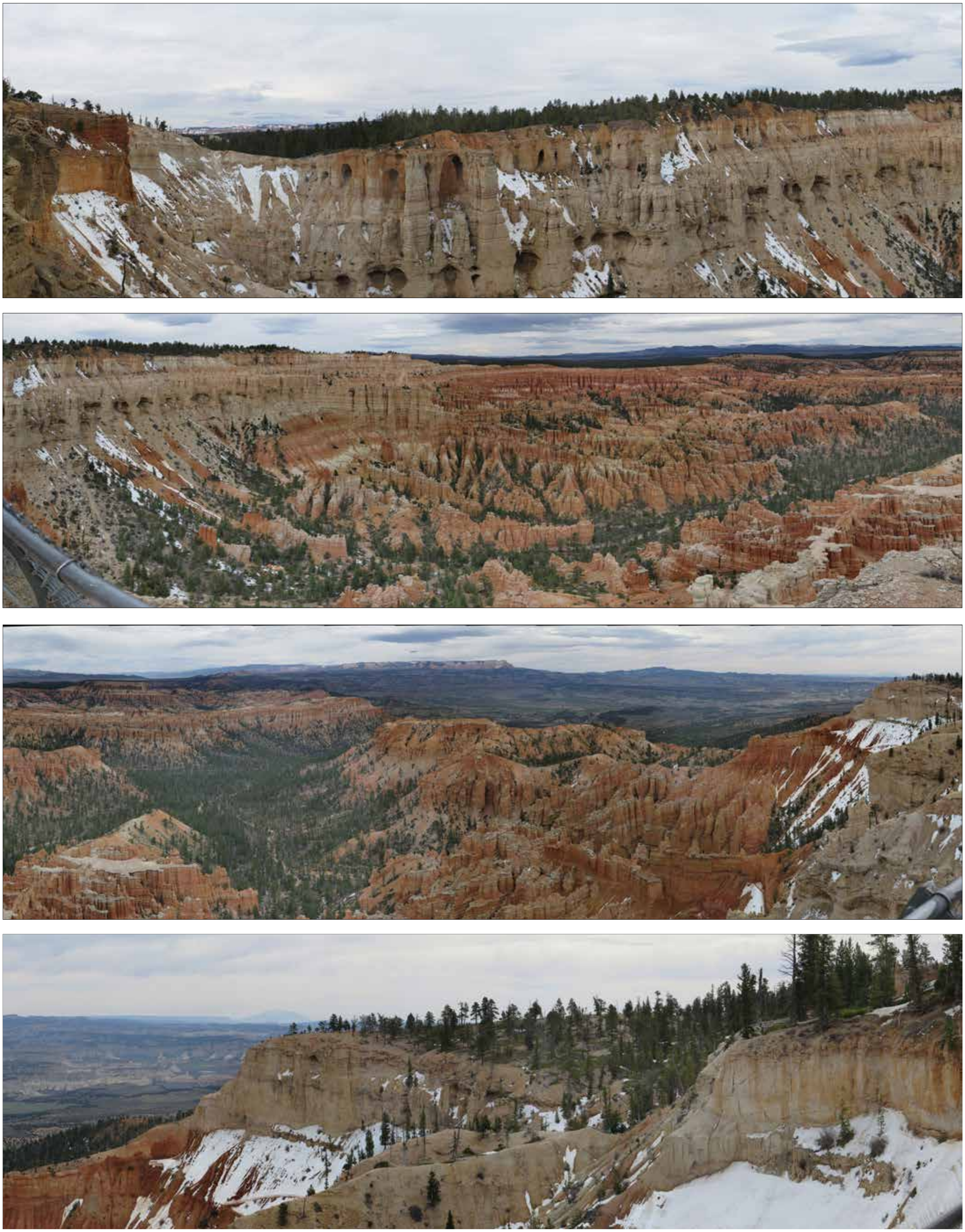


Figure 4.1.4-3. Panoramic views in each direction from the Bryce Point key observation point in Bryce Canyon NP (from top: southwest to west, west to north, north to east, and east to southeast - the sidewalk was omitted).

Figure 4.1.4-4. Panoramic views from the Farview Point key observation point in Bryce Canyon NP (from top: north to east and east to south.

this measure. Overall, few non-contributing features were present at the six observation locations and the viewshed is considered good with high confidence and unknown trend since these data represent baseline conditions.

Extent of Development

The composite viewshed (based on the six key observation locations) shows that areas to the south and east of the park are most visible, while areas to the west and north are least visible. This was consistent with the GigaPan images described above, but the visible areas to the south and east were probably underrepresented. Based on data compiled in NPScape (Budde et al. 2009 and Monahan et al. 2012), housing densities surrounding the park were low (Table 4.1.4-1). The majority (48%) of all housing consisted of private undeveloped lands and densities less than 1.5 units/km^2 (32%). Furthermore, most of this rural development occurred west of the park, which was largely outside of the park's viewshed. The white spaces within this boundary indicate no census data; thus, housing densities could not be calculated for these areas. However, these data originate with the U.S. Census Bureau and units with unknown densities were probably not reported, which likely indicates undeveloped areas. Most (94%) areas of the AOA in which housing densities were calculated have not changed since 1970, while the remaining 6% have increased by 100%. Nearly all of the areas showing an increase in housing density occur outside of the viewshed. The housing and road density figures are included in Appendix C.

Total road density within the 97 km (60 mi) AOA was 0.55 km/km^2. Figure 4.1.4-9 shows road density by various classes. Road density within the park's viewshed was less dense than it is elsewhere in the AOA and is representative of a relatively rural landscape since there are few areas with a high density of roads. Based on these results, we consider the condition for this measure of scenic and historic integrity to be good with medium confidence and unknown trend for road density and an unchanging trend for housing density. Although the trend in road density is unknown, it likely tracks that of housing density.

Figure 4.1.4-5. Panoramic views in each direction from the Rainbow Point key observation point in Bryce Canyon NP (from top: north to east and east to south).

Conservation Status
Of the total AOA, approximately 94% was categorized in one of the four GAP Status categories. The majority (73%) of land area within the AOA is within GAP Status 3, or permanently protected lands managed for multiple uses (e.g., mining or logging). Only 19 % of land within the AOA is GAP Status 1 (permanently protected lands managed for biodiversity and natural processes) or GAP Status 2 (permanently protected lands managed for biodiversity but with suppression of disturbances). Only 4% of land is considered GAP status 4 (no known protections). The BLM administers the majority (53%) of land in the AOA followed by the U.S. Forest Service (30%). Most of the remaining lands are managed by the State of Utah or the NPS. Areas visible from the park are located largely within GAP Status 3 lands, most of which are managed by the BLM. The conservation status figures are included in Appendix C.

While there are some areas where scenic conservation status is high, many of the land management agencies responsible for the lands that are visible from Bryce Canyon NP's observation points allow for extractive uses, therefore, we consider conservation status for Bryce Canyon NP to be of moderate concern. Because these results are based on modeled data, confidence is medium. Trend is unknown.

Overall Condition, Trend, Confidence Level, and Key Uncertainties
Based on this assessment, the viewshed condition at Bryce Canyon NP is good with an unknown trend and medium confidence (Table 4.1.4-2). There were few non-contributing features in the park's viewshed as observed from the six key observation locations, and those that were present blended relatively well with the natural landscape. The composite viewshed shows that views to the west are blocked from within the park, but this was a result of natural features of the landscape (i.e., vegetation). The housing and road density analyses show that the region surrounding the park is mostly rural, but most of the landscape in the AOA is GAP Status 3 and open to future extractive uses that could alter the viewshed.

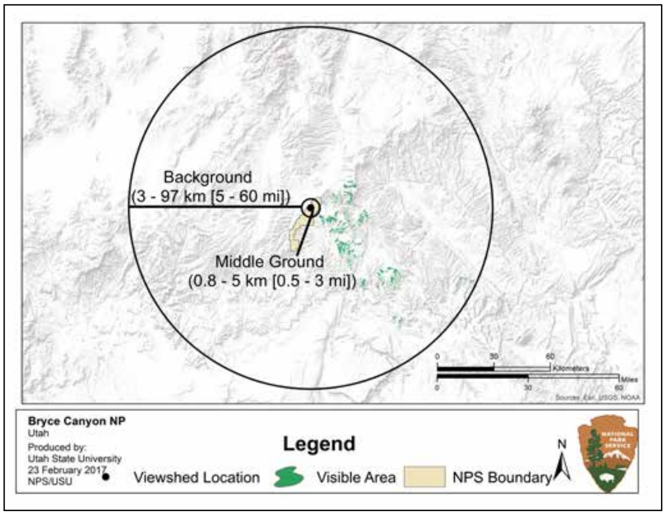
This assessment represents baseline condition for Bryce Canyon NP's viewshed; therefore, we could

Figure 4.1.4-6. Panoramic views in each direction from the Yovimpa Point key observation point in Bryce Canyon NP (from top: east to south and south to west).

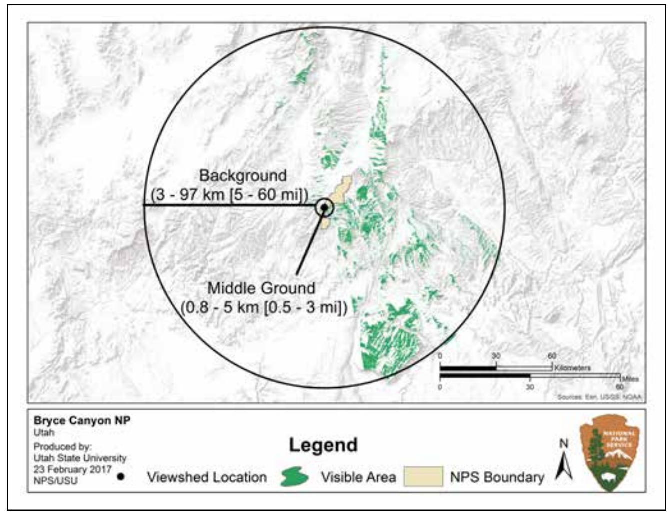
not report on trend except for housing density, which indicated unchanging conditions. Two of the three measures were assigned medium confidence. Factors that influence confidence level include age of the data (<5 years unless the data are part of a long-term monitoring effort), repeatability, field data vs. modeled data, and whether data can be extrapolated to other areas of the park. We assigned high confidence to the conspicuousness of non-contributing features because the GigaPan images are current and were ground-truthed. We assigned medium confidence to the extent of development and conservation status measures because these results were based on modeled data. Furthermore, the viewshed analysis appeared to underestimate the visible areas from each location. The discrepancy may be attributed to the resolution of the DEM, which was 10 m (32.8 ft). Finer resolution data would probably give a better indication of the areas that are actually visible from each location. Furthermore, we did not account for vegetation height in the viewshed analysis, which could have also accounted for some of the discrepancy. Lastly, the USGS' GAP Analysis Program's PAD contained many overlapping features (i.e., some land areas were counted more than once for multiple GAP Status categories and/or land management agencies). While most overlapping features were corrected prior to analysis, some features may have been missed due to the nature of the error (e.g., errors along boundaries or sliver errors).

Threats, Issues, and Data Gaps

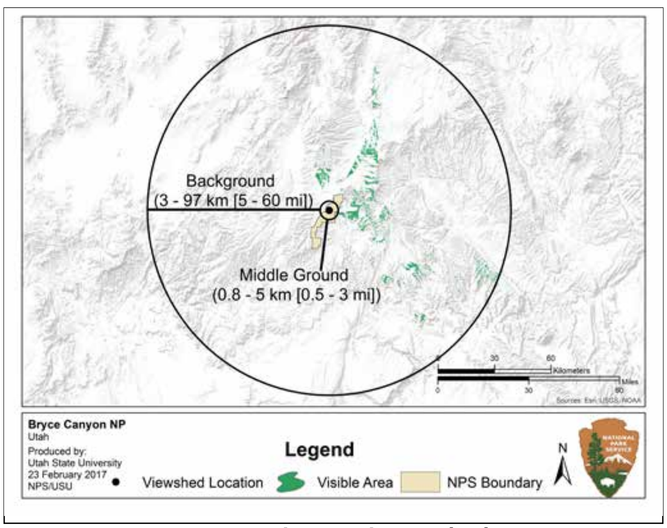
Potential threats to Bryce Canyon NP's viewshed include development within the AOA, increased visitation to the park, and atmospheric dust and smog as a result of climate change. But according to the housing density analysis, development within the park's viewshed is not expected to change substantially over the next 50 to 60 years. Even by 2100, the analysis showed only a slight increase in development. It is important to keep in mind, however, that this prediction is based on past development and may not reflect actual future development. According to the U.S. Census Bureau, Utah is the fastest growing state in the nation (U.S. Census Bureau 2016b).



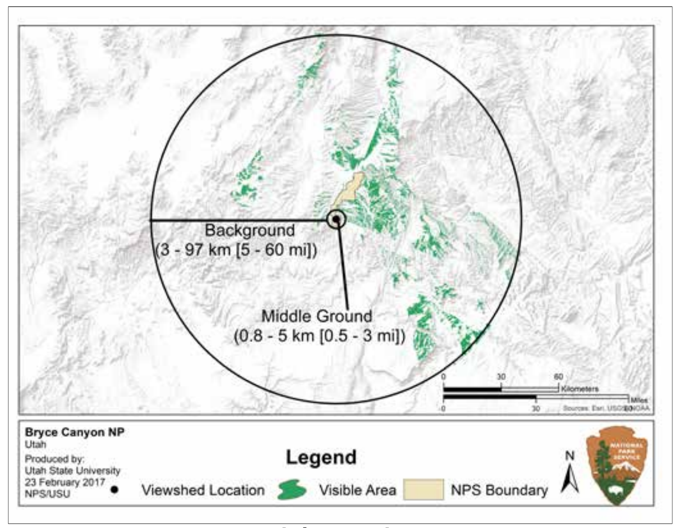
Fairyland Point



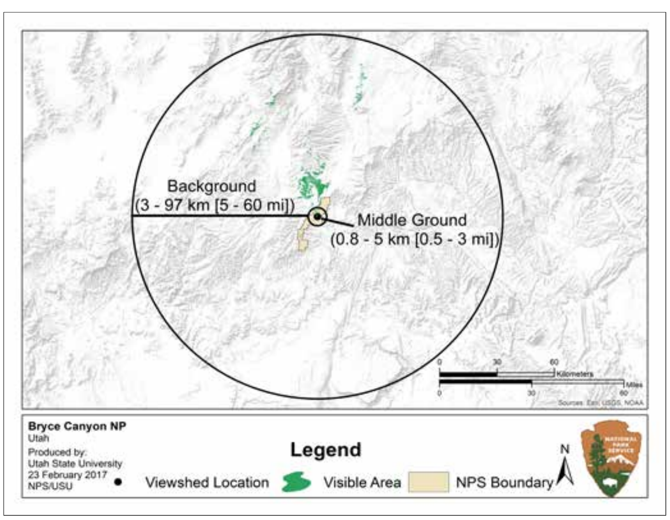
Farview Point



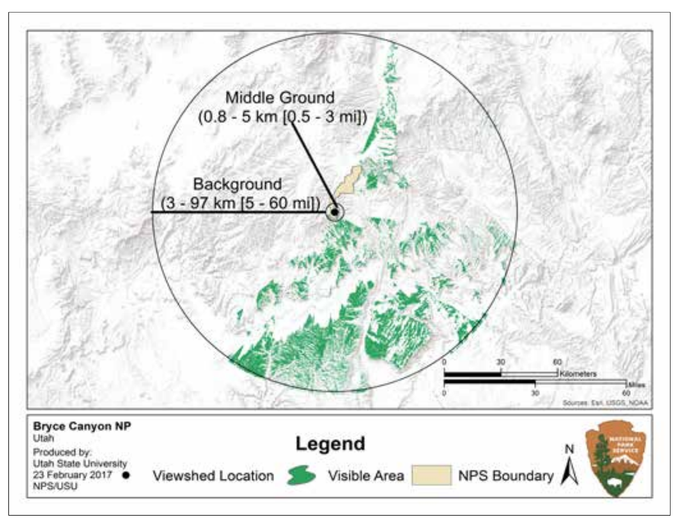
Sunset Point - Main Overlook



Rainbow Point



Bryce Point



Yovimpa Point

Figure 4.1.4-7. Visible areas from each of the six key observation locations in Bryce Canyon NP.

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

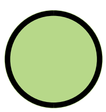
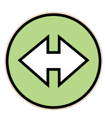
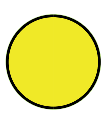
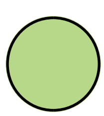
Density Class	Area (km^2)	Percent
Private Undeveloped	2,642	48
< 1.5 units	1,789	32
1.5 - 6 units	618	11
> 6 units	419	8
Commercial/Industrial	39	0.7
Urban-Regional Park	17	.3
Total Area	5,524	100

Increased visitation may also impact the viewshed. Like many parks in 2017, Bryce Canyon NP experienced the highest visitation on record, with more than 2.5 million visitors (NPS 2018). While the majority of visitors are concentrated along road corridors, at pullouts, visitor centers, and interpretive exhibits rather than dispersed across the backcountry, off-trail travel is a concern in some areas (NPS 2014a). Visitation has also increased in the form of air tours. In 2016, 455 air tours were reported for the park (NSNSD, E. Brown, acoustical resource specialist, unpublished report, 27 March 2017). Air tours are not only visually disruptive, but they are also the primary source of noise in the park (NPS 2011a), which is a contributing factor in assessing the conspicuousness of a non-contributing feature. Finally, atmospheric dust and mineral aerosols have increased in the interior western U.S. by 500% over the late Holocene average (Neff et al. 2008). This increase is directly related to increased western settlement and livestock grazing during the 19th century (Neff et al. 2008). Atmospheric dust can impact viewshed quality.

4.1.5. Sources of Expertise

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

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 park's viewshed as observed from the six 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, chain link fencing, iron railings, and trails that were visible in the foreground. At some locations agricultural fields, roads, and the town of Tropic, Utah were visible in the background. Trend is unknown and confidence is high.
	Extent of Development		The composite viewshed shows that areas to the south and east of the park are most visible, while areas to the west and north are least visible. But the composite viewshed appeared to under represent what was actually visible from each location. The majority (48%) of all housing consists of private lands and densities less than 1.5 units/km^2 (32%), most of which occurs west of the park. Total road density was 0.55 km/km^2, which is representative of a rural landscape. Since 1970, 94% of housing density has not changed. Based on these results, we consider the condition to be good. Trend is unchanging and confidence is medium.
	Conservation Status		While there are some areas where scenic conservation status is high, many of the land management agencies responsible for the lands that are visible from Bryce Canyon NP's observation points allow for extractive uses, therefore, we consider conservation status for Bryce Canyon NP to be of moderate concern. Trend is unknown and confidence is medium.
Overall Condition, Trend, and Confidence Level			There were few non-contributing features in the park's viewshed, and those that were visible were not conspicuous. The composite viewshed shows that views to the west and north are blocked, but this was a result of natural features of the landscape (i.e., vegetation). The housing and road density analyses show that the region surrounding the park is mostly rural, but most of the landscape in the AOA is GAP Status 3 and open to future extractive uses that could alter the viewshed. Based on these results, the viewshed in Bryce Canyon NP 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 National Park Service (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 2010d). Additionally, in an estimated 20 national parks, stargazing events are the most popular ranger-led program (NPS 2010d).

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

Maintaining a dark night sky was identified in Bryce Canyon National Park's (NP) Foundation Document as fundamental to protecting the wilderness setting and biodiversity of the park (NPS 2014a). In 1975, approximately 46% of the park was recommended for inclusion in the National Wilderness Preservation System (NPS 2014a). Bryce Canyon NP is one of the best places on the Colorado Plateau to experience dark night skies and is an important component of the visitor experience. For the last 17 years, the park has hosted a popular annual astronomy festival but has offered astronomy programs since 1969, including a weekly Starry Nights Telescope Viewing program

Figure 4.2.1-1. Bryce Canyon NP's night sky. Photo Credit: © Gerald Oskoboiny.

(NPS 2014a). These programs reach up to 10% of the park's overnight visitors (Collison and Poe 2013) and have been shown to be an important component of the overall visitor experience on par with other park resources such as scenic viewsheds (Valliere and Manning 2014).

To protect and further promote dark night skies in the park, NPS staff are applying for Dark Sky Park status from the International Dark Sky Association (IDA) (NPS 2014a). 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 a night sky monitoring program, and working with nearby communities to protect the park'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 Bryce Canyon NP 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).

In addition, Air Resource Specialists, Inc. installed a digital SLR camera system, optimized to monitor visual conditions and light pollution in night sky images near Yovimpa Point since September 2013 (ARS 2013). The purpose of the project was to establish baseline nighttime visibility conditions capturing night sky images of the light dome (sky region) over the Alton Coal Mine and St. George, Utah, southwest of the park. The images capture the direct light from the dome, as well as light scattered by haze and clouds in the dome. The current plan is to continue to operate the night sky camera as long as funding is available. As of May 2017, there are over 35,000 night sky photos. A representative photo is included in Appendix D.

NSNSD scientists conducted an assessment of Bryce Canyon NP's night sky condition at four locations from 2003 to 2007 (Figure 4.2.2-1). 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

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.

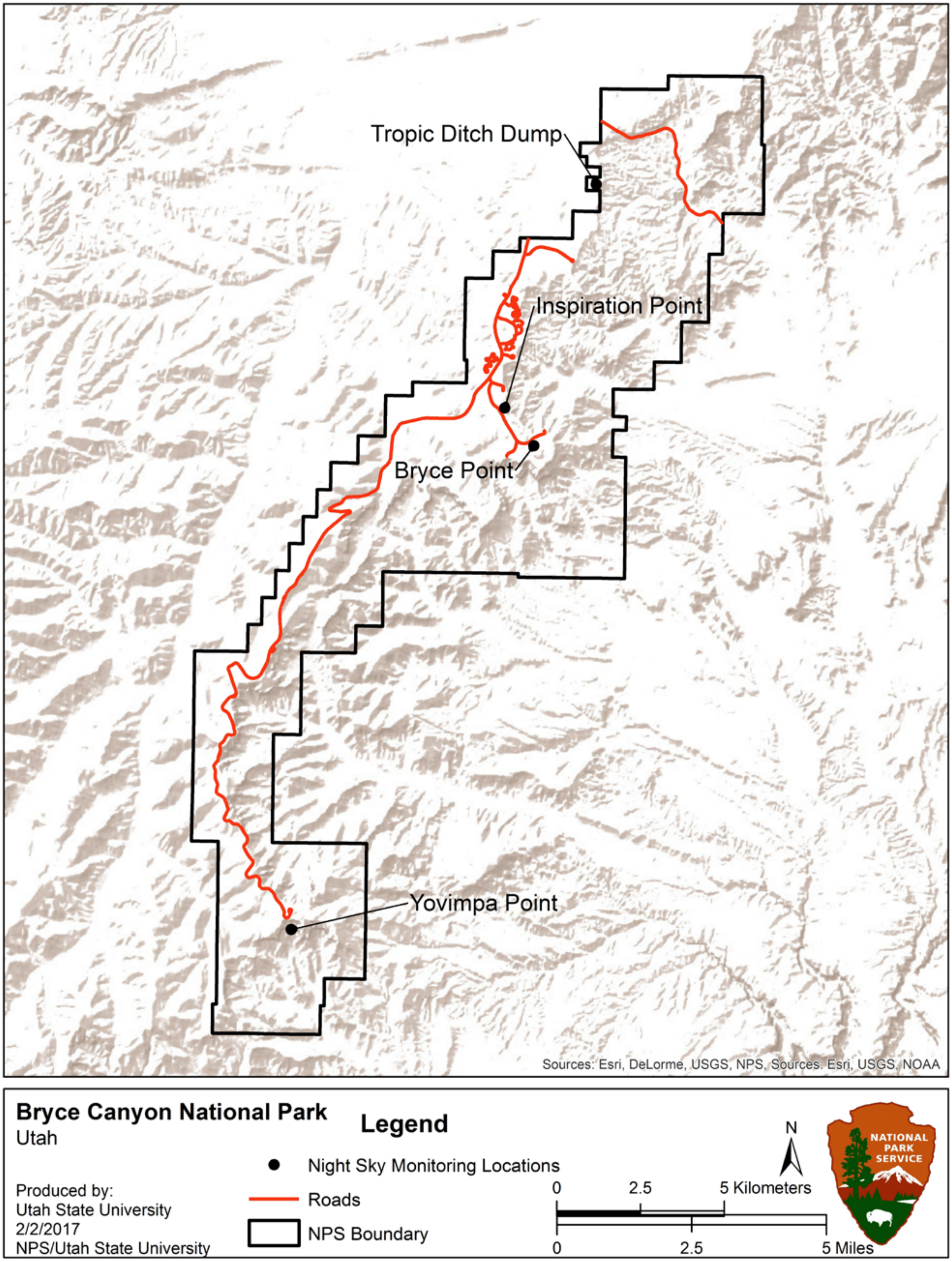


Figure 4.2.2-1. Location of the night sky monitoring sites in Bryce Canyon NM.

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.

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 reported the observed (artificial + natural) maximum vertical and horizontal illuminance. We also reported 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. As with maximum vertical and horizontal illuminance, we reported the observed zenith sky brightness in addition to its corresponding LPR.

Bortle Dark Sky Scale

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

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).

suitable for conditions ranging from the darkest skies to the brightest urban areas (Moore 2001, Figure 4.2.2-2).

4.2.3. Reference Conditions

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

Bryce Canyon NP 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). Nearly half of the park is also managed as wilderness (NPS 2014a). 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.

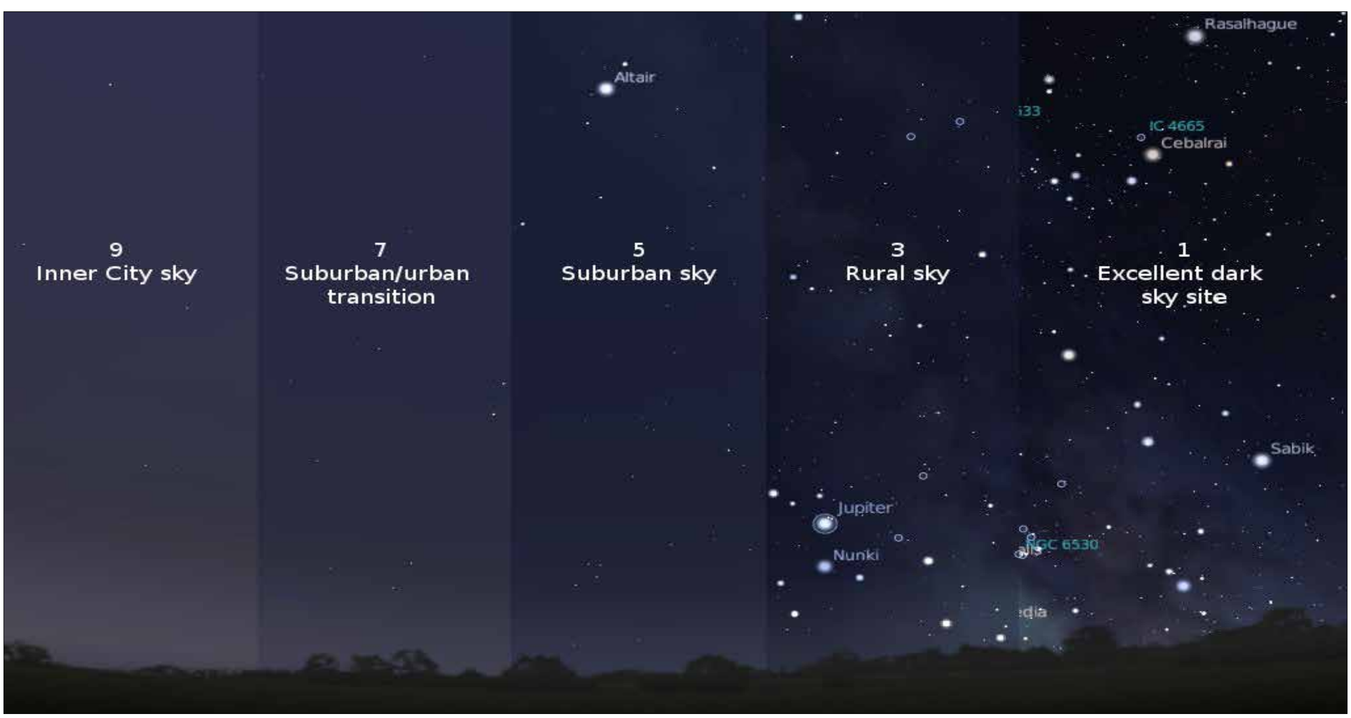


Figure 4.2.2-2. A graphic representation of the Bortle Dark Sky Scale (Bortle 2001). Figure Credit: NPS Natural Sounds and Night Skies Division.

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).

Zenith Sky Brightness

Reference conditions for night sky brightness can vary moderately based on the time of night (time after sunset), time of the month (phase of the moon), time of the year (the position of the Milky Way), and the activity of the sun, which can increase "airglow"—a kind of faint aurora. For the minimum night sky brightness measure, the darkest part of a natural night sky is generally found near the zenith. A value of 22.0 magnitudes per square arc second (msa) is considered to represent a pristine sky, though it may vary naturally by more than +0.2 to -0.5 depending on natural conditions (Duriscoe 2013). Lower (brighter) values indicate increased light pollution and a departure from natural conditions. The astronomical magnitude scale is logarithmic, so a change of 2.50 magnitudes corresponds to a difference of l0x; thus a 19.5 msa sky would be 10x brighter than natural conditions. Minimum night sky brightness values of 21.4 to 22.0 msa, are generally considered to represent natural (unpolluted) conditions (Duriscoe et al. 2007).

Bortle Dark Sky Scale

A night sky with a Bortle Dark Sky Scale Class 1 is considered in the best possible condition (Bortle 2001). Unfortunately, a sky that dark is so rare that few observers have ever witnessed it (Moore 2001). Non-urban park skies with a Bortle Class 3 or darker are considered to be in good condition, Bortle Class 4 warrants moderate concern, and Bortle Class 5 warrants significant concern. At Bortle 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

Modeled data by the NPS Night Skies Program shows a median ALR of 0.12 for the entire park (Table 4.2.4-1). This is 12% brighter than average natural conditions. The modeled ALR values for the wilderness and non-wilderness areas of the park were 0.11 and 0.13, respectively. These values correspond to 11% and 13% brighter than average natural conditions.

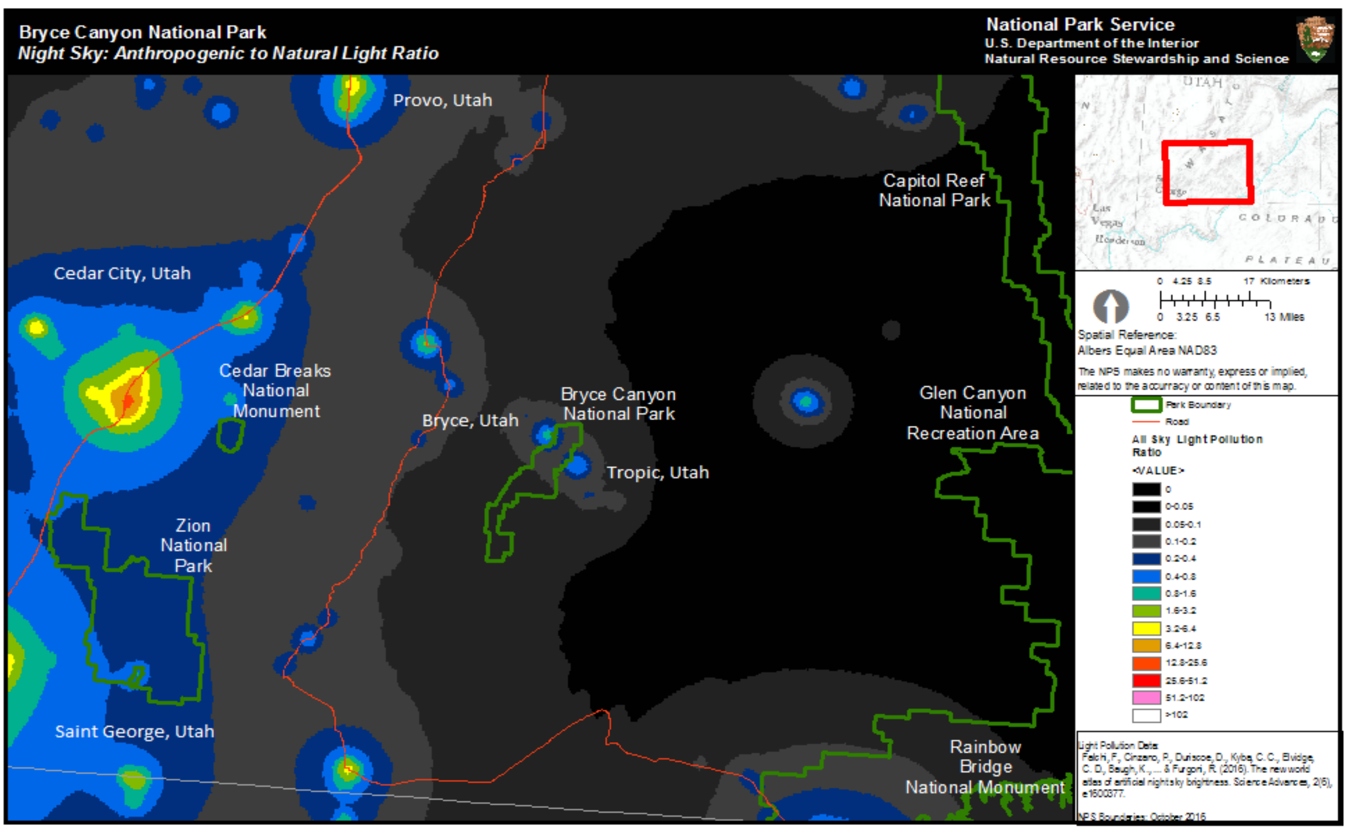
Figure 4.2.4-1 shows the modeled ALR for the region surrounding Bryce Canyon NP and the extent of the light domes cast by cities located in the region. The figure shows that the park is influenced by lights from the border communities of Tropic, Utah and Bryce, Utah. The much larger communities of Cedar City, Utah (79 km west [49 mi]; Saint George, Utah (137 km southwest [85 mi]), and Provo, Utah (291 km north [181 mi]) also contribute to light pollution in the park.

Modeled ALR values were generally greater than ground-based measurements (Table 4.2.4-1). Ground-based ALRs varied from < 0.04 to 0.13, which corresponds to a range of 4% to 13% brighter than average natural conditions. Figures 4.2.4-2, -3, -4, and -5 show the most recent natural and anthropogenic light sources for each monitoring site. Earlier images for Bryce Point and Yovimpa Point are shown in Appendix D. These data images are shown in false color with yellow, red, and white corresponding to brighter sky and blue, purple, and black corresponding

Table 4.2.4-1. Night sky measurements collected Bryce Canyon NP.

Location	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	–	0.12	–	–	–	–
Wilderness	–	0.11	–	–	–	–
Non-Wilderness	–	0.13	–	–	–	–
Bryce Point	2 March 2003	< 0.04	0.66	0.99	21.60	2
	1 February 2005	0.06	0.37	0.67	21.79	–
	25 August 2006	0.12	0.38	0.62	21.69	–
Inspiration Point	7 September 2007	0.09	0.50	0.79	21.54	–
Tropic Ditch Point	8 May 2007	0.13	0.62	0.79	22.01	3
Yovimpa Point	17 November 2004	0.08	0.58	0.94	21.55	2
	9 December 2004	0.10	0.72	1.00	21.67	–
	14 February 2007	0.07	0.50	0.78	21.43	2
	13 March 2007	0.08	0.45	0.63	22.08	2
	19 June 2007	0.06	0.53	0.79	21.80	2

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).



NPS Natural Sounds & Night Skies Division and NPS Inventory and Monitoring Program MAS Group 20170301

Figure 4.2.4-1. Modeled ALR map for Bryce Canyon NP. Figure Credit: NPS Natural Sounds and Night Skies Division.

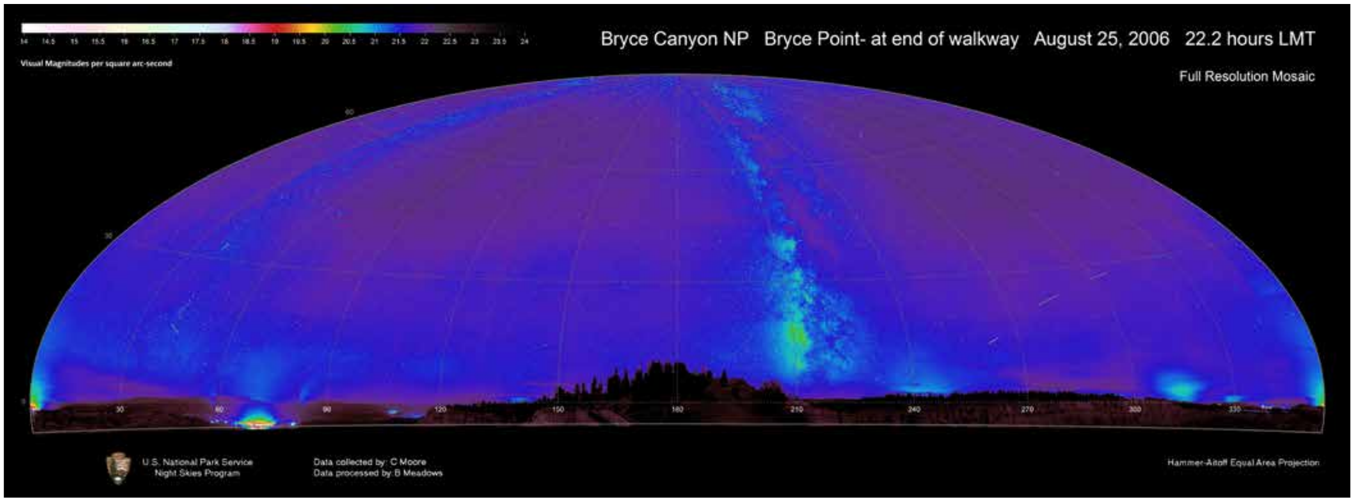


Figure 4.2.4-2. Panoramic all-sky mosaic of all light sources on 25 August 2006 at Bryce Point. Light sources include natural and anthropogenic. Figure Credit: NPS Natural Sounds and Night Skies Division.

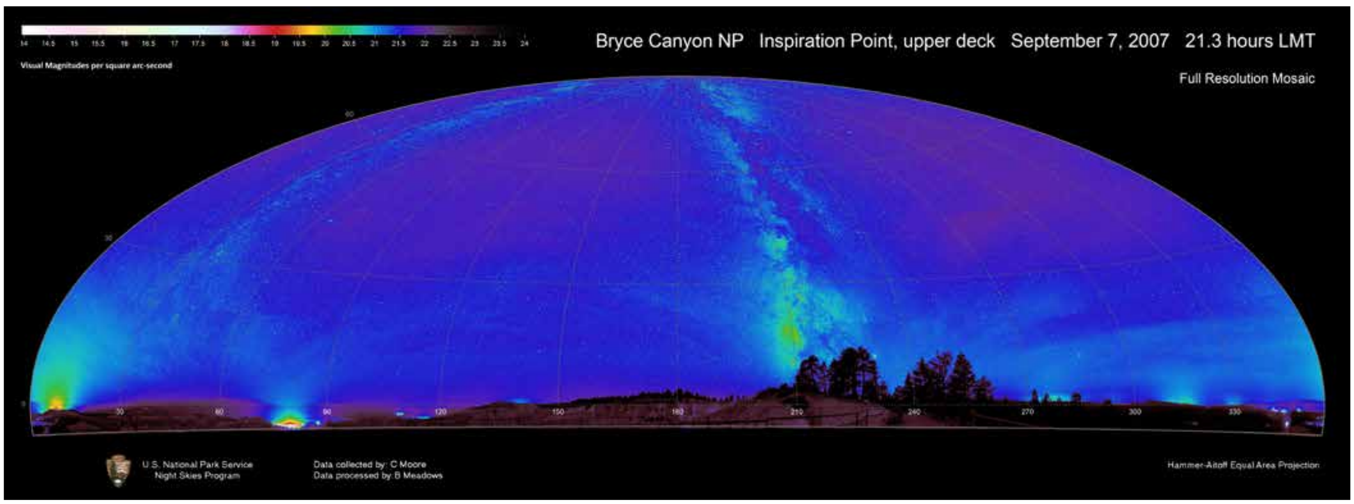


Figure 4.2.4-3. Panoramic all-sky mosaic of all light sources on 7 September 2007 at Inspiration Point. Light sources include natural and anthropogenic. Figure Credit: NPS Natural Sounds and Night Skies Division.

Figure 4.2.4-4. Panoramic all-sky mosaic of all light sources on 8 May 2007 at Tropic Ditch Dump. Light sources include natural and anthropogenic. Figure Credit: NPS Natural Sounds and Night Skies Division.

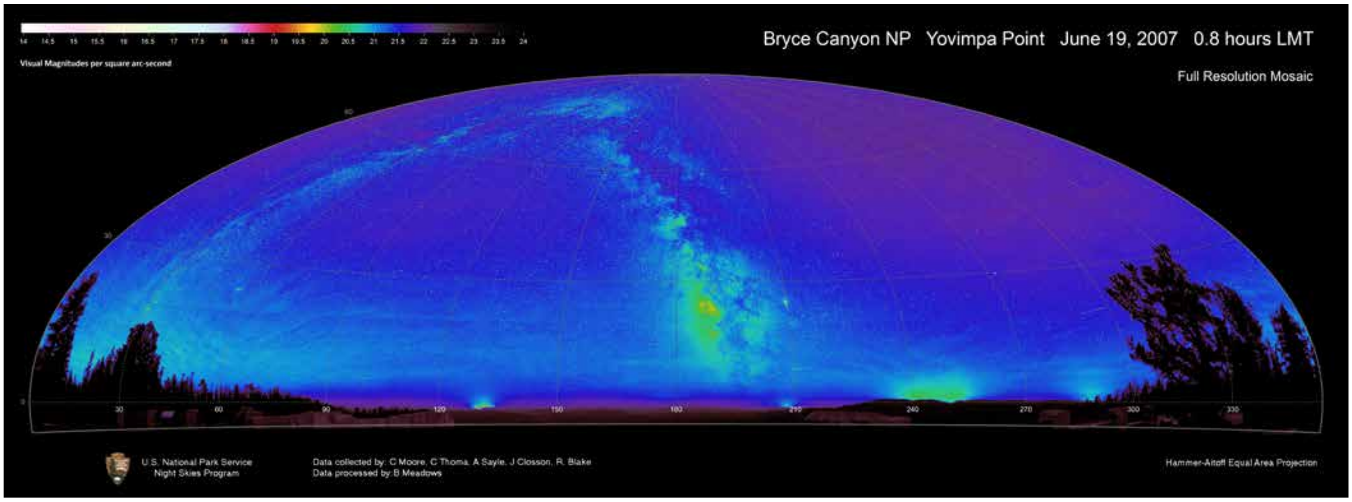


Figure 4.2.4-5. Panoramic all-sky mosaic of all light sources on 19 June 2007 at Yovimpa Point. Light sources include natural and anthropogenic. Figure Credit: NPS Natural Sounds and Night Skies Division.

to darker sky. Since all ALR measurements, modeled and ground-based, were less than 0.33, we consider this measure of sky brightness to be good. All ALR values were well below the threshold separating good and moderate concern. Confidence in this condition rating is medium since it was based on field data that are 10 years old. The data used in this assessment were collected on 10 nights over a five-year period, which is insufficient to determine trend; however, the data do indicate that the night sky condition was stable over the period during which measurements were collected.

Maximum Vertical Illuminance (milli-Lux)
Observed maximum vertical illuminance ranged from 0.37 to 0.72 milli-Lux (Table 4.2.4-1). After subtracting out the natural components specific to those measurements, the corresponding LPR is 14% and 20% brighter than average natural conditions, respectively Eight of the 10 monitoring dates 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; however, the data indicate stability this measure of brightness over the five-year period.

Horizontal Illuminance (milli-Lux)
Observed horizontal illuminance ranged from 0.62 to 1.00 milli-Lux (Table 4.2.4-1). After subtracting out the natural components specific to those measurements, the corresponding LPR for these values is 9% and 4% brighter than average natural conditions. The NPS Night Skies Program recommends a threshold of 0.8 milli-Lux, which was exceeded during three of the 10 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; however, the data indicate stability this measure of brightness over the five-year period.

Zenith Sky Brightness (msa)
Zenith sky brightness varied from 21.43 to 22.08 msa (Table 4.2.4-1). The corresponding LPR measurements for these values is 12% and < 10% brighter than average natural conditions. Data for seven of the monitoring dates indicate good condition, while data from three dates indicate moderate concern. We consider this measure of illuminance to be in good condition since the majority of data indicate good condition. We assigned medium confidence to this condition rating since the most recent field data were collected 10 years ago.

Bortle Dark Sky Class
NPS Night Skies Program observers estimated the night sky quality on six of the 10 monitoring dates (Table 4.2.4-1). Observers estimated sky quality to class 2 on five nights and class 3 on one night. Bortle Class 2 corresponds to a typical dark sky and Class 3 corresponds to a rural sky. The Bortle Class designation is somewhat subjective depending on the observer, but was consistent on all nights of data collection. A Bortle Class 1-3 is considered good. We assigned medium confidence to this condition rating since this measure

is subjective and observer-dependent. Furthermore, the most recent data were collected 10 years ago. We could not determine trend based on these data, but they indicate unchanging conditions.

Overall Condition, Trend, Confidence, and Key Uncertainties

Overall, we consider the night sky at Bryce Canyon NP to be good with an unknown trend and medium overall confidence level in the condition rating. For a summary of indicators, measures, and their condition see Table 4.2.4-2. The overall condition rating and confidence level were based on the three measures for which condition thresholds have been developed. These measures were all-sky light pollution ratio, zenith sky brightness, and the Bortle Dark Sky Class designation.

Those measures for which confidence in the condition rating was high were weighted more heavily in the overall condition rating than measures with medium confidence. None of the measures were assigned low confidence. Factors that influence confidence level include age of the data (<5 years unless the data are part of a long-term monitoring effort), repeatability, field data vs. modeled data, and whether data can

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

Indicators of Condition	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Sky Brightness	All-sky Light Pollution Ratio (ALR)	(green circle)	Modeled data shows a park-wide median ALR of 0.12, a wilderness ALR of 0.11, and a non-wilderness ALR of 0.13. Ground based ALRs varied from < 0.04 to 0.13. These data indicate good condition. Confidence in this condition rating is medium since the most recent field data is ten years old. We did not assign a trend; however, the data do indicate that the night sky condition was stable over the period during which measurements were collected.
	Vertical Maximum Illuminance (milli-Lux)	(dashed circle)	Observed maximum vertical illuminance ranged from 0.37 to 0.72 milli-Lux. Eight of the 10 monitoring dates exceeded the NPS Night Skies Program recommendation of 0.4 milli-Lux; however, since there are no reference condition thresholds, we did not assign a condition for this measure. Confidence is low due to lack of reference conditions. We could not determine trend, but the data indicate stability this measure of brightness over the five-year period during which measurements were collected.
	Horizontal Illuminance (milli-Lux)	(dashed circle)	Observed horizontal illuminance ranged from 0.62 to 1.00 milli-Lux. The NPS Night Skies Program recommends a threshold of 0.8 milli-Lux, which was exceeded during three of the 10 monitoring dates. However, since there are no reference condition thresholds, we did not assign a condition for this measure. Confidence is low due to lack of reference conditions. We could not determine trend, but the data indicate stability this measure of brightness over the five-year period during which measurements were collected.
	Zenith Sky Brightness (MSA)	(green circle)	Zenith sky brightness varied from 21.43 to 22.08 msa. Data for seven of the monitoring dates indicate good condition, while data from three dates indicate moderate concern. We consider this measure of illuminance to be in good condition since the majority of data indicate good condition. We assigned medium confidence to this condition rating since the most recent field data is 10 years old.
Sky Quality	Bortle Dark Sky Class	(green circle)	Observers estimated sky quality to Class 2 on five nights and Class 3 on one night. Bortle Class 2 corresponds to a typical dark sky and Class 3 corresponds to a rural sky. A Bortle Class 1-3 is considered good. We assigned medium confidence to this condition rating since this measure is subjective and observer-dependent. Furthermore, the most recent data were collected 10 years ago. We could not determine trend based on these data, but they indicate unchanging conditions.
Overall Condition, Trend, and Confidence Level		(green circle)	Overall, we consider the night sky at Bryce Canyon NP to be good with an unknown trend and medium overall confidence level in the condition rating. The all-sky light pollution ratio, zenith sky brightness, and the Bortle Dark Sky measures are in good condition. The condition for the remaining two measures are unknown since thresholds have not been established by the NPS Night Skies Program. Confidence in the overall condition rating is medium since the most recent data were collected 10 years ago. We could not determine overall trend based on these data.

be extrapolated to other areas in the park. All three measures were assigned medium confidence since the most recent field data were collected ten years ago (i.e., 2007). The data used in this assessment were collected on 10 nights over a five-year period, which is insufficient to determine trend. However, over time, and in conjunction with other measurements, these data will provide a robust dataset with which to monitor and assess the night sky environment at Bryce Canyon NP.

Regional and Local Context

Bryce Canyon NP preserves a dark night sky rarely found elsewhere. Park staff are committed to long-term monitoring of night skies in addition to continuing outreach and education programs that highlight the park's nocturnal landscape (NPS 2014a). Bryce Canyon NP 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, more than anywhere else in the world (CPDSC 2017). The low population density of the region coupled with good air quality and the 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 2016b). As a result of increased population growth, there has been an overall increase in outdoor lighting in local communities and regional cities (NPS 2014a). Lights from within the park itself also influence the quality of the night sky but many of them have been or will be retrofitted to comply with IDA standards (NPS 2014a). Additional threats include the transport of air pollutants and nighttime air traffic as well as lights from the Alton Coal Project located 12 mi (19 km) southwest of the park (NPS 2014a). Although the park has little control over regional air and light pollution, the park is committed to providing educational opportunities that highlight the importance of dark night skies and developing partnerships with nearby communities to implement energy conservation strategies that will minimize light pollution within the park (NPS 2014a).

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. Subject matter review experts are listed in Appendix B.

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, 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 sounds. While the severity of impacts varies 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

Figure 4.3.1-1. Sunrise in Bryce Canyon NP provides solitude for park visitors. Photo Credit: © Brian B. Roanhorse.

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 (Shannon et al. 2015, McLaughlin and Kunc 2013). An interesting recent publication showed that even plant communities can be adversely affected by noise because key dispersal species avoid certain areas (Francis et al. 2012).

Bryce Canyon National Park's (NP) backcountry and wilderness areas provide an increasingly rare opportunity for visitors to experience a natural soundscape. In 1975, approximately 46% of the park was recommended for inclusion in the national wilderness preservation system (NPS 2014a). The park's wilderness character coupled with its proximity to Las Vegas, Nevada provides a unique opportunity for park staff to engage numerous visitors in appreciating and preserving the park's natural soundscape through interpretive programs and guided hikes (NPS 2014a). As visitation increases however, the park's natural soundscape has become increasingly threatened by noise from air tours, commercial jets, tour buses, shuttle buses, recreational vehicles, and motorcycles (NPS 2014e).

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.

Summary of Previous Soundscape Monitoring Efforts

In 1980, Foch and Oliver (1980) conducted the first study of Bryce Canyon NP's acoustic environment. They found that human-caused noise in the park was minimal and that natural ambient sound levels were often below the noise floors of their monitoring equipment. While noise from aircraft was occasionally present, it had only a small effect on ambient sound levels in the park (Foch and Oliver 1980). In 1995, Foster and Bryant (1997) monitored sound levels at five locations in the park. The objective was to determine the proportion of time aircraft noise (e.g., fixed-wing, helicopters, and jets) was audible. They found that aircraft noise was audible an average of 19% of the time across the five sites but ranged from 29% at the frontcountry Fairyland site to only 11%

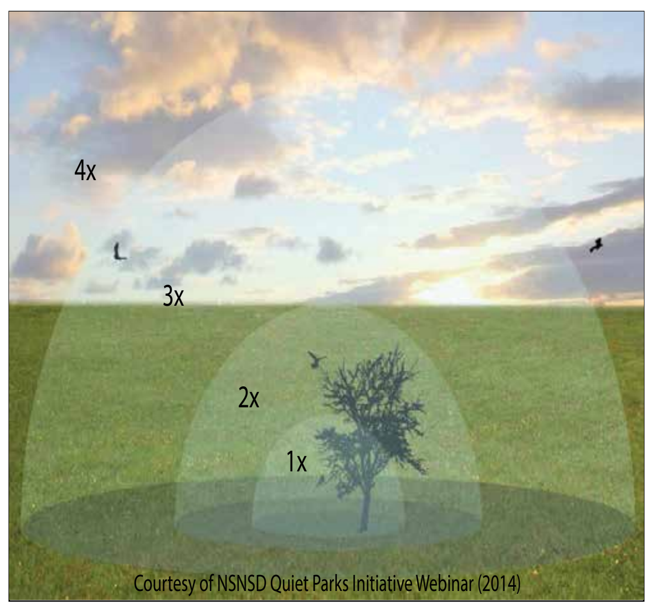


Figure 4.3.1-2. A 6 dB reduction in background noise level would produce a 4x increase in listening area. Figure Credit: © Ted E. Dunn.

at a backcountry site along the Bristlecone Loop Trail (Foster and Bryant 1997).

Several other efforts have investigated the effects of noise on the visitor experience (Fleming et al. 1998, Mace 2011) and wildlife, such as peregrine falcons (*Falco peregrinus*) (Haas et al. 2011, NPS 2011a) and prairie dogs (*Cnomys parvidens*) (Gandy 2011). Noise from aircraft and vehicles was found to significantly affect the visitor experience, with 25% of visitors expressing annoyance at hearing aircraft (Fleming et al. 1998). In another study, the longer aircraft was audible for test subjects, the great the annoyance and the lower the observer rated the scenic beauty, serenity, and naturalness of an area while viewing digital photographs of the park (Mace 2011).

The response of wildlife to noise was less clear. Noise from aircraft was the most frequently occurring source of noise near peregrine falcon territories and although peregrine falcons did not appear to exhibit sensitivity to aircraft noise, this type of noise may be a chronic stressor that could affect physiology and behavior (Haas et al. 2011). In another study, there was some evidence that prairie dogs responded to traffic traveling above 15 mph, especially if the vehicle was in close proximity to a burrow or was considered loud by the observer (Gandy 2011).

In 2000 the NPS initiated a soundscape monitoring program (NPS 2011a). Two sites were monitored during 2002 and 2003 during both summer (March-September) and winter (October-February) months (NPS 2011a). The results of this effort revealed that winter months were significantly quieter than summer months but that minimum sound levels were recorded at or near the noise floor of the monitoring equipment during all months regardless of season (NPS 2011a). In 2009 and 2010, 17 sites were monitored in support of the development of an air tour management plan and a soundscape management plan (NPS 2011a). These sites were also used in the study of sound effects on peregrine falcons described previously. Finally, during 2011 to 2013, soundscape monitoring equipment was deployed at least once at an additional 18 sites, five of which were monitored during the 2009-2010 effort (Stack 2013). According to Stack (2013), there are 41 soundscape monitoring sites in Bryce Canyon NP that are divided into three regions: frontcountry (26), backcountry (12), and amphitheater (3) (Stack 2013).

4.3.2. Data and Methods

For the purposes of this assessment, we focused on the acoustic monitoring sites that have been surveyed over several seasons and those sites located in areas of specific management concern (i.e., frontcountry vs. backcountry). In the park's soundscape monitoring database, each site and date combination was given a unique identifier and treated as a separate monitoring site. However, we considered sites that were located less than 50 m (164 ft) apart as the same site since the acoustic environment is not expected to vary much over that distance (NSNSD, E. Brown, acoustical resource specialist, e-mail message, 18 May 2017). We also only included those sites that were monitored during the summer season, which was designated as late April through mid-October. This is the period during which anthropogenic sounds are most likely to impact the visitor experience and wildlife. Furthermore, the winter monitoring dates were associated with the absence of the shuttle bus rather than true winter months (i.e., early April or late October to early November). This resulted in 25 sites.

Stack (2013) partitioned these acoustical monitoring sites into three zones. The zones were: frontcountry (n = 13), backcountry (n = 9), and amphitheater (n = 3) (Table 4.3.2-1). However, the draft soundscape management plan and environmental assessment describes the amphitheater as part of the frontcountry zone, so we included the three amphitheater sites in that zone (NPS 2015a). The frontcountry acoustic zone includes all roads, developed areas, overlooks along the rim, and the short hikes located in the amphitheater. In the frontcountry zone, human-caused noise is common, and visitors generally have a lower expectation of quiet in these areas than in wilderness areas. In the backcountry zone however, there is a greater expectation for the absence of human noise and the predominance of natural sounds. This zone includes all areas east of the road and below the rim, much of which has been recommended for inclusion in the national wilderness preservation system (NPS 2014a, NPS 2015a). Most locations were monitored for only one season, but three frontcountry sites and two backcountry sites were monitored over two or three seasons each. Figure 4.3.2-1 shows the 25 soundscape monitoring locations used to assess the park's soundscape.

Table 4.3.2-1. Subset of acoustical monitoring sites at Bryce Canyon NP.

Acoustic Zone	Site Name	Identifier	Year	Dates
Frontcountry	Inspiration	13	2009	6/4-7/1
	Inspiration	18	2010	5/11-6/7
	Sheep/ Swamp	7	2009	4/29-6/8
	Inspiration	14	2009	8/10-8/28
	Yovimpa	8	2009	4/30-6/3
	Yovimpa	19	2010	5/13-6/14
	Yovimpa	43	2013	9/26-10/4
	Bryce Creek-	29	2011	6/30-7/28
	Peek-a-Boo!	31	2011	8/4-9/19
	Farview	17	2010	4/15-5/11
	Paria	16	2010	4/12-5/12
	Sunset Point	25	2010	9/8-10/10
	Sunset Point	26	2011	5/19-6/23
	Sunset Point	33	2012	4/27-5/25
	VC Meadow/ Visitor's Center	24	2010	9/8-10/10
	VC Meadow/ Visitor's Center	42	2013	8/29-9/30
	Bryce Point	27	2011	5/20-5/29
	Lodge	28	2011	6/28-7/29
	Mixing Circle	30	2011	7/30-10/11
	Bryce Point Junction	39	2012	8/8-8/30
	Fairyland	36	2012	6/27-7/26
	Sunset Campground	35	2012	5/30-6/19
Backcountry	Paria	9	2009	8/5-8/13
	Yovimpa	12	2009	7/8-7/30
	Farview	22	2010	7/19-8/13
	Paria	20	2010	6/15-7/1
	Sheep/ Swamp	21	2010	6/18-7/7
	Yovimpa	23	2010	7/20-8/11
	Riggs Spring	34	2012	5/16-6/14
	Riggs Spring	40	2013	6/11-8/24
	Sheep Creek Flat	37	2012	6/28-7/26
	Yovimpa Pass	38	2012	8/3-8/22
	Yovimpa Pass	41	2013	7/18-9/12

% Time Above Reference Sound Levels

The percent time above reference sound levels is a measure of the amount of time that the sound level exceeds specified decibel values (NPS 2015a). Research into the effects of noise on wildlife is rapidly developing, and observed responses to noise sources and sound levels have been found across a variety of species. In a literature review of the effects of noise on wildlife, Shannon et al. (2015) found that responses to noise can include "altered vocal behavior to mitigate masking, reduced abundance in noisy habitats, changes in vigilance and foraging behavior, and impacts on individual fitness and the structure of ecological communities." Of the organisms studied, wildlife responses were observed at noise levels as low as 40 dBA, and further, 20% of studies documented impacts below 50 dBA. Human responses to sound levels can serve as a proxy for potential impacts to other vertebrates because humans have more sensitive hearing at low frequencies than most species (Dooling and Popper 2007). Table 4.3.2-2 summarizes sound levels that relate to human health and speech, as documented in the scientific literature.

The first, 35 dBA, is designed to address the health effects of sleep interruption. Recent studies suggest that sound events as low as 35 dBA can have adverse effects on blood pressure while sleeping (Haralabidis 2008). The second value addresses the World Health Organization's recommendations that noise levels inside bedrooms remain below 45 dBA (Berglund et al. 1999). The third value, 52 dBA, is based on the United States Environmental Protection Agency's (USEPA) speech interference threshold for speaking in a raised voice to an audience at 10 meters (32.8 feet) (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 meter (3.3 feet). Hikers and visitors viewing scenic vistas in the park would likely be conducting such conversations. For each of the 25 locations we reported the percent time above reference sound levels for both day (7:00 am to 7:00 pm) and night (7:00 pm to 7:00 am) in each acoustic zone.

% 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

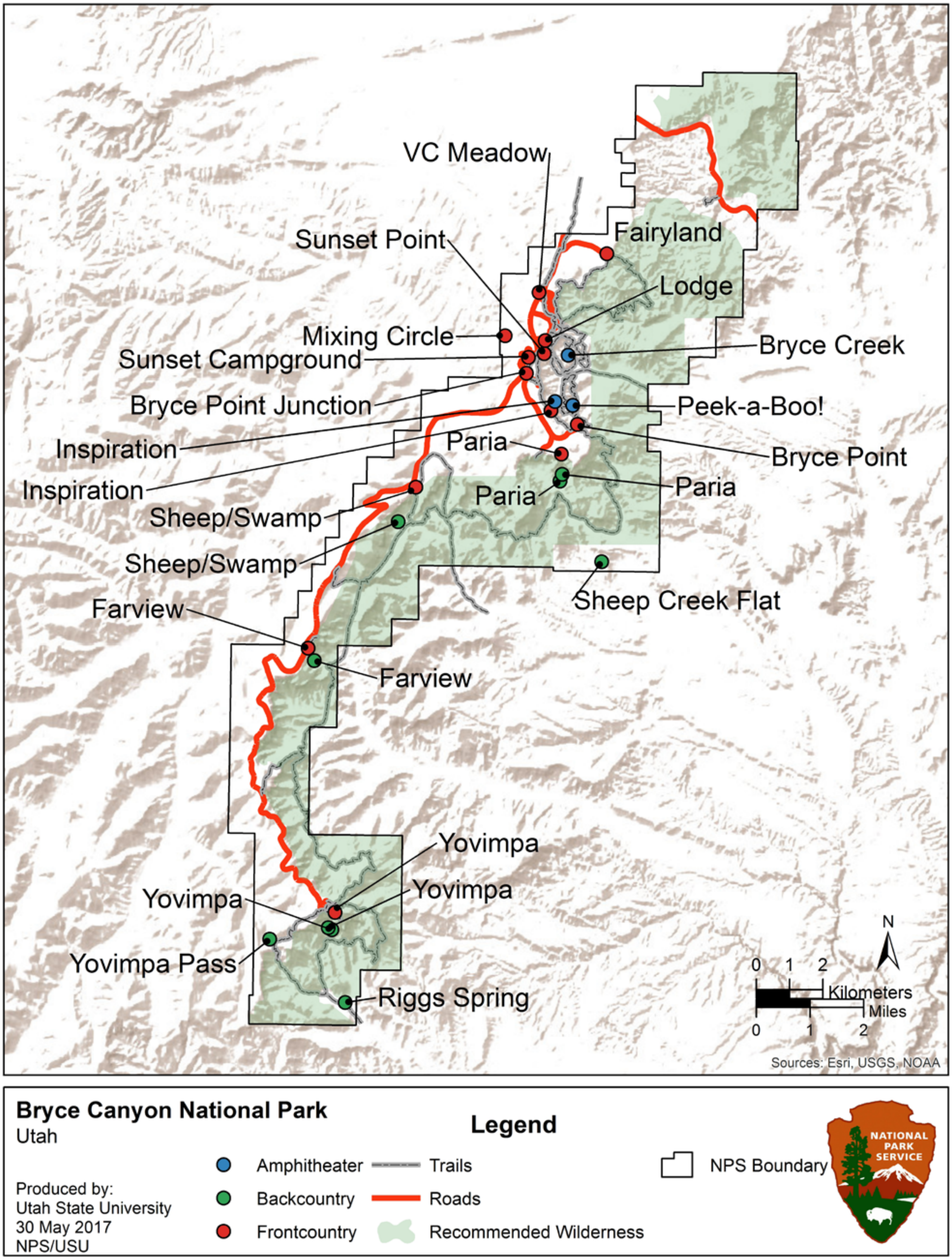


Figure 4.3.2-1. **Locations of acoustical monitoring sites at Bryce Canyon NP.**

Table 4.3.2-2. Sound level values related to human health and speech (NPS 2013).

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)

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.

We calculated the percent reduction in listening area from natural ambient sound level to existing ambient sound level for the 20 sites for which there were data. Natural ambient sound level refers to all naturally occurring sounds and excludes all anthropogenic noise. Existing ambient sound level includes all sounds in a given area, natural and anthropogenic. These metrics were reported as the level of sound that was exceeded fifty percent of the time at a given location, or L_{50} (NPS 2011a).

% Time Audible

Percent time audible is the amount of time that various sound sources are audible to humans with normal hearing. It is a measure that correlates well with visitor complaints of excessive noise and annoyance. Most noise sources are audible to humans at lower levels than virtually all wildlife species. Therefore, percent time audible is a protective proxy for wildlife. Park staff "analyzed a selected subset of audio samples (eight days per site) to identify durations and sources of audible sound...Two hours (10 seconds every 2 minutes) of each sub-sampled day was listened to and coded with audible sounds by acoustic technicians" (NPS 2011a). The percent time noise was audible was calculated for both day and night for each acoustic zone across 23 sites. In addition, percent time audible was partition by noise source (i.e., people, vehicles, jets, helicopters, and fixed-wing aircraft) for each zone.

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 thresholds for good, moderate concern, and significant concern conditions by acoustic zone for each of the four measures.

Table 4.3.3-1. Reference conditions used to assess the sound levels at Bryce Canyon NP.

Indicator	Measure	Management Zone	Good	Moderate Concern	Significant Concern
Sound Level	% Time Above Reference Sound Levels	Frontcountry	The majority of sound levels recorded were ≤ 52 dBA during the day and ≤ 45 dBA at night.	The majority of sound levels recorded were > 52 dBA during the day and > 45 dBA at night.	The majority of sound levels recorded were > 52 dBA during the day and > 45 dBA at night.
	% Time Above Reference Sound Levels	Backcountry	The majority of sound levels recorded were ≤ 45 dBA during the day and ≤ 35 dBA at night.	The majority of sound levels recorded were > 45 dBA during the day and > 35 dBA at night.	The majority of sound levels recorded were > 45 dBA during the day and > 35 dBA at night.
	% Reduction in Listening Area*	Frontcountry	Listening area was reduced by ≤ 50% over natural ambient sound levels.	Listening area was reduced by > 50% over natural ambient sound levels.	Listening area was reduced by > 50% over natural ambient sound levels.
	% Reduction in Listening Area*	Backcountry	Listening area was reduced by ≤ 30% over natural ambient sound levels.	Listening area was reduced by > 30% over natural ambient sound levels.	Listening area was reduced by > 30% over natural ambient sound levels.
Audibility of Anthropogenic Sounds	% Time Audible	Frontcountry	The hourly percent time extrinsic sounds were audible was < 50% during the day and < 30% at night.	The hourly percent time extrinsic sounds were audible was ≥ 50% during the day and ≥ 30% at night.	The hourly percent time extrinsic sounds were audible was ≥ 50% during the day and ≥ 30% at night.
	% Time Audible	Backcountry	The hourly percent time extrinsic sounds were audible was < 25% during the day and < 20% at night.	The hourly percent time extrinsic sounds were audible was ≥ 25% during the day and ≥ 20% at night.	The hourly percent time extrinsic sounds were audible was ≥ 25% during the day and ≥ 20% at night.
Geospatial Model	L_{50} Impact*	Park-wide	≤ 1.5	1.5 - ≤ 3.0	>3

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

Reference conditions are more protective for the backcountry zone than for the frontcountry zone. From an ideal perspective, a good reference condition for the park's acoustical environment would be that ambient sounds are predominant, if not exclusive, throughout the entire park, despite the management zone designation. However, this is not possible since NPS also has a mandate to provide visitor opportunities, which is why areas throughout the park have been specifically prescribed a certain type of management zone where more noise is acceptable and sometimes may even be the prominent sound depending upon time of day and season (NPS 2011a). For this reason, it is important to view indicators in the context of not only how loud, long, or frequently they occur, but also where and when they occur (Rossman 2004). The draft soundscape management plan and environmental assessment provides a suite of indicators and thresholds for evaluating the soundscape in each of the two management zones (NPS 2015a). While these indicators and thresholds provide a basis for evaluating current condition of the soundscape at Bryce Canyon NP, many thresholds could not be used in this assessment since the data were not analyzed according to the standards outlined in the draft management plan (NPS 2015a). Therefore, we relied on the current standard set of indicators and measures provided by the NPS Natural Sounds and Night Skies Division (NSNSD) and used the reference conditions for the preferred alternative of the environmental assessment as a general guide.

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

We used decibel levels presented in Table 4.3.2-2 as thresholds to separate reference conditions for the two acoustic zones (USEPA 1974, Berglund et al. 1999, and Haralabidis et al. 2008). If the majority of sounds were equal to or less than 52 dBA during the day and 45 dBA at night in the frontcountry, then we considered the condition to be good. If sound levels in the backcountry were equal to or less than 45 dBA during the day and equal to or less than 35 dBA at night, then we considered the condition to be good. If these thresholds were not met, then we considered the condition to warrant moderate to significant concern.

% Reduction in Listening Area

Bryce Canyon NP is considered a non-urban park, or park with at least 90% of their land located outside an urban area. Parks outside an urban area are usually quieter and more susceptible to noise intrusions (Turina et al. 2013). Visitors likely have a greater expectation for quiet at non-urban parks and wildlife are likely more adapted to a noise-free environment. Therefore, the thresholds separating reference conditions for non-urban parks are more stringent than for those located in urban areas. A reduction in listening area of no more than 30% would indicate good condition in the backcountry acoustic zone, while a no more than 50% reduction in listening area would be considered good in the frontcountry acoustic zone (Turina et al. 2013, NPS 2015a). If conditions exceeded these thresholds, then this measure would warrant moderate to significant concern.

% Time Audible

We considered this measure to be in good condition if the dominant sounds in the backcountry were natural (i.e., < 25% extrinsic noise during the day and < 20% extrinsic noise at night). While some anthropogenic noise is expected, it generally does not interfere with the natural soundscape. In contrast, if the dominant sounds are from anthropogenic sources, then we consider this measure to warrant moderate to significant concern in backcountry areas. For the frontcountry acoustic zone, the threshold for good condition was less stringent at < 50% extrinsic sounds during the day and < 30% extrinsic sounds at night.

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

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

4.3.4. Condition and Trend

% Time Above Reference Sound Levels

Figures 4.3.4-1 through 4.3.4-4 show the percent time sound levels were above reference sound levels for the frontcountry and backcountry zones during day

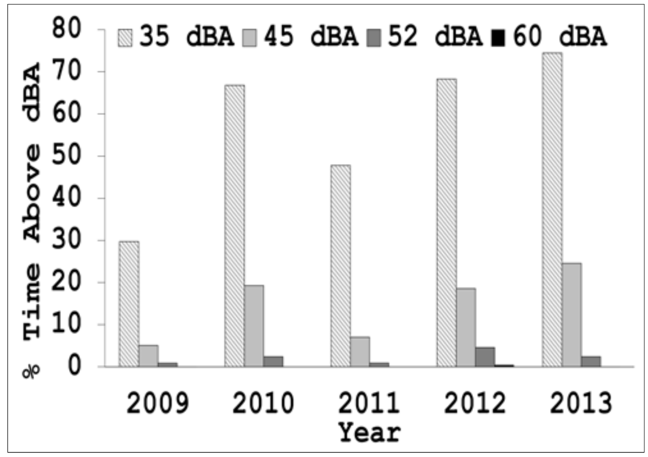


Figure 4.3.4-1. Percent time above reference sound levels during the day in the frontcountry acoustic zone.

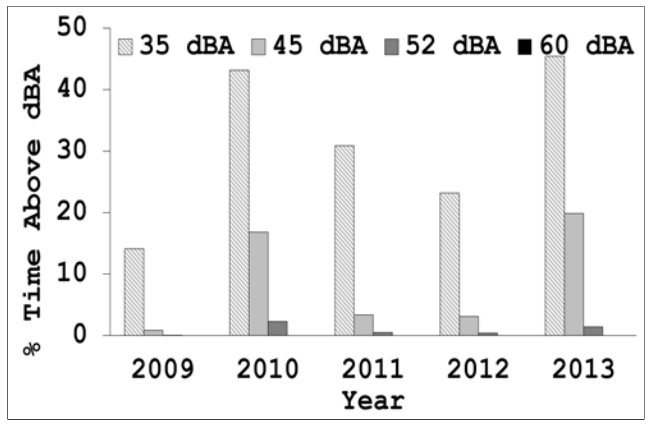


Figure 4.3.4-2. Percent time above reference sound levels at night in the frontcountry acoustic zone.

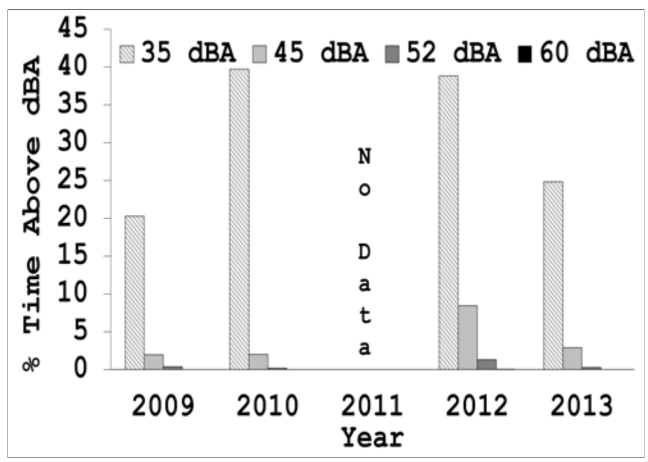


Figure 4.3.4-3. Percent time above reference sound levels during the day in the backcountry acoustic zone.

(7 a.m. - 7 p.m.) and night (7 p.m. - 7 a.m.) hours. During the day at frontcountry sites, the percent time above reference sound levels has increased slightly over time, particularly at 35 dBA (Figure 4.3.4-1). For all years, the percent time above 35 dBA was greater

than 50% but was much lower for 45 dBA, and the percent time above rarely exceeded 52 dBA. At night, there was no trend in the percent time above reference sound levels because of high inter-annual variability (Figure 4.3.4-2). For the majority of time, sound levels at night did not exceed 35 dBA. Since both day and night reference conditions were met, this measure is in good condition.

In the backcountry, the majority of daytime sound levels did not exceed 35 dBA and rarely exceeded 45 dBA (Figure 4.3.4-3). With only four years of data, trend could not be determined although it appears that the proportion of time above 35 and 45 dBA peaked in 2010 and then declined. These data indicate good daytime conditions for the backcountry zone. Nighttime backcountry sound levels exceed 35 dBA an average of 25% of the time over the four years for which there were data, but in 2009 and 2012 the percent time above 35 dBA approached 50% (Figure 4.3.4-4). However, since the majority of time sound levels were below 35 dBA, we consider the condition to be good.

Overall, we consider this measure to be in good condition for both the frontcountry and backcountry acoustic zones. Confidence in these condition ratings is high given the size of the dataset and multiple years over which data were collected. The trend for the frontcountry zone has deteriorated slightly, at least during the day. There was no trend for the remaining data. Data for individual sites is provided in Appendix E.

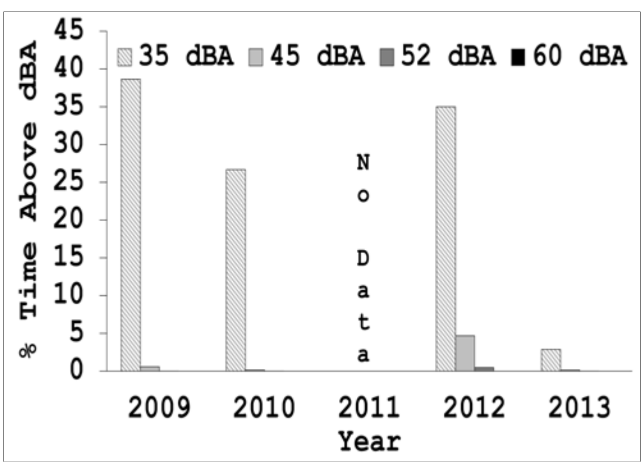


Figure 4.3.4-4. Percent time above reference sound levels at night in the backcountry acoustic zone.

% Reduction in Listening Area

As expected, the reduction in listening area was greater in the frontcountry zone than in the backcountry zone (Figure 4.3.4-5). In both zones however, the reduction in listening area has increased over time, but it is important to note that there were no data for backcountry sites in 2011 and in the frontcountry, only two locations were monitored in 2011 and 2013 (see Appendix E for data on individual sites). On average, the reduction in listening area exceeded 50% during all years in the frontcountry, which warrants moderate to significant concern. In the backcountry, the reduction in listening area exceeded 30% in 2012 and 2013 but not in 2009 or 2010. However, the reduction in listening area during 2010 was 28%. Therefore, we consider this measure to warrant moderate to significant concern for the backcountry acoustic zone. Confidence in these condition ratings is high given the size of the dataset and multiple years over which data were collected. The trend indicates deteriorating conditions.

% Time Audible

The results of off-site listening showed that the proportion of time extrinsic sounds were audible during 2009-2013 was greater during the day (82%) than at night (61%) and increased over time (Figure 4.3.4-6). However, only two sites were monitored in 2012 and only one site was monitored in 2013. Still, there is an increasing trend from 2009 to 2011 when four to six sites were monitored per year. Noise from vehicles (47%), people (14%), and jets (16%) over the five years accounted for the largest noise sources in the frontcountry, while fixed-wing aircraft (1%) and helicopters were rarely audible (< 1%). Because extrinsic sounds were audible more than 50% of the

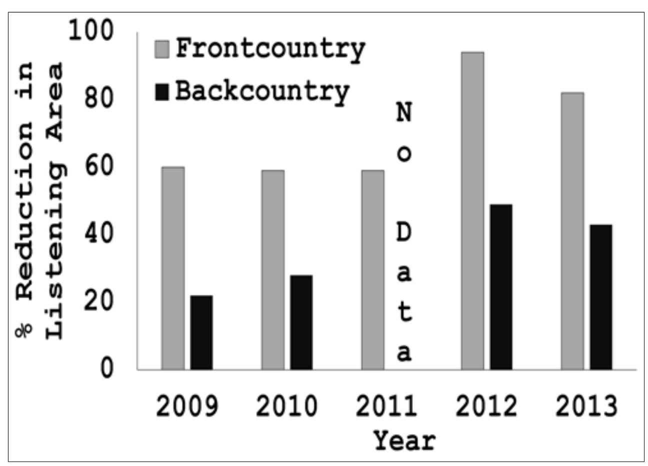


Figure 4.3.4-5. Percent reduction in listening area.

time during the day and more than 30% of the time at night, this measure warrants significant concern for the frontcountry zone.

In the backcountry zone, there were fewer extrinsic noise intrusions. Extrinsic noise was audible an average of 30% during the day and 20% at night during 2009-2013, which indicates moderate to significant concern during both day and night (Figure 4.3.4-7). Average data nighttime noise is on the cusp of good condition; however, data from 2012 and 2013 show that extrinsic sounds were audible approximately 30% of nighttime hours. Jets were audible 21% of the time and fixed-wing aircraft were audible 10% of the time during the five-year period (no data for 2011). Helicopters were rarely audible (0.5%). Overall, extrinsic noise increased over time, but as already stated, this is based on a limited number of sites (see Appendix E for data on individual sites).

Overall, the percent time audible exceeded reference conditions for both day and night in the frontcountry and backcountry zones. Therefore, this measure warrants moderate to significant concern. Confidence in these condition ratings is high given the size of the dataset and multiple years over which data were collected. The trend indicates deteriorating conditions.

L_{50} Impact

Figure 4.3.4-8 shows the modeled mean impact sound level map for the park. The modeled mean impact was 1.7 dBA above natural conditions but ranged from 0 dBA in the least impacted areas to 13.1 dBA in the most impacted areas. The map depicts the area most influenced by human-caused sounds (i.e., lighter areas). The existing and natural acoustic environment condition maps for the park are included in Appendix E.

Summary statistics of the L_{50} values for the natural, existing, and impact conditions are provided in Table 4.3.4-1. Average values represent the average L_{50} value occurring within the park boundary, and since this value is a mean, visitors may experience sound levels higher and lower than the average L_{50}. A one decibel change is not readily perceivable by the human ear, but any addition to this difference could begin to impact a visitor's listening ability to hear natural sounds or interpretive programs.

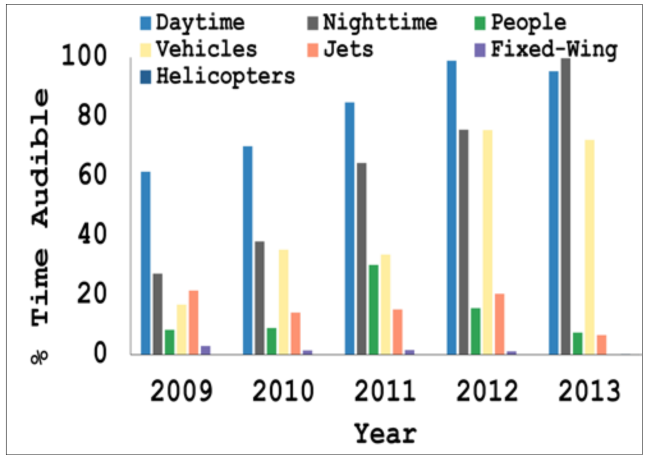


Figure 4.3.4-6. Results off-site listening for the frontcountry zone.

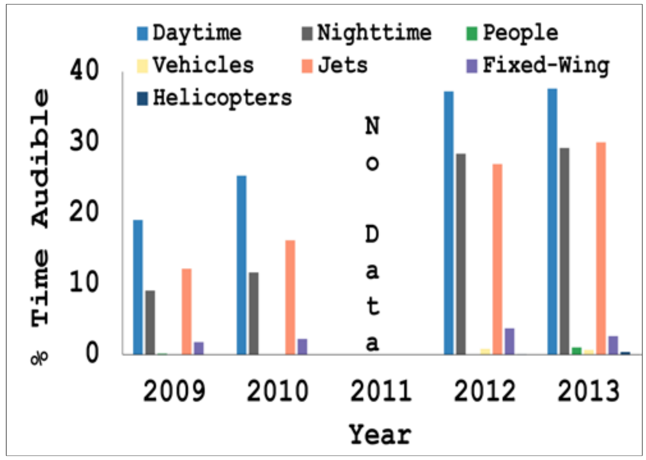


Figure 4.3.4-7. Results off-site listening for the backcountry zone.

Mennitt et al. (2013) suggest that in a natural environment, the average summertime L_{50}, which is the sound level exceeded half of the time (and is a fair representation of expected conditions) is not expected to exceed 41 dBA. However, acoustical conditions vary by area and depend on vegetation, landcover, elevation, climate, and other factors (Mennitt et al. 2013). Any one place may be above or below this average depending on these and other variables. Mennitt et al. (2013) also state that "an impact of 3 dBA suggests that anthropogenic noise is noticeable at least 50% of the hour or more." The modeled median impact result for the park was 1.7 dBA, which warrants moderate concern 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.

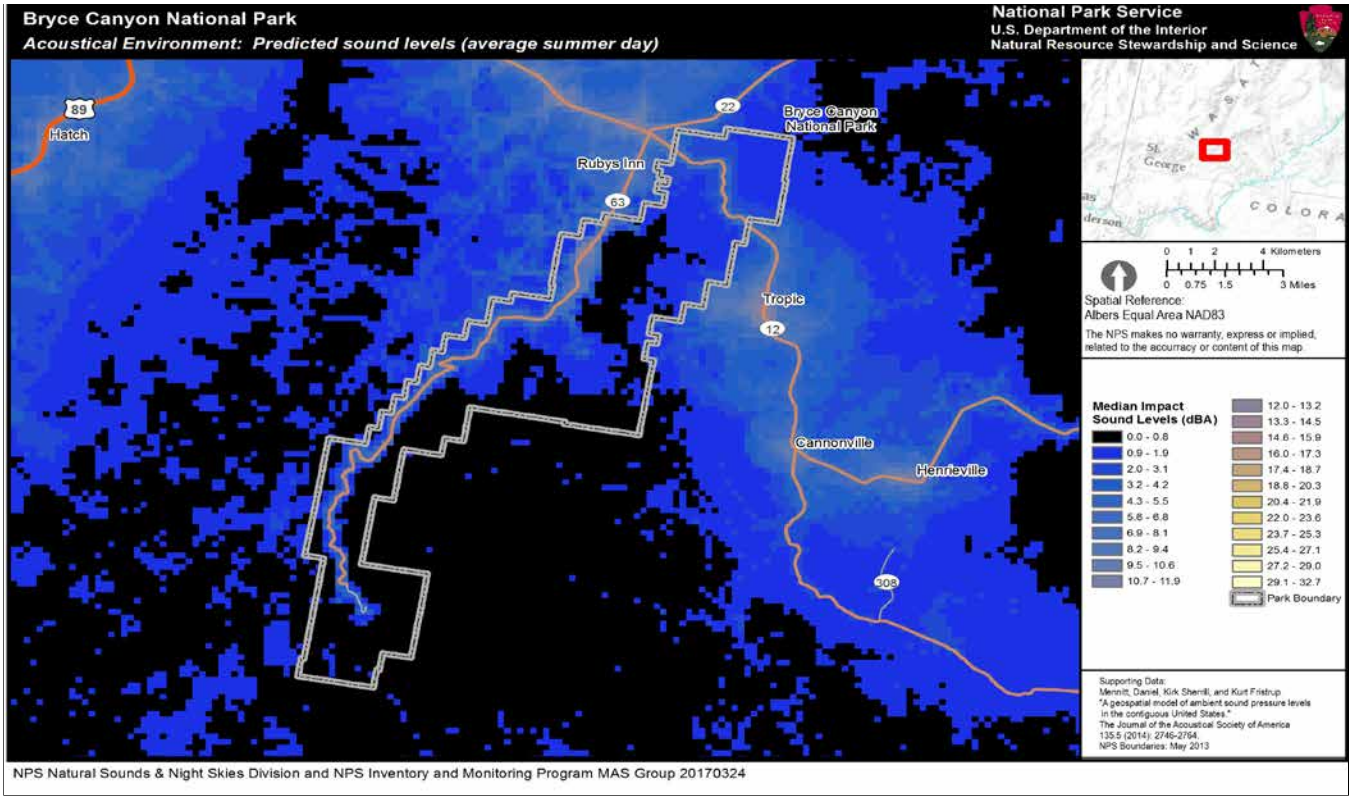


Figure 4.3.4-8. The modeled L_{50} impact sound level at Bryce Canyon NP. Lighter colors represent higher impact areas. Figure Credit: Emma Brown, NPS NSNDS.

Overall Condition, Trend, Confidence Level, and Key Uncertainties

Overall, we consider the soundscape at Bryce Canyon NP to warrant moderate to significant concern with a deteriorating trend. Confidence in the condition rating is high. This condition rating was based on three indicators with a total of four measures, which are summarized in Table 4.3.4-2. In sum, noise levels were greater at night than during the day, and most noise was attributed to vehicles in the frontcountry and jets in the backcountry, although other sources of noise, including people and fixed-wing aircraft were also audible. Anthropogenic noise dominated the park's soundscape, but the proportion of time decibels were above reference conditions was relatively low, especially for sounds greater than 45 dBA, which indicated good condition, but this was the only measure in good condition.

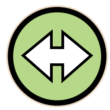
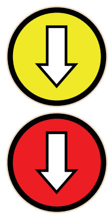
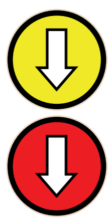
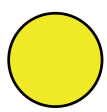
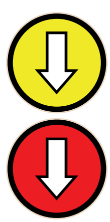
Those measures for which confidence in the condition rating was high were weighted more heavily in the overall condition rating than measures with medium confidence. None of the condition ratings were assigned low confidence. Factors that influence confidence in the condition rating include age of the data (<5 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 of the park. Only one of the four measures, L_{50} impact, was given a medium confidence rating since it was based on modeled data. Although we assigned this measure medium confidence, the model provides a useful map of how sound may vary across the park. The remaining measures were assigned high confidence since they were based on field data, were collected at 25 sites over a five year period, and were collected relatively recently (i.e., within 5 years). The data for at least two measures (% reduction in listening area and % time audible) indicate deteriorating conditions in the park's soundscape, but this trend should be

Table 4.3.4-1. Summary of the modeled minimum, maximum, and average L_{50} measurements in Bryce Canyon NP.

Acoustic Environment	Min. (dBA)	Max. (dBA)	Avg. (dBA)
Natural	25.7	31.2	29.0
Existing	25.7	42.1	30.6
Impact	0.0	13.1	1.7

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

Table 4.3.4-2. 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		For all years, the percent time above rarely exceeded 52 dBA during the day and 45 dBA at night in the frontcountry. In the backcountry, the majority of daytime sound levels did not exceed 35 dBA and rarely exceeded 45 dBA. Nighttime backcountry sound levels exceed 35 dBA an average of 25% of the time over the four years for which there were data. Confidence in these condition ratings is high given the size of the dataset and multiple years over which data were collected. The trend for the frontcountry zone has deteriorated slightly, at least during the day. There was no trend for the remaining data.
	% Reduction in Listening Area		On average, the reduction in listening area exceeded 50% during all years in the frontcountry, which warrants moderate to significant concern. In the backcountry, the reduction in listening area exceeded 30% in 2012 and 2013 but not in 2009 or 2010. However, the reduction in listening area during 2010 was 28%. Therefore, we consider this measure to warrant moderate to significant concern for the backcountry acoustic zone as well. Confidence is high given the size of the dataset and multiple years over which data were collected. The trend indicates deteriorating conditions.
Audibility of Anthropo-genic Sounds	% Time Audible		In the frontcountry, extrinsic sounds were audible 82% of the time during the day and 61% of the time at night during 2009-2013. In the backcountry, extrinsic noise was audible an average of 30% of the time during the day and 20% of the time at night from 2009-2013. Overall, the % time audible exceeded reference conditions for both day and night in both zones. Therefore, this measure warrants moderate to significant concern. Confidence is high given the size of the dataset and multiple years over which data were collected. The trend indicates deteriorating conditions.
Geospatial Model	L_{50} Impact		The modeled mean impact sound level map for the park was 1.7 dBA above natural conditions but ranged from 0 dBA in the least impacted areas to 13.1 dBA in the most impacted areas. Since the modeled median impact results for the park was above 1.5 and below 3.0, the L_{50} Impact warrants moderate concern. Confidence is medium. Trend could not be determined.
Overall Condition, Trend, and Confidence Level			Overall, we consider the soundscape at the national park to warrant moderate to significant concern. Noise levels were greater during the day than at night, and extrinsic noise was high, especially from vehicles (frontcountry) and jets (backcountry). Although anthropogenic noise dominated the park's soundscape, the proportion of time decibels were above reference conditions was relatively low, especially for sounds greater than 45 dBA. Lastly, the geospatial model indicates moderate concern across the park. Trend in sound levels had deteriorated and confidence in the condition rating is high.

interpreted with caution since some years were based on only a few or even a single location.

Few sites have been monitored for more than one or two seasons, yet there are 41 total monitoring sites. While data from multiple locations is useful, it would also be informative to establish long-term monitoring at the same site. Monitoring fewer sites over a longer period of time would allow for more accurate trend analysis. Natural ambient conditions are likely to remain the same since the last monitoring period, but existing ambient sound levels (which includes natural and human-caused sounds) could have changed since the last monitoring inventory was conducted in 2013.

The completion of the soundscape management plan would help guide management of the park's soundscape. A review and selection of a subset of site locations would also help manage the large amount of data and key into those sites that are most useful for monitoring in the long-term.

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

Most anthropogenic sounds in the frontcountry were associated with noise produced inside the park (i.e., vehicles), while noise in the backcountry was largely produced outside the park (i.e., jets and fixed-wind aircraft). Perhaps jets were more audible in backcountry areas because there is less masking by vehicles than in the frontcountry. Noise from air tours was also audible in the backcountry 10% of the time. Although this seems fairly low, individual events can be very disruptive to the visitor experience, especially in the backcountry where there is a greater expectation of quiet. Park visitors have identified noise from air tours as disruptive to their experience (Mace 2011). Not only is noise from air tours disruptive to the visitor experience, but the sound vibrations from air tours and other aircraft may affect sensitive geologic features (Moore et al. 2016).

The number of air tours has increased over the last several years. In 2013 there were 385 air tours reported for the park, but in 2016 there were 455 reported air tours (NSNSD, E. Brown, acoustical resource specialist, e-mail communication, 27 March 2017). This still only represents 12-15% of the more than 3,100 allowable air tours in the park. Since there are more than 50 air tours in the park per year, the Federal Aviation Administration (FAA) requires the NPS to develop an air tour management plan (FAA 2016). Some of the sites monitored in this study were established to develop this plan; however, it has not been completed to date and the park may instead develop a voluntary agreement with commercial air tour operators, which functions similarly to an air tour management plan but can be completed in a shorter amount of time (NSNSD, E. Brown, acoustical resource specialist, e-mail message, 24 March 2017).

In addition to air tours, general visitation has increased rapidly over the last several years, particularly in response to the 2016 centennial celebration of the NPS. From 2015 to 2016, visitation increased 25% to nearly 2.5 million visitors (NPS Public Use Statistics Office 2018). The increased number of visitors means more noise from vehicles and people in the frontcountry. Traffic and parking are significant management issues in the park (NPS 2014e). Several areas of particular concern were identified in the transportation plan environment assessment, including several of the overlooks, Bryce Canyon Lodge, and the entrance station (NPS 2014e). The park's shuttle bus, which runs from mid-April through the end of October, helps to alleviate some of the noise from traffic but also contributes to noise, especially at shuttle stops (NPS 2014e). Despite the shuttle, the park is often over vehicle carrying capacity during the summer, and vehicles routinely idle while waiting for a parking space (NPS 2014e). These issues are not unique to Bryce Canyon NP.

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

Several potentially noise-sensitive species reside in Bryce Canyon NP, including peregrine falcons (*Falco peregrinus*), northern goshawks (*Accipiter gentilis*), and prairie dogs (*Cynomys parvidens*) (NPS 2015a). Although there are recommendations for human exposure to noise, there are no guidelines 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).

Anthropogenic noise is not only intrusive, but it also decreases our capacity to hear natural sounds and is a growing concern in many natural areas (Buxton et al. 2017). A recent study revealed that anthropogenic noise has doubled in 63% of protected areas in the U.S. (Buxton 2016). Bryce Canyon NP staff has continued to collect sound data to further evaluate changes in the park's soundscape and possible effects anthropogenic noise may have on wildlife.

4.3.5. Sources of Expertise

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

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

Assessment author is Lisa Baril, biologist and science writer, Utah State University. Subject matter review experts are listed in Appendix B.

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). Bryce Canyon National Park (NP) is designated as a Class I 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, including in Bryce Canyon NP. Also, the park's Foundation Document points out that the quality of the air is critical to meeting a key park purpose mentioned in the Bryce Canyon NP enabling legislation: "preserving in their natural state the outstanding scenic features" (NPS 2014a). Park documents also discuss the importance of air quality in protecting the park's recommended wilderness, which includes almost 46% of the park's area (NPS 2014a).

Figure 4.4.1-1. A view of Bryce Canyon NP on a clear day. Photo Credit: NPS.

Air Quality Standards

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

The NPS' ARD (NPS-ARD) air quality monitoring program uses USEPA's NAAQS, natural visibility goals, and ecological thresholds as benchmarks to assess current conditions of visibility, ozone, and atmospheric deposition throughout Park Service areas.

Visibility affects how well (acuity) and how far (visual range) one can see (NPS-ARD 2002), but air pollution can degrade visibility. Both particulate matter (e.g. soot and dust) and certain gases and particles in the atmosphere, such as sulfate and nitrate particles, can create haze and reduce visibility.

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

Ozone is a gaseous constituent of the atmosphere produced by reactions of nitrogen oxides (NO_x) from vehicles, power plants, 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

Figure 4.4.1-2. A scenic view from the Rim Trail at Bryce Canyon NP. Photo Credit: NPS.

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 USEPA (2016b), in the United States, roughly two thirds of all sulfur dioxide (SO_2) and one quarter of all nitrogen oxides (NO_x) come from electric power generation that relies on burning fossil fuels. Sulfur dioxide and nitrogen oxides are released from power plants and other sources, and ammonia is released by agricultural activities, feedlots, fires, and catalytic converters. In the atmosphere, these transform to sulfate, nitrate, and ammonium, and can be transported long distances across state and national borders, impacting resources (USEPA 2016b), including at Bryce Canyon NP.

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 Bryce Canyon NP's airshed was developed by the NPS-ARD for use in Natural Resource Condition Assessments (NPS-ARD 2015a,b). NPS-ARD uses all available data from NPS, USEPA, state, and/or tribal monitoring stations to interpolate air quality values, with a specific value assigned to the maximum value within each park. Even though the data are derived from all available monitors, data 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.

<u>Haze Index</u>

Visibility 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 Bryce Canyon NP.

Additional (qualitative) visibility monitoring has occurred at Bryce Canyon NP, with a summary of all efforts presented in Table 4.4.2-1. Representative images from three of the photographic monitoring efforts are included in Appendix F.

Level of Ozone

Ozone is monitored across the U.S. through air quality monitoring networks operated by the NPS, USEPA, states, and others. Aggregated ozone data are acquired from the USEPA Air Quality System (AQS) database. Note that prior to 2012, monitoring data were also obtained from the USEPA Clean Air Status and Trends Network (CASTNet) database. There are no on-site or nearby representative monitors to assess human or vegetation health ozone trends.

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

The primary NAAQS for ground-level ozone is set by the USEPA, and is based on human health effects. The 2008 NAAQS for ozone was a 4th-highest daily maximum 8-hour ozone concentration of 75 parts per billion (ppb). On October 1, 2015, the USEPA strengthened the national ozone standard by setting the new level at 70 ppb (USEPA 2016a). The NPS-ARD assesses the status for human health risk from ozone using the 4th-highest daily maximum 8-hour ozone concentration in ppb. Annual 4th-highest daily maximum 8-hour ozone concentrations are averaged over a 5-year period at all monitoring sites. Five-year averages are interpolated for all ozone monitoring locations to estimate 5-year average values for the contiguous U.S. The ozone condition for human health risk at the park is the maximum estimated value within park boundaries derived from this national analysis.

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

Exposure indices are biologically relevant measures used to quantify plant response to ozone exposure. These measures are better predictors of vegetation response than the metric used for the human health standard. 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.

Table 4.4.2-1. Summary of visibility monitoring efforts at Bryce Canyon NP.

Date	Visibility Monitoring Description
11/1979 to 08/2001 (archived at NPS ARD office) 1984-1996 (online archive)	35 mm color slides were developed from camera film at a location 800 m (2,625 ft) south Rainbow Point of the Navajo Mountain view. Images of Navajo Mountain were taken three times per day at 9 am, 12 pm, and 3 pm from 11/1979 to 08/2001. Jim Cheatham, with the NPS Air Resources Division, confirmed that a nearly full photographic archive of 35 mm slides is physically housed in NPS Air Resources Division's second floor file cabinets (May 2017). He stated that "a few gaps are likely but the collection looks quite thorough." An online archive summary of some (1984-1996 only) of the Navajo Mountain images is located on IMPROVE's website at http://vista.cira.colostate.edu/Datawarehouse/IMPROVE/Data/Photos/BRCN/start.htm. Sites with over five years of data were selected to show a range of visual conditions, with representative images selected to showcase regional haze, layered haze, scenic, and historical scenes. A couple of photos from this effort for Bryce Canyon NP are included in Appendix F.
3/2/1988 - present	The IMPROVE aerosol monitoring site, BRCA1, UT, has been in operation since 3/2/1988. NPS Air Resources Division analyzes data annually. The current air quality condition for visibility is based on data collected at this monitor and data can be obtained online from https://nature.nps.gov/air/data/products/parks/index.cfm.
mid - 2000s - unknown	NPS ARD believes the camera for this monitoring effort was installed by the park, not Air Resource Specialists, Inc. (ARS), the contractor that works with NPS ARD. No additional details about this effort are known. NPS ARD suggested that the information may be housed at Bryce Canyon NP.
September 2013 - present	ARS installed a digital SLR camera system, optimized to monitor visual conditions and light pollution in night sky images near Yovimpa Point since September 2013 (ARS 2013). The purpose of the project was to establish baseline nighttime visibility conditions capturing night sky images of the light dome (sky region) over the Alton Coal Mine and St. George, Utah, southwest of the park. The images capture the direct light from the dome, as well as light scattered by haze and clouds in the dome. The current plan is to continue to operate the night sky and web (below) cameras as long as funding is available. As of May 2017, there are over 35,000 night sky photos. A representative photo is included in Appendix F.
2016 - present	Bryce Canyon NP is one of 19 national parks that comprise the NPS ARD Air Quality Web Camera Network. The camera at Bryce Canyon NP is located at Yovimpa Point, facing east, and current images can be viewed at https://www.nature.nps.gov/air/webcams/parks/brdacam/brdacam.cfm. The webcam image archive for Bryce Canyon NP is available at https://npgallery.nps.gov/AirWebCams/brda. The photographs provide a qualitative measure of daytime visibility, and the images are archived to provide a long-term record of visibility. NPS ARD is also currently working on methods to make semi-quantitative estimates of haze based on the photographs (but this is still a research product and has not yet been peer-reviewed as of May 2017). The webcam images are updated every 15 minutes and are linked to real-time air quality data (e.g. ozone measurements), providing a means to communicate air quality data along with the images, except for Bryce Canyon NP. The images at Bryce were not originally included in the Air Quality webcam network, but were simply archived, although ARD is uncertain as to the reasons why. Bryce Canyon NP is somewhat unique in that it does not have any real time air quality measurements available to display on the webcam page, just metadata. However, Bryce Canyon NP does have a night sky camera (described above), which none of the other parks have. ARD's goal is to add the night sky images to the webcam page. A couple of representative webcam photos are included in Appendix F.

Wet Deposition

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.

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. Monitoring data from the NADP-NTN UT99 site were used to determine the wet sulfur and nitrogen deposition trends at Bryce Canyon NP.

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.

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).

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 USEPA (USEPA 2016a) at a level to protect human health: 4th-highest daily maximum 8-hour ozone concentration of 70 ppb. The NPS-ARD rates ozone condition as: "good" if the ozone concentration is less than or equal to 54 ppb, which is in line with the updated Air Quality Index breakpoints; "moderate concern" if the ozone concentration is between 55 and 70 ppb; and of "significant concern" if the concentration is greater than or equal to 71 ppb.

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

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

ARD recommends a W126 of < 7 ppm-hrs to protect most sensitive trees and vegetation; this level is considered good; 7-13 ppm-hrs is considered to be of "moderate" concern; and >13 ppm-hrs is considered to be of "significant concern" (NPS-ARD 2015a).

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

Mercury
Ratings for mercury wet deposition and predicted methylmercury concentrations can be evaluated using the mercury condition assessment matrix shown in Table 4.4.3-2 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).

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).

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 (2.6 dv) for the park's visibility condition fell within the moderate concern condition rating, which indicates visibility is degraded from the good reference condition of <2 dv above the natural condition (NPS-ARD 2015a,b). For 2006-2015, the trend in visibility at Bryce Canyon NP 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% clearest days (excerpted from NPS-ARD 2017a). 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 4.4.4-4, 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 and organic carbon. On the haziest days, organic carbon, ammonium sulfate, and coarse mass 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-hour Concentration

Ozone data used for this measure were derived from estimated five-year (2011-2015) values of 68.1 parts per billion for the 4th highest 8-hour concentration, which resulted in a condition rating warranting moderate concern for human health (NPS-ARD 2017a). Trend could not be determined because there are not sufficient on-site or nearby 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-hour W126)

Ozone data used for this measure of the condition assessment were derived from estimated five-year (2011-2015) values of 13.2 parts per million-hours (ppm-hrs) for the W126 Index. Using these numbers, vegetation health risk from ground-level ozone warrants significant concern at Bryce Canyon NP (NPS-ARD 2017a). Trend could not be determined because there are not sufficient on-site or nearby monitoring data. Our level of confidence in this measure is medium because estimates are based on interpolated data from more distant ozone monitors.

Table 4.4.4-1. Condition and trend results for air quality indicators at Bryce Canyon NP.

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 (2.6) (2011-2015)	Moderate Concern (68.1) (2011-2015)	Significant Concern (13.2) (2011-2015)	Moderate Concern (1.7) (2011-2015)	Good (0.7) (2011-2015)	Significant Concern (5.8-10.1)* (2013-2015)	Good (0.05) (2013-2015)
Trends (2006-2015)	The trend in visibility improved on the 20% clearest days and improved on the 20% haziest days (IMPROVE Monitor ID: BRCA1, UT) (NPS 2017a). The trend in total wet nitrogen concentrations in rain and snow remained relatively unchanged (no statistically significant trend; NADP Monitor ID: UT99, UT) (NPS 2017a). The trend in total wet sulfur concentrations in rain and snow improved (NADP Monitor ID: UT99, UT) (NPS 2017a).						

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

* Note that to maintain the greatest level of protection, the higher deposition value of 10.1 was used to assess condition (NPS-ARD 2017b).

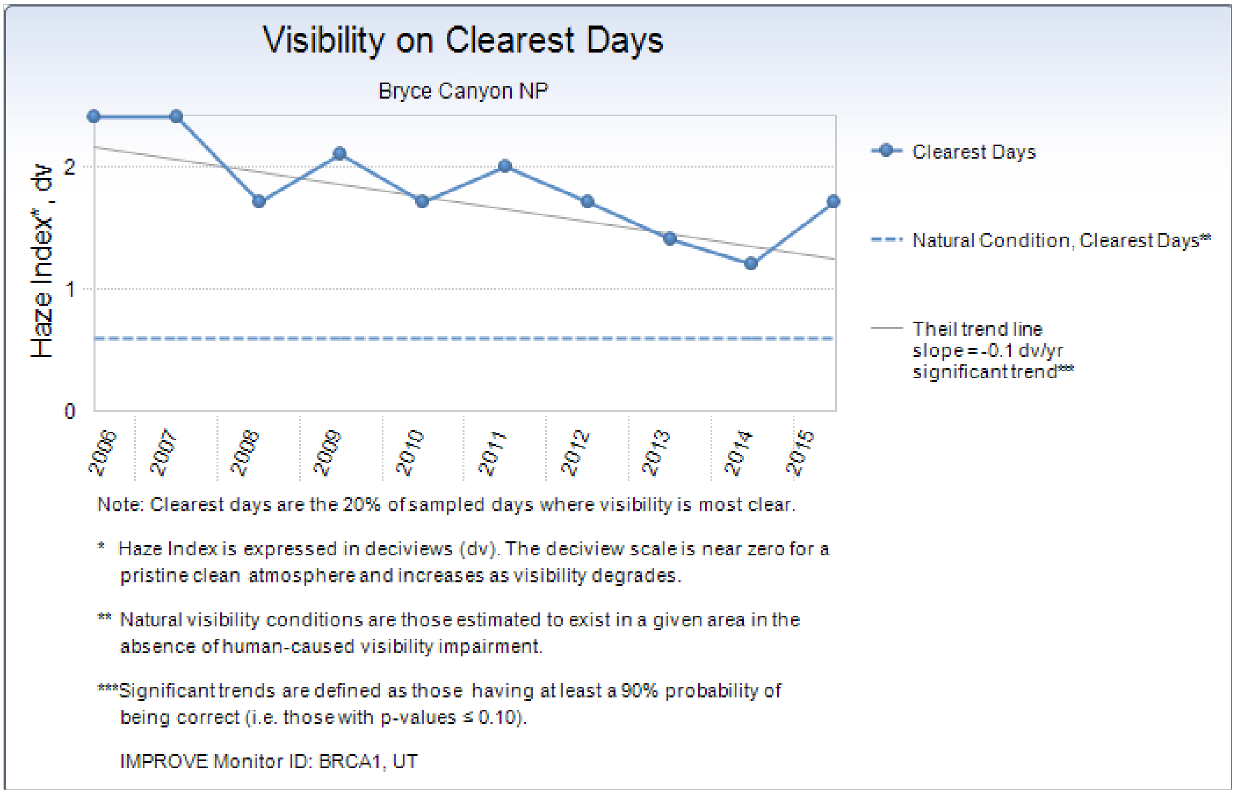


Figure 4.4.4-1. **For 2006-2015, the trend in visibility at Bryce Canyon NP improved on the 20% clearest days. Figure Credit: NPS-ARD 2017a.**

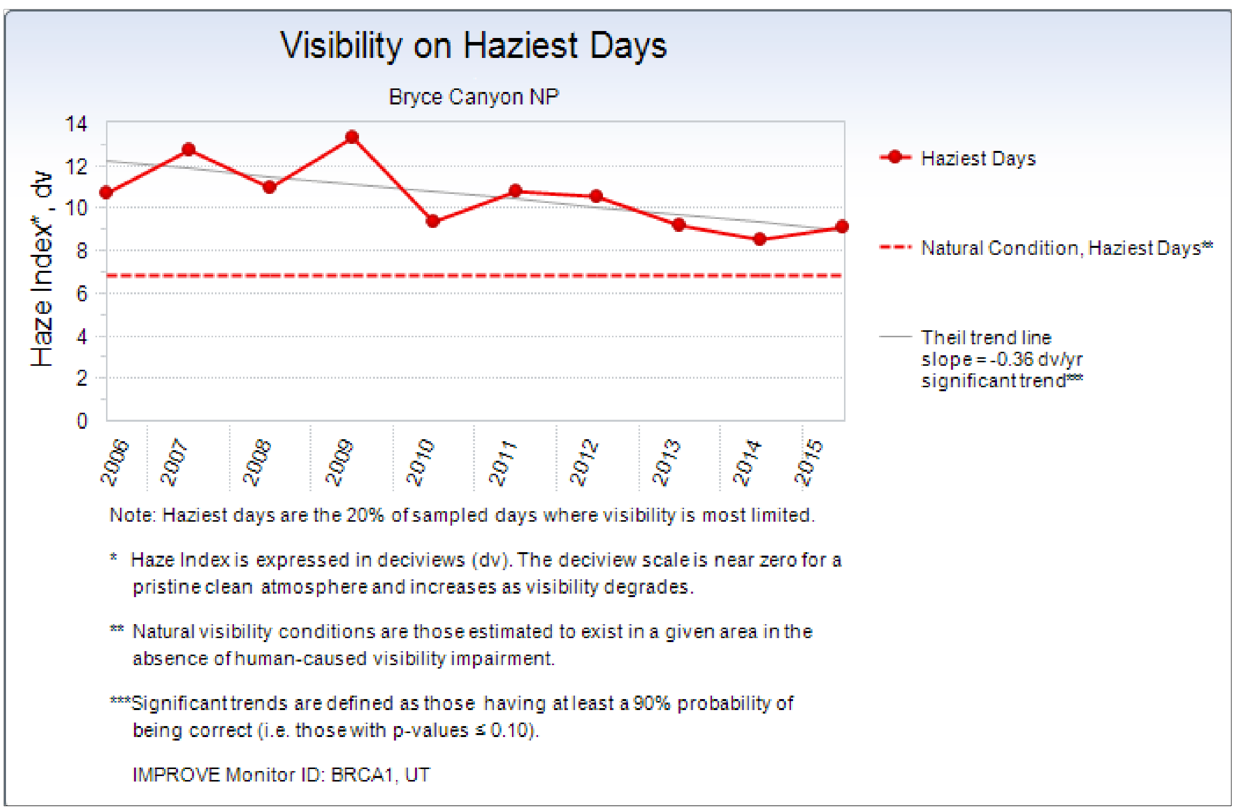


Figure 4.4.4-2. **For 2006-2015, the trend in visibility at Bryce Canyon NP improved on the 20% haziest days. Figure Credit: NPS-ARD 2017a.**

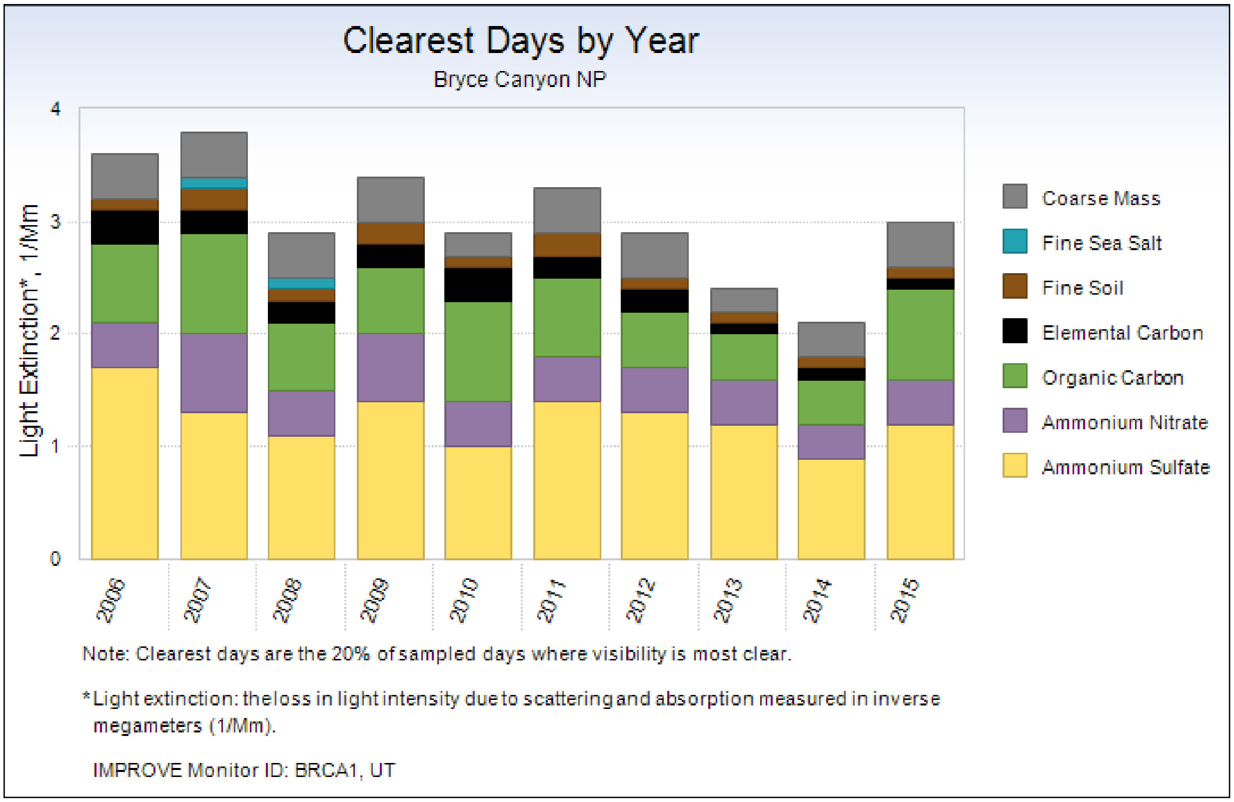


Figure 4.4.4-3. **Visibility data collected at BRCA1, UT IMPROVE station showing the composition of particle sources contributing to haze during the clearest days by year (2006-2015). Figure Credit: NPS-ARD 2017a.**

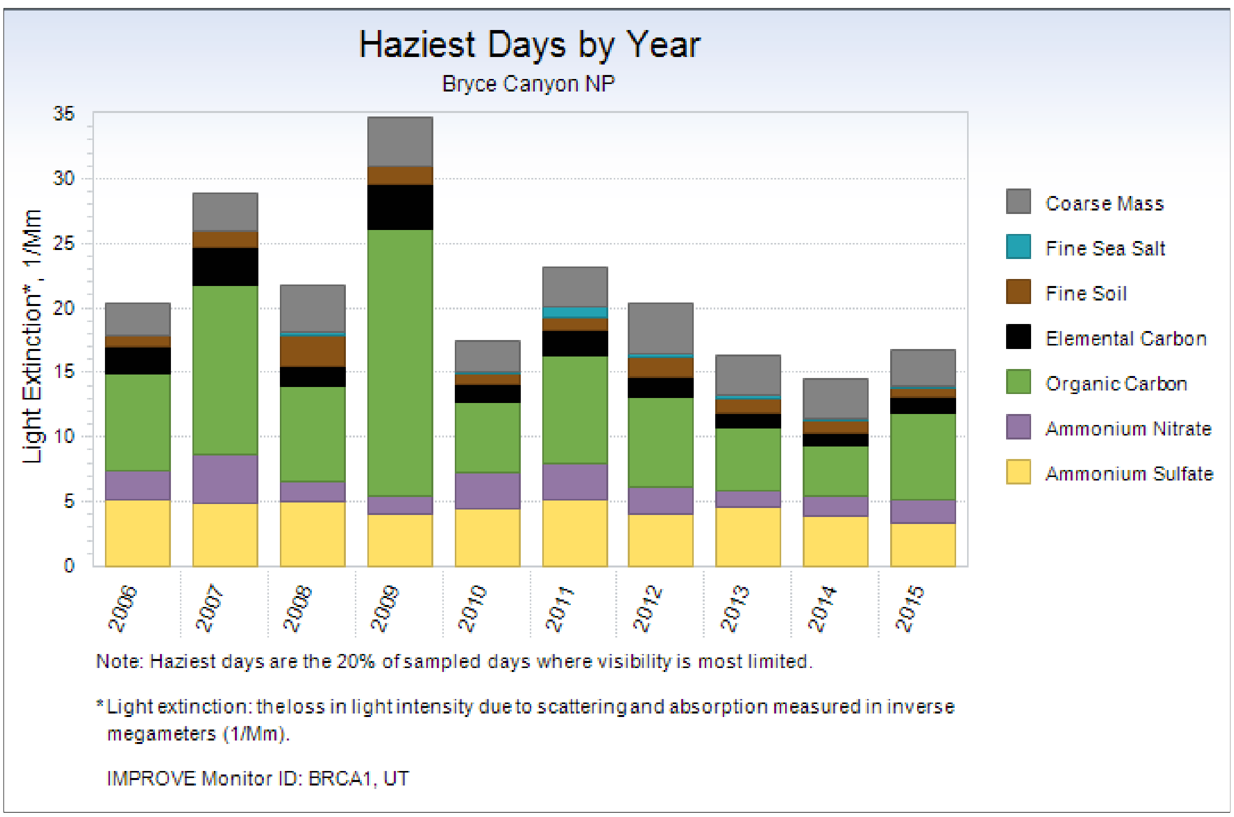


Figure 4.4.4-4. **Visibility data collected at BRCA1, UT IMPROVE station showing the composition of particle sources contributing to haze during the haziest days by year (2006-2015). Figure Credit: NPS-ARD 2017a.**

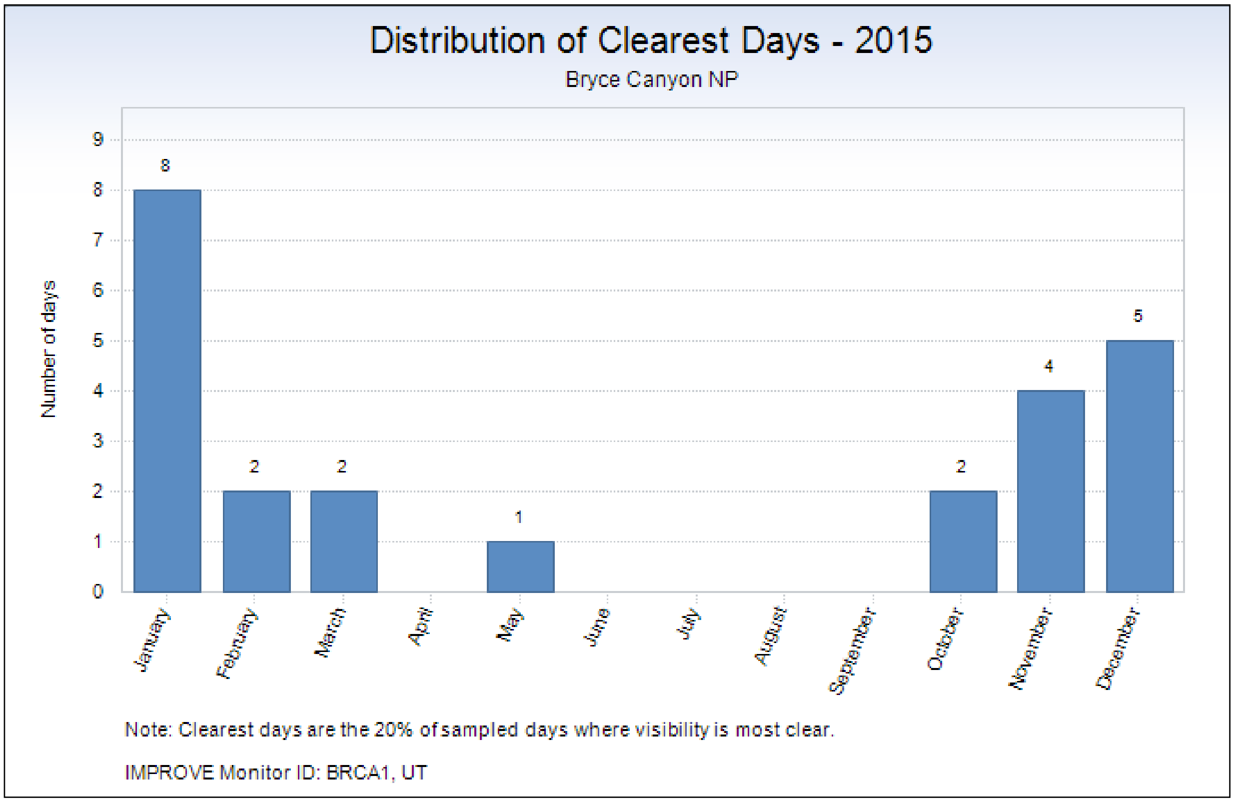


Figure 4.4.4-5. Visibility data collected at BRCA1, UT IMPROVE station showing the distribution of clearest days by month for 2015. Figure Credit: NPS-ARD 2017a.

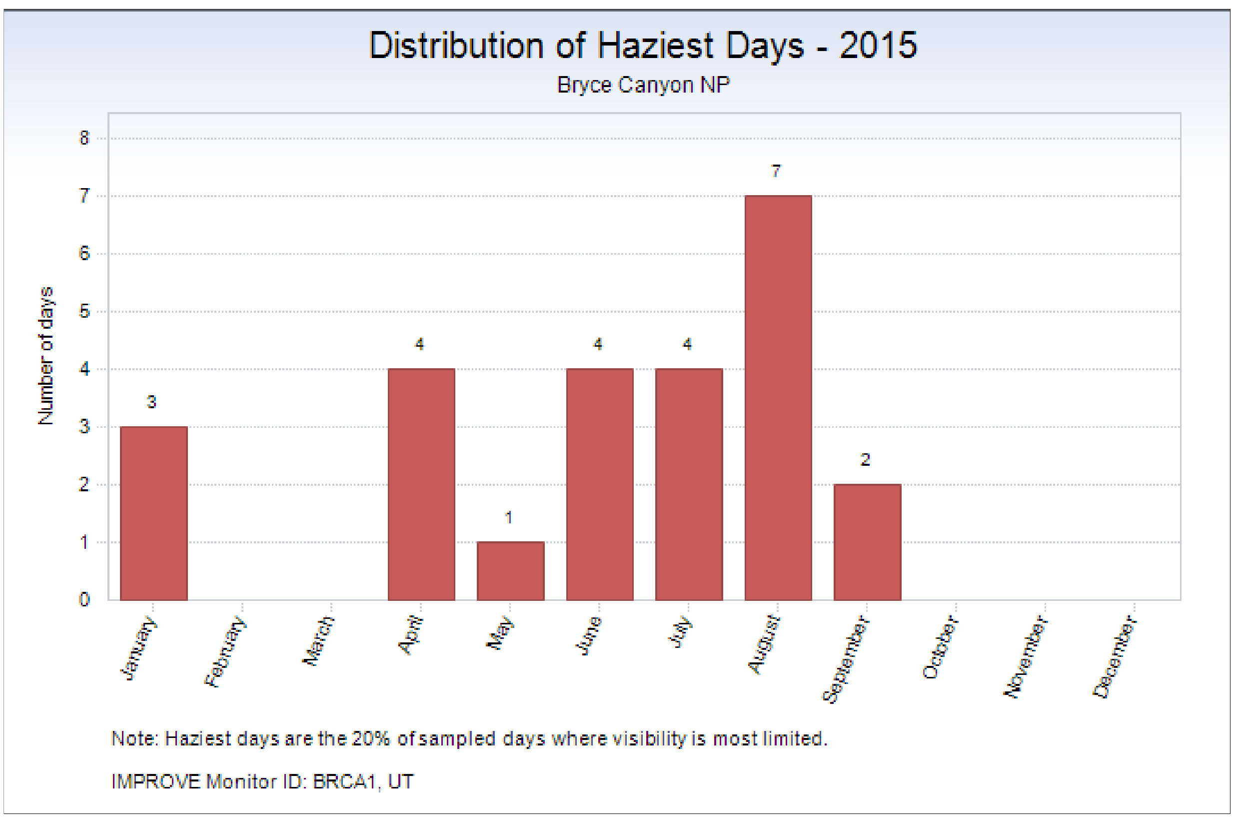


Figure 4.4.4-6. Visibility data collected at BRCA1, UT IMPROVE station showing the distribution of haziest days by month for 2015. Figure Credit: NPS-ARD 2017a.

An ozone risk assessment conducted by Kohut (2004, 2007) for NCPN parks concluded that plants in the national park were at low risk of foliar ozone injury. The four plant species identified as ozone sensitive at the park during the Kohut (2004) effort are listed in Table 4.4.4-2. All four 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 three additional species for the park 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 Bryce Canyon NP 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. One species (blue elderberry [*Sambucus caerulea*], in one location) was reported to have probable ozone injury, and another species (mountain snowberry [*Symphoricarpos oreophilus*]) was reported to have possible 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 1.7 kg/ha/yr. This resulted in a condition rating of moderate concern (NPS-ARD 2017a). For 2006-2015, the trend in total wet nitrogen concentrations in rain and snow remained relatively unchanged (no statistically significant trend; NADP Monitor ID: UT99, UT). Confidence in the assessment is high because there is an on-site or nearby deposition monitor. 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 0.7 kg/ha/yr, which resulted in a good condition rating for Bryce Canyon NP (NPS-ARD 2017a). For the 2006-2015 period, the trend in total wet sulfur concentrations in rain and snow improved at the park (NADP Monitor ID: UT99, UT). Confidence in the assessment is high because there is an on-site or nearby deposition monitor. 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 Bryce Canyon NP. 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 very 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 very high for park protection, with an overall summary risk of

Table 4.4.4-2. Ozone sensitive plants found at Bryce Canyon NP.

Scientific Name	Common Name	Bell (in review)	Kohut (2004)	Bioindicator?
Amelanchier alnifolia *	Saskatoon serviceberry	X	–	No
Amelanchier utahensis	Utah serviceberry	X	–	No
Apocynum androsaemifolium	Spreading dogbane	–	X	Yes
Apocynum cannabinum *	Common dogbane	X	–	No
Pinus ponderosa	Ponderosa pine	–	X	Yes
Populus tremuloides	Quaking aspen	X	X	Yes
Rhus trilobata	Skunkbush	–	X	Yes

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

Note: X = Present.

moderate for the national park. Potential effects of nitrogen deposition include the disruption of soil nutrient cycling and impacts to the biodiversity of some plant communities, including arid and semi-arid communities, grasslands and meadows, and alpine communities. These nitrogen sensitive communities cover approximately 11% of the area of Bryce Canyon NP, mostly as arid and semi-arid communities (Figure 4.4.4-7).

In general, nitrate, sulfate, and ammonium deposition levels have changed over the past 20 years throughout the United States. Regulatory programs mandating a reduction in emissions have proven effective for decreasing both sulfate and nitrate ion deposition, primarily through reductions from electric utilities, vehicles, and industrial boilers, although a rise in ammonium ion deposition has occurred in large part due to the agricultural and livestock industries (NPS-ARD 2012d). A study conducted by Lehmann and Gay (2011) indicated a statistically significant decrease in sulfate concentrations from 1985-2009 in the area surrounding the park, but no statistically significant change in nitrate concentrations. According to the Lehmann and Gay (2011) study, for the areas that saw a change in nitrate concentrations across the county, most saw a decrease; increases were seen primarily in Arizona, New Mexico, and a portion of western Texas. It seems reasonable to expect a continued improvement in sulfate deposition levels because of CAA requirements. At this time, however, ammonium levels are not regulated by the USEPA, and may therefore continue to rise (NPS-ARD 2010).

Mercury and Predicted Methylmercury

The 2013-2015 wet mercury deposition ranged from 5.8 to 10.1 micrograms per square meter per year (NPS-ARD 2017b) and is considered high. The predicted methylmercury concentration in park surface waters was estimated to be 0.05 ng/L (USGS 2015), which is very low. Wet deposition and predicted methylmercury ratings were combined to determine a condition of moderate concern.

The degree of confidence in the mercury/toxics deposition condition is low because there are no park-specific studies examining contaminant levels. Trend could not be determined.

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

Based on these indicators and measures, we consider the overall condition of air quality at Bryce Canyon NP to warrant moderate concern. Among the six individual measures, one was considered to be in good condition, four were considered to be of moderate concern, and one was considered to be of significant concern. We consider the confidence level as high for visibility based on the IMPROVE monitoring station, BRCA1, UT. The confidence levels for wet deposition of N and S are also considered high because there is an on-site or nearby deposition monitor. The confidence levels for the ozone measure are medium because estimates are based on interpolated data from more distant monitors. Finally, the confidence levels for wet mercury deposition and predicted methylmercury concentration are low, because the estimates are based on interpolated or modeled data. 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 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 park.

Because trend information for the majority of the seven measures was not available, we did not assign an overall trend for air quality. However, it should be noted that the three measures for which trend information was available were also the three measures in which we had high confidence. For 2006-2015, the trend in visibility improved at the park on the 20% clearest days and on the 20% haziest days. Over the same years, the trend in total wet sulfur concentrations also improved. The trend in total wet nitrogen concentrations at the park over 2006-2015 remained relatively unchanged (no statistically significant trend).

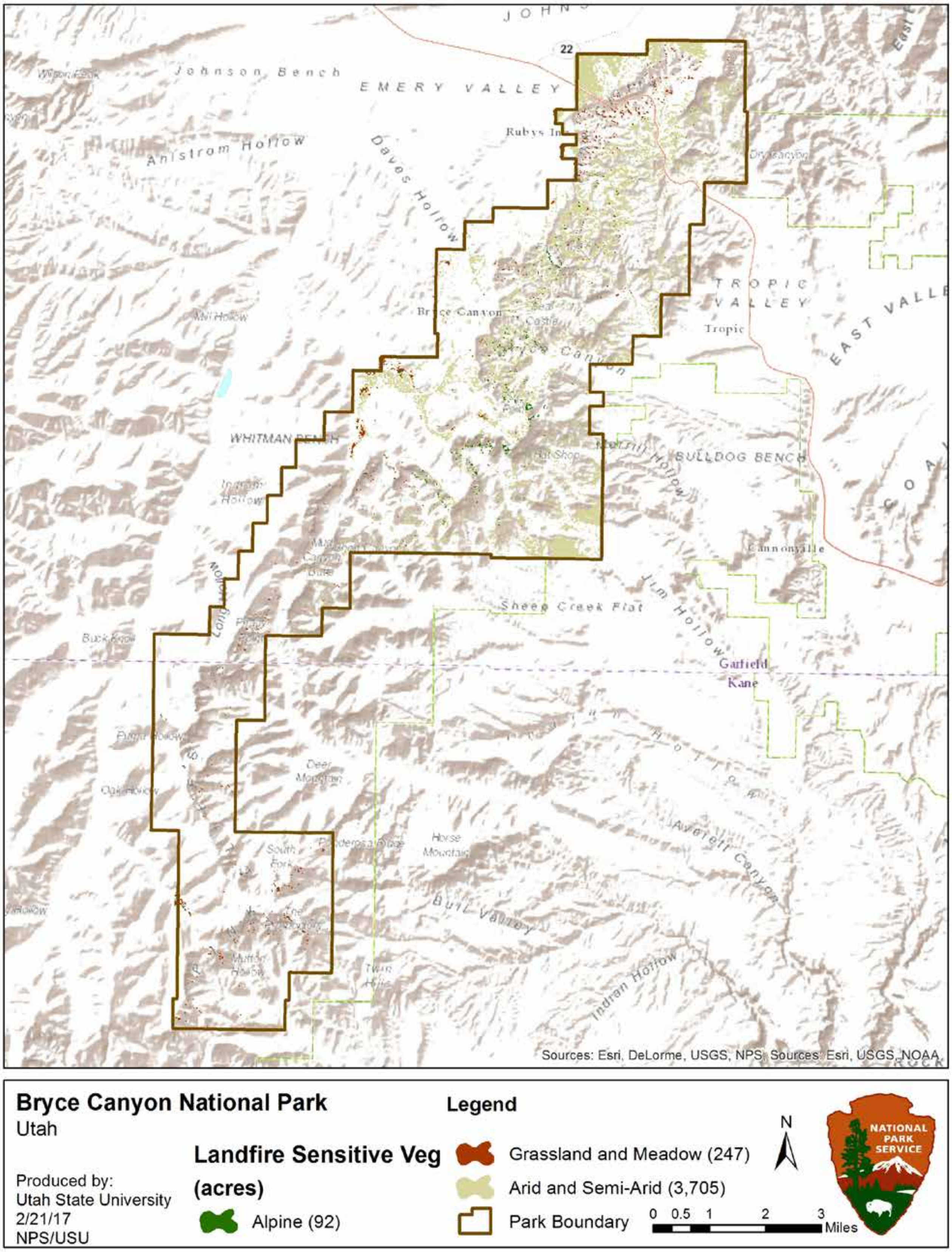
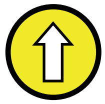
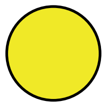
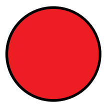
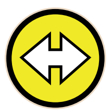
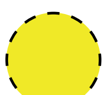
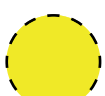


Figure 4.4.4-7. Locations of nitrogen sensitive communities at Bryce Canyon NM using the NPS/USGS vegetation mapping dataset. Secondary Data Source: E&S Environmental Chemistry, Inc. (2009).

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 Bryce Canyon NP. This is based on NPS ARD benchmarks and the 2011-2015 estimated visibility on mid-range days of 2.6 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 68.1 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 13.2 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 1.7 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). The trend from 2006-2015 in total wet nitrogen concentrations at the park remained relatively unchanged (no statistically significant trend; NADP Monitor: UT99, UT). Confidence is high because there is an on-site or nearby deposition monitor.
	S in kg/ha/yr		Wet sulfur deposition is in good condition. This status is based on NPS ARD benchmarks and the 2011-2015 estimated wet sulfur deposition of 0.7 kilograms per hectare per year (kg/ha/yr). Ecosystems in the park were rated as having high sensitivity to acidification effects relative to all Inventory & Monitoring parks (Sullivan et al. 2011a, Sullivan et al. 2011b). The trend from 2006-2015 in total wet sulfur concentrations at the park improved; NADP Monitor: UT99, UT). Confidence is high because there is an on-site or nearby deposition monitor.
	Mercury		The 2013-2015 estimated wet mercury deposition was high at the park and ranged from 5.8 to 10.1 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 low (0.05 nanograms per liter). This measure is used in conjunction with wet mercury deposition to determine the overall condition of mercury/toxics. Together, these measures indicate a condition of moderate condition. Trends could not be determined. Confidence 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.

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

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, Trend, and Confidence Level		(yellow circle, no trend, no confidence symbol)	Overall, we consider air quality at Bryce Canyon NP to be of moderate concern. Of the three measures with a high confidence level, one was in good condition and two were of moderate concern. Of the two measures with a medium confidence level (both for ozone), one was of moderate concern and the other was of significant concern. Finally, of the two measures with a low confidence level (for mercury/ toxics), when combined they were of moderate concern. Trends were reported for three of the measures; trends were improving for two measures and unchanging for the third. 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 (2017a,b).

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, NPS 2014a). Further, the protection of air quality in Bryce Canyon NP plays a role in meeting a key park purpose mentioned in the park's enabling legislation: "preserving in their natural state the outstanding scenic features" (NPS 2014a). The majority of threats to air quality within Bryce Canyon NP originate from outside the park and local surroundings (NPS 2014a). In general, sources of air quality threats may include forest fires (natural or prescribed), dust created from mineral and rock mines and quarries, and carbon emissions. Potential increases in commercial or industrial development around the park could lead to air quality effects (NPS 2014a). For example, NPS (2013a) 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 12 mi (19 km) to the west/southwest of the park). Increased annual visitation to the park could also lead to increases in emissions due to transportation (NPS 2014a).

As described in the park's Foundation Document (NPS 2014a), trends in CO_2 emissions have increased (U.S. Energy Information Agency data) in southwestern states from 1980 through 2010. The temperature has increased (statistically significant) from 1901-2002 in the immediate area surrounding Bryce Canyon NP (NPS 2014a). Precipitation has decreased across the southwestern U.S., including the area surrounding the park, but the trend is not statistically significant (NPS 2012b as cited in NPS 2014a).

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).

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

Bryce Canyon National Park (NP) protects 14,502 ha (356,835 ac) of sparsely vegetated "breaks", open woodlands, and dense coniferous forests (Tendick et al. 2011). Elevations in the park vary dramatically from a low of 2,006 m (6,580 ft) along the eastern edge of the park near the town of Tropic, Utah to 2,778 m (9,115 ft) at Rainbow Point in the southern part of the park (Tendick et al. 2011). The park was established in 1923 to preserve the distinctive geologic formations found in the breaks (NPS 2014f). 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 2005). 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 2014f). During wet periods sand, silt, and mud from highland streams 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 2005). By about 35 million years ago, Lake Claron had permanently disappeared, and sediments in the dry lake bed solidified into rock (NPS 2014f). About 15 million years ago, the underlying bedrock uplifted, creating the Colorado Plateau. As the plateau rose, deep faults split it into seven smaller units, including the Paunsaugunt Plateau, which forms the eastern edge of Bryce Canyon NP (NPS 2014f). 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 Bryce Canyon NP. With more than 200 days of frost per year, water seeping into cracks in the rock freezes and expands, exerting extreme pressure that splits apart rock (NPS 2014f). Chemical weathering from acidic rain and slope failures caused by intense rainstorms also sculpt the landscape (Thornberry-Ehrlich 2005). 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 park visitors. While natural erosional processes dominate in Bryce Canyon NP, anthropogenic impacts can accelerate erosion and damage or destroy sensitive geologic features (NPS 2014g).

Figure 4.5.1-1. A hoodoo in Bryce Canyon NP. Photo Credit: NPS.

4.5.2. Data and Methods

This assessment focuses on the anthropogenic impacts to geologic features in the park. The first indicator, known deterioration of geological and paleontological features, and its two measures are based on those used to monitor the wilderness character of geological features in other NPS units, including Cedar Breaks National Monument, which has similar geology to Bryce Canyon NP (Thornberry-Ehrlich 2006, Booth-Binczik 2014, NPS 2014a). Since the park is located in a seismically active zone, we also included an indicator of seismic activity, with one measure.

<u>Anthropogenic Incidents</u>

Resource management and law enforcement staff record instances of damage to park 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 staff at Bryce Canyon NP searched the IMARS database for these types of incidents that occurred from 2012 to March 2017. We reported the number and type of incident.

From 2006 to 2013, researchers from Weber State University in Ogden, Utah conducted a study of paleontological resources in the park (Eaton 2013a). Several additional sites were discovered during 2011-2013 (Eaton 2013a, Eaton 2013b). These surveys were initiated because several important fossil sites were discovered in 1989, 1997, and 2003 (Eaton 2013c). We reviewed data and reports from these surveys for evidence of vandalism or damage to paleontological resources in the park.

<u>Rockfall or Slope Failures Along Visitor Use Areas</u>

We used data reported as part of Bryce Canyon NP's rockfall reporting system to determine the number and type of known rockfall and slope failures in the park. Generally, only rockfall or slope failures that have affected trails were reported. Other events that have not affected trails may also be reported if park staff are aware of them, but the primary purpose of the reporting system is to evaluate trails and other areas where visitors may be at risk.

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

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-mi) radius of the park 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).

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 park 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 park.

4.5.4. Condition and Trend

<u>Anthropogenic Incidents</u>

There were nine entries in IMARS related to human impacts to geological and paleontological features at Bryce Canyon NP that occurred from 2012 to March 2017. Two incidents occurred on the Navajo Loop Trail, while each of the remaining seven incidents occurred in a different park location (i.e., Inspiration Point, Mossy Cave Trail, Sunset View, Paria View, Sunset Campground, Swamp Canyon-Sheep Creek Trail, and Queen's Garden Trail). Seven reports describe off-trail travel or climbing on hoodoos and two incidents were related to rock and possibly fossil collection in the park. Incidents were either reported to law enforcement by visitors or observed by law enforcement. These nine incidents represent a

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 Condition	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 low 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 Failure Along Visitor Use Areas	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 park. There also appear to be no areas of concern for such occurrences.	There have been a low 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 park.	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 park.
Seismic Activity	Presence/ Absence of Earthquakes	No anthropogenic seismic events have occurred in the vicinity of the park.	Anthropogenic seismic events have occurred in the vicinity of the park, but they occur at a low to medium level (in either frequency or magnitude).	Anthropogenic seismic events have occurred in the vicinity of the park, and they occur at a medium to high level (in either frequency or magnitude).

minimum number. The actual occurrence of damage to these resources is likely greater, especially since visitation has increased significantly over the last several years (NPS 2014g).

During 2006 to 2010, 144 sites were found to contain paleontological resources in Bryce Canyon NP (Tweet et al. 2012), but there was no evidence of vandalism or theft at any of them (Weber State University, Jeffrey Eaton, paleontologist, e-mail communication, 19 May 2017). There are two primary reasons for the low occurrence of theft or destruction of fossils in the park: 1) the vast majority of fossils are small and not easily recognized by the average observer (e.g., gastropods and plant seeds) and 2) the majority of fossils are located in rock types that visitors rarely encounter along established hiking trails (Weber State University, Jeffrey Eaton, paleontologist, e-mail communication, 19 May 2017).

Although there are no known incidents of damage to paleontological resources in the park, several instances of damage to geological features were reported by NPS law enforcement staff. Furthermore, NPS staff indicate these incidents probably occur more often than is reported, especially with increased visitation (NPS, Cynthia Morris, chief of resource management and visitor protection, 6 April 2017, NRCA scoping meeting). The numerous trails leading into the breaks also provides access to sensitive features. For these reasons, the condition for this measure warrants moderate concern. Trend is unknown and confidence is low since there has not been a focused inventory of anthropogenic damage to geological and paleontological resources in the park.

<u>Rockfall or Slope Failures Along Visitor Use Areas</u>

Numerous rockfalls and slope failures were reported for several trails in the park; however, Table 4.5.4-1 does not provide a complete history. Rockfall is especially common in the Wall Street portion of the Navajo Loop Trail (Greco 2005, Biglow and Besana-Ostman 2008, Harp and Greco 2010, Moore 2015, Bilderback 2015). At least eight areas were identified as hazardous, although rockfalls may occur anywhere along Wall Street (Harp and Greco 2010, Moore 2015). The trail has been closed several times in response to these events (Figure 4.5.4-1). In 2006, the trail was closed for more than a year when an estimated 400-500 tons of rock fell on the trail (Moore 2015). The trail was eventually re-routed, but because of the high rockfall potential elsewhere along the trail, it is closed during the winter and intermittently when conditions are considered unsafe (Greco 2005, Biglow and Besana-Ostman 2008, Gonder 2010). For example, most events are associated with significant and rapid snowmelt or 20 mm (0.8 in) of rain within a 24-hour period (Bilderback 2015).

Table 4.5.4-1. History of documented rockfall and slope failures along trails.

Location	Year	Event
Navajo Loop Trail (Wall Street section)	1984	Rockfall leading to trail closure. Trail reopened in 1987.
	2004/2005	Collapse of CCC era retaining walls, loss of trail tread, gullies, and deposition of sediment on trail caused by greater than average snowpack and rainfall.
	2006	400 to 500 tons of rockfall leading to a 14-month trail closure.
	2010	Rockfall; 2 visitors were injured; trail re-opened in 2010.
	2011	Rockfall
	2015	Numerous rockfall events
Boat Mesa	2013	Large segment from southeastern cliff wall broke off, triggering a massive rock slide; No trails were impacted.
Peek-a-boo Connector	2013	A large segment of cliff separated from the cliff wall above the Peek-a-boo connector and just east of Bryce Point triggering a large rock slide that covered the trail below.
Mossy Cave	2014/2015	Mass wasting and erosion along social trails leading to the "turtle" formation; "Turtle" head formation broke off; Significant erosion by social trails near the stream bank downstream of the waterfall.
Fairlyland Loop Trail	2015	Rockfall from a heavily weathered hoodoo.

Figure 4.5.4-1. Rockfall hazard along the Navajo Loop Trail. Photo Credit: NPS.

Figure 4.5.4-2. Rockfall along the Fairyland Trail. Photo Credit: NPS.

Rockfall and slope failures have also occurred along other trails in the park, including the Fairyland Loop Trail (Figure 4.5.4-2). The Fairyland Loop Trail, along with the Navajo Loop Trail, Queen's Garden Trail, Peekaboo Loop Trail, and the Rim Trail are on the National Register of Historic Places (NPS 1995), so park staff prefer to keep them open when and where conditions allow (Gonder 2010).

Paleontological resources are lost to natural erosion, but erosion also exposes new fossils (Weber State University, Jeffrey Eaton, paleontologist, e-mail communication, 19 May 2017). Of the approximately 150 locations surveyed during 2006 to 2013, none were recommended for salvage based on the potential loss of important fossil specimens (Weber State University, Jeffrey Eaton, paleontologist, e-mail communication, 19 May 2017). Although there is little concern for erosion to disrupt paleontological resources, there have been numerous rockfall and slope failures along trails in the park. These events are unpredictable and relatively common. Where they occur along trails, they pose a significant threat to visitor safety. Furthermore, these events sometimes require significant trail maintenance and restoration before they are reopened. Therefore, this measure warrants significant concern. 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 174 earthquakes recorded from 1997 to 2017 (Figure 4.5.4-3). Of the 174 earthquakes, 94 were considered micro (< 3 magnitude), 73 were considered minor (3 - 3.9 magnitude), and seven were considered light (4 - 4.9 magnitude). None of the seismic events were related to anthropogenic activities (e.g., blasting, aircraft, sonic booms). Furthermore, earthquake activity does not appear to be increasing over the 20-year period (Figure 4.5.4-4). 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 unchanging.

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

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 Bryce Canyon NP was split between moderate and significant

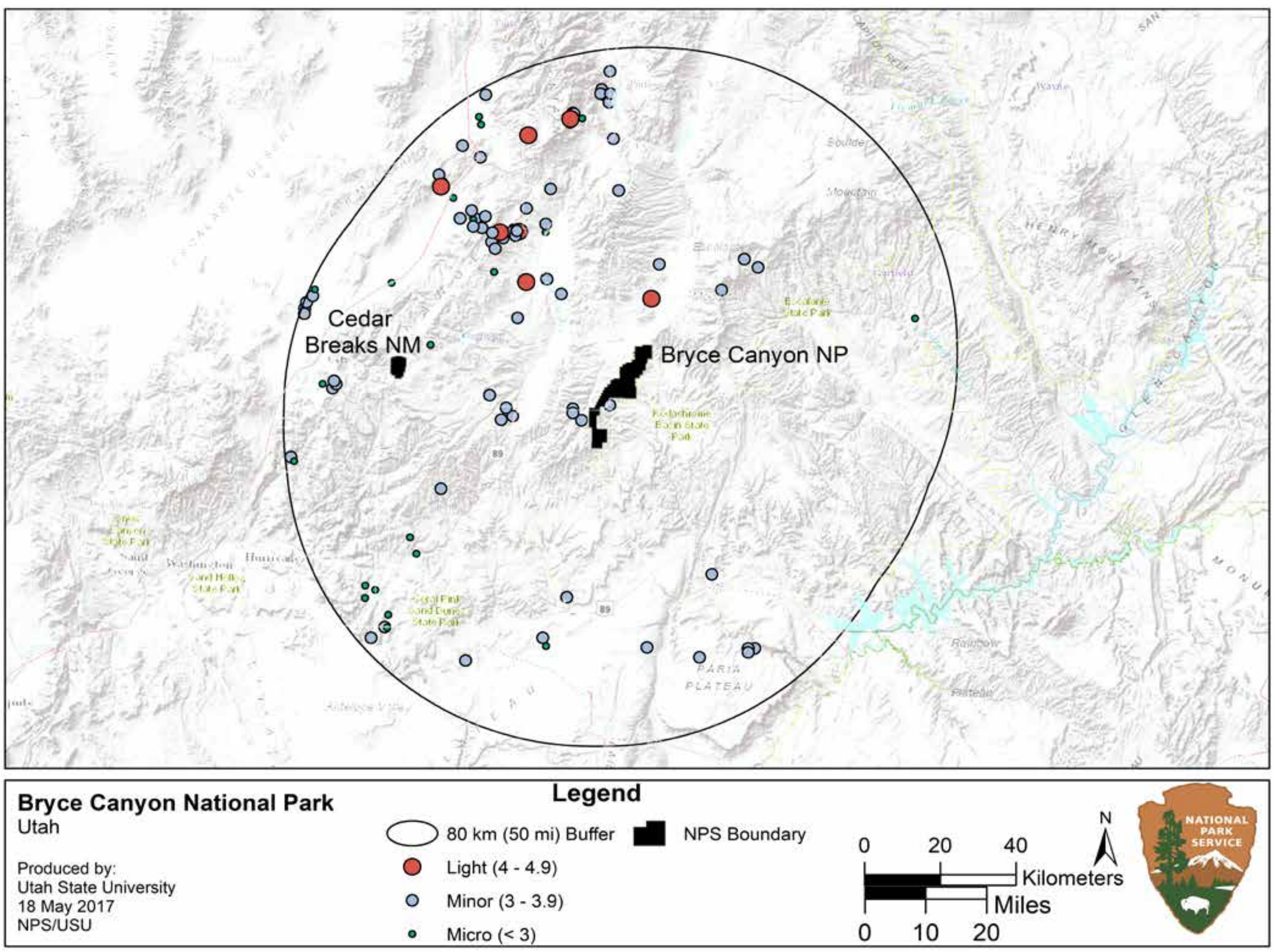


Figure 4.5.4-3. Map of earthquakes and anthropogenic seismic events during 1997-2017.

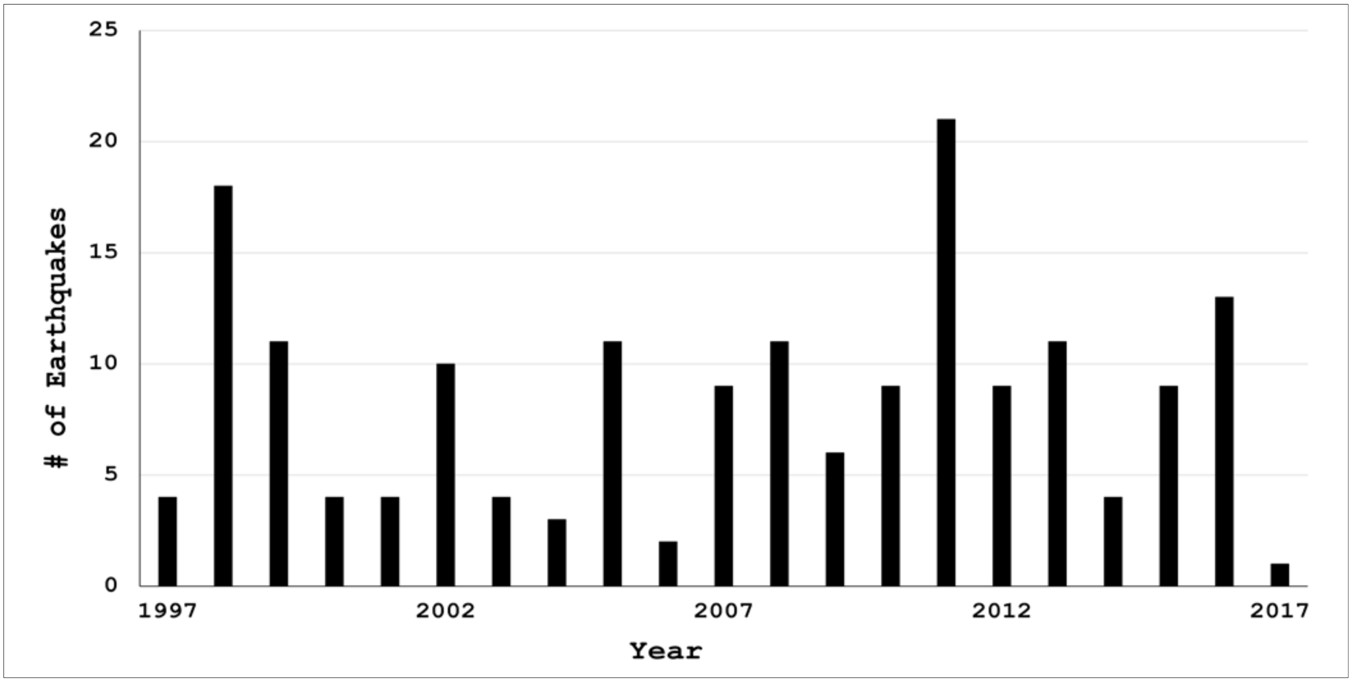


Figure 4.5.4-4. Number of earthquakes during 1997-2017.

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		Although there are no known incidents of damage to paleontological resources in the park, there were nine instances of damage to sensitive geological features during 2012-2017. NPS staff indicate these incidents are probably under-reported and access to geological features via designated and social trails is high. Therefore, the condition for this measure warrants moderate concern. Trend is unknown and confidence is low due to the absence of a focused inventory of anthropogenic damage to geological and paleontological resources.
	Rockfall or Slope Failures Along Visitor Use Areas		Although there is little concern for erosion to disrupt paleontological resources, there have been numerous rockfall and slope failures along trails. These events are unpredictable and relatively common. Where they occur along trails, they pose a significant threat to visitor safety. Therefore, this measure warrants significant concern. 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 174 earthquakes were relatively small and none were related to human activities, this measure indicates good condition. Confidence is high and the trend is unchanging.
Overall Condition, Trend, and Confidence Level			The overall condition rating for geologic resources was split between moderate and significant concern. This condition rating was based largely on the first two measures since they have the most immediate impact on geological features in the park. Overall trend is unknown and confidence is medium.

concern. This 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 park. While a single earthquake in close proximity to the park, 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 have exacted the most damage.

The first measure, anthropogenic incidents, was assigned low confidence since it is unlikely that all or even most incidents were recorded in the IMAR system. The proportion of law enforcement staff to visitors is low, thus most occurrences of resource damage will not be reported (NPS, Cynthia Morris, chief of resource management and visitor protection, 6 April 2017, NRCA scoping meeting). Fortunately, theft and damage to paleontological resources is probably rare due to the remote location of most specimens and the difficulty visitors would have in finding and recognizing them as fossils. Medium confidence was assigned to the measure of rockfall and slope failure because these events may also be under-reported. However, the park has developed a rockfall reporting form (Bilderback 2015). As the database grows, park staff will be better able to assess the risk posed to visitors, which is the primary threat from this natural process.

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 174 earthquakes appeared to be related to anthropogenic activities. Although natural earthquakes have the potential to alter the geology of the park, these are natural occurrences that are partly responsible for shaping this dynamic landscape as well.

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 park.

Threats, Issues, and Data Gaps

There are a number of threats, issues, and data gaps related to geologic resources at Bryce Canyon NP. Rockfall and slope failures are a potential hazard along all roads and trails (Thornberry-Ehrlich 2005). 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 2005). Many popular park trails are established through these highly erodible areas, potentially threatening visitor safety. The Wall Street portion of the Navajo Loop Trail is of particular concern with a decades-long history of rockfall. However, there is no comprehensive study of the erosion processes at the park with respect to the different rock formations associated with administrative features, including buildings, roads, and trails (Thornberry-Ehrlich 2005).

Although erosion is a natural and important geologic process reflective of the region's dynamic landscape, erosion due to anthropogenic causes may alter the park's geology beyond what is natural. Social trails, contribute to erosion, soil compaction, and the destruction of native vegetation (NPS 2014g). From 1994 to 1998, a study on visitor impacts at high use areas showed that social trails were common at park overlooks, and that the area of bare ground as a result of foot traffic had increased over time (Foster and Bryant 1996, Mitton 1999). Social trails also pose a threat to visitor safety in the advent of a rockfall or slope failure. Some visitors may not be aware that they have left a designated trail or that climbing on hoodoos and other geologic features is illegal, and even a small number of visitors can have a significant impact on these sensitive rock features (NPS 2017b). Although boundary fences and barriers have been erected in some areas to discourage the use of social trails and to protect native vegetation, visitors sometimes ignore them, but once social trails have become established they are difficult to rehabilitate (NPS 2010e). This is of particular concern since many of the park's rare plant species occur in the breaks (NPS 2010c). Livestock trespass is also common in some areas of the park but usually not in the breaks (NPS 2014g). Finally, fire also increases erosion, at least in the short-term, but this disturbance is a natural and necessary process for the fire-adapted forests on the plateau (NPS 2014g).

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 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 Bryce Canyon NP were summarized in Monahan and Fisichelli (2014). Extreme climate changes were defined as temperature and precipitation conditions exceeding 95% of the historical range of variability (Monahan and Fisichelli 2014). These results indicate a trend toward warmer but not necessarily drier conditions within the park (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 the timing, rate, and degree of erosion (Thornberry-Ehrlich 2005).

Bryce Canyon NP is located in a seismically active zone, but most earthquakes are of low magnitude. Although several mines that use blasting are located near the park (e.g., Alton Coal Mine) (Thornberry-Ehrlich 2005), 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 Bryce Canyon NP is needed (Thornberry-Ehrlich 2005). Even seismic perturbations created by low altitude aircraft may influence geologic features in the park, but this is unknown (NPS 2014g). There are two abandoned mineral land features in the park, neither of which requires mitigation (Burghardt et al. 2014).

The geologic features of Bryce Canyon NP are the defining resource of the park. 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 park 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 park'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 review experts are listed in Appendix B.

4.6. Water Quality

4.6.1. Background and Importance

Bryce Canyon National Park (NP) is located on the divide between two major river drainages — the Paria River, which drains areas below the rim, and the East Fork of the Sevier River, which drains the Paunsaugunt Plateau above the rim (Thornberry-Ehrlich 2005). Only three perennial streams occur in the park: Yellow Creek, Willis Creek, and Sheep Creek (NPS 1996) (Figure 4.6.1-1). All other streams flow intermittently or are ephemeral (NPS 1996). With an average of 2 m (8 ft) of snow annually (NPS 2014a), snowmelt is the principal source of groundwater recharge in the park (NPS 1996). Summer monsoonal rains also contribute to groundwater recharge but to a lesser extent (NPS 1996).

Water is the primary driving force responsible for the unusual geologic formations found in the breaks (Thornberry-Ehrlich 2005). 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 2005). With more than 200 days of frost per year, water seeping into cracks and fissures freezes and expands, exerting extreme pressure that splits apart rock (NPS 2014a). Chemical weathering from acidic rain and slope failures caused by intense rainstorms also sculpt the landscape (Thornberry-Ehrlich 2005).

Approximately 33 springs and seeps occur on the steep slopes of the breaks where the ground surface intersects an aquifer or groundwater conduit (NPS 1996, Thornberry-Ehrlich 2005). 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).

Historically, water resources have been developed for livestock grazing allotments and for park facilities and visitor use (NPS 1996). Although legal grazing ended in the 1960s, livestock trespass is occasionally observed at some springs along the park boundary (Tendick et al. 2011, Warren and Haas 2012). Tropic Ditch, which traverses the northern end of the park, is an irrigation canal constructed during the 1890s (NPS 1996). The 16-km (10-mi) canal diverts water from the East Fork of the Sevier River for residents of Tropic Valley (NPS 1996). The ditch is on the National Register of Historic Places (NPS 1996). The water rights for Tropic Ditch and some springs are owned by outside entities such as the City of Tropic and private irrigators (Utah Division of Water Rights 2017).

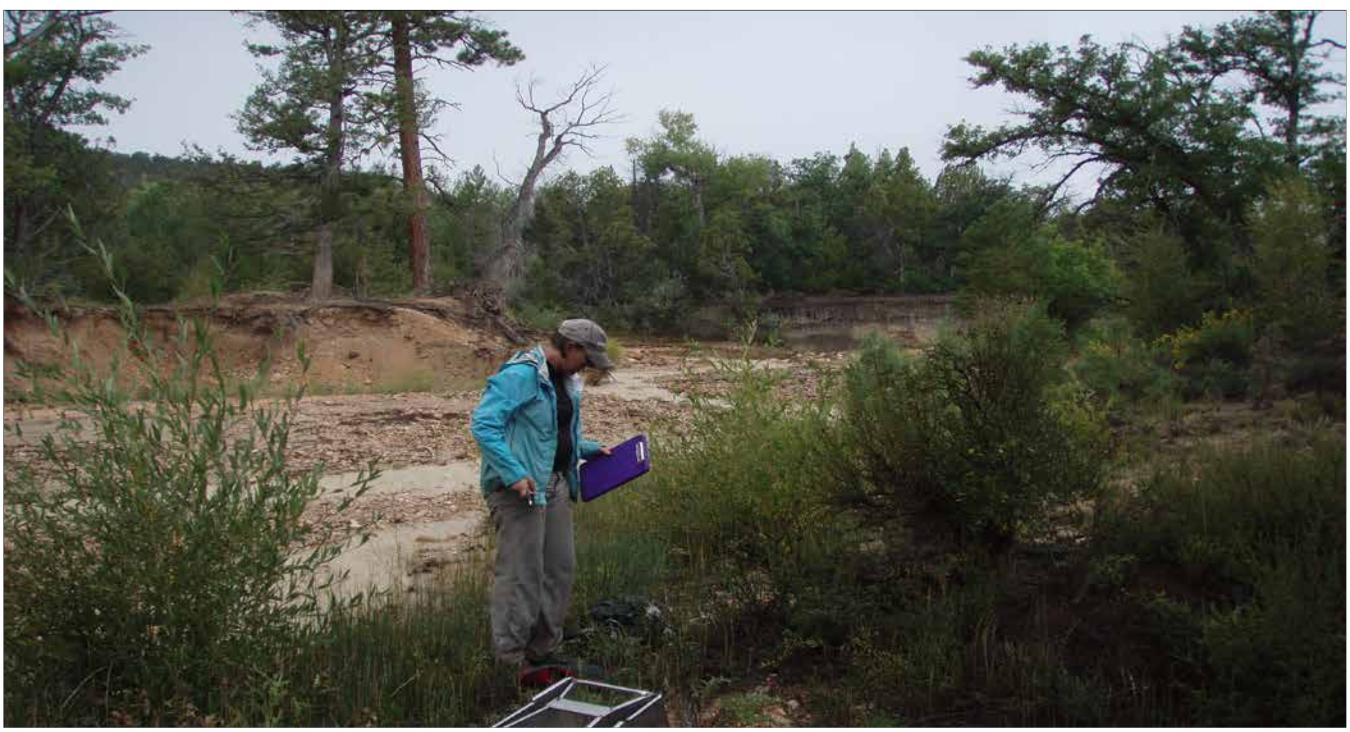


Figure 4.6.1-1. Yellow Creek sampling at Bryce Canyon NP. Photo Credit: NPS

Riparian areas, springs, and seeps provide habitat for aquatic invertebrates, amphibians, birds, and mammals. In June 2012, park staff began monitoring backcountry perennial springs for wildlife use using motion-triggered, infrared cameras (Warren and Haas 2012). The study was initiated, in part, because of black bear (*Ursus americanus*)-human conflicts at backcountry sites located near springs (Warren and Haas 2012). In addition to black bears, mule deer (*Odocoileus hemionus*), northern goshawks (*Accipiter gentilis*), owls, mountain lions (*Puma concolor*), and bobcats (*Lynx rufus*) were observed using backcountry springs (Warren and Haas 2012). Maintaining good water quality is essential to the wildlife and plants that depend on aquatic resources in the park.

4.6.2. Data and Methods

To assess the current condition of water resources in Bryce Canyon NP, we used two indicators with between five and three measures each for a total of eight measures. The two indicators are water quality (five measures) and contaminants of emerging concern (three measures). Each measure includes a suite of attributes (water quality) or analytes (chemical constituent for contaminants of emerging concern). Water quality was identified as an important vital sign for monitoring at select Northern Colorado Plateau Network (NCPN) parks (O'Dell et al. 2005). Although waters in NCPN parks tend to be located far from metropolitan areas, human land-use activities within the parks and/or their watersheds may expose park waters to harmful chemicals that may affect wildlife and human health. NCPN staff selected four locations for monitoring water quality and contaminants of emerging concern (CEC) in Bryce Canyon NP (Figure 4.6.2-1). Table 4.6.2-1 shows the years each of the four sites were monitored.

Core Parameters, Major Ions, Nutrients, Trace Elements, and Fecal Indicator Bacteria

NCPN staff monitored water quality at four locations in Bryce Canyon NP from 2005 to 2015. Data were generally reported for water years. A water year spans 12 months and begins October 1 and ends September 30. Approximately 12 samples were collected per year at each site, although not all sites were monitored annually (Thoma et al. 2009). A site visit typically yielded approximately 30 water quality attribute measurements; however, not all attributes were measured during each site visit (Thoma et al. 2009). Usually, core water quality attributes, major ions, nutrients, and fecal indicator bacteria, were measured during each site visit, while trace elements were monitored quarterly (Van Grinsven et al. 2010). Table 4.6.2-2 shows the five water quality measures and their attributes.

Pesticides, Wastewater Indicators, and Pharmaceutical and Personal Care Products

In 2010, in cooperation with the U.S. Environmental Protection Agency (EPA) Region 8, the NCPN began screening selected surface waters in network parks for pesticides, pesticide degradation products, and organic wastewater indicators. After a sampling hiatus in 2011, pharmaceuticals and personal care products (PPCPs) were added to the analytical suite in 2012. In 2012, wastewater indicator samples were not taken during every sampling visit due to limitations in laboratory processing availability. Samples were analyzed for 73 pesticide analytes, 102 PPCP

Table 4.6.2-1. Water monitoring locations and sampling dates.

Site Name	Water Quality	Contaminants of Emerging Concern
Sheep Creek (below spring)	2006-2012	2010 (July, September, November)
Yellow Creek (below spring)	2006-2012	2010 (November), 2012 (July, August, September)
Mossy Cave Spring	2008-2015	2010 (September)
Tropic Ditch	2008-2015	–

Table 4.6.2-2. Water quality measures and their attributes.

Measures	Attributes
Core Field Parameters	discharge, water temperature, dissolved oxygen, specific conductance, pH, turbidity
Major Ions	alkalinity, bicarbonate, calcium, chloride, hardness, magnesium, potassium, sodium, sulfate, and total dissolved solids
Nutrients	ammonia, nitrite+nitrate, nitrogen, dissolved phosphorus, total phosphorus
Trace Elements	aluminum, arsenic, barium, cadmium, chromium, copper, iron, lead, manganese, mercury, selenium, silver and zinc
Fecal Indicator Bacteria	fecal coliform, *E. coli*

Source: Thoma et al. (2009).

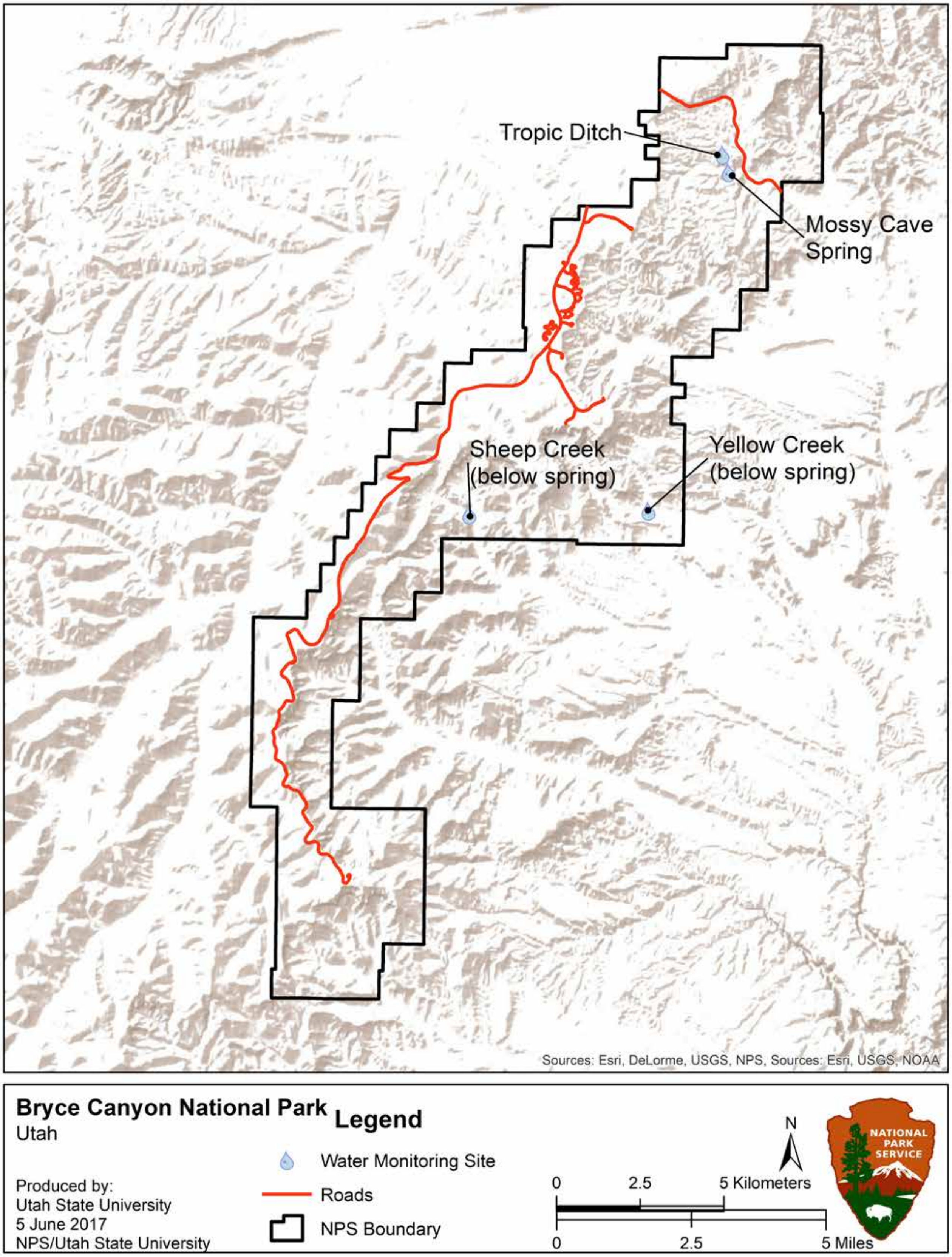


Figure 4.6.2-1. Locations of water quality monitoring sites in Bryce Canyon NP.

analytes, and 83 wastewater analytes. In 2014, the U.S. Geological Survey (USGS) expanded the project to include testing for hormones in water and sediment, and organic waste indicators in sediment, to track the source, movement, and fate of contaminants of emerging concern in aquatic environments. For the complete list of analytes and details on data collection and laboratory analysis methods see Weissinger et al. 2013, Weissinger 2015, and Weissinger et al. 2016a.

PPCPs and wastewater contaminants tend to have the strongest effects on vertebrates, while pesticides affect the foundations of the aquatic food chain, such as invertebrates and algae. Micro-organisms can also be impacted; there is concern that the presence of antibiotic compounds may hasten the development of drug resistance in the wild.

4.6.3. Reference Conditions

Reference conditions for this assessment are shown in Table 4.6.3-1. Reference conditions are described for resources in good, moderate concern, and significant concern conditions for each of the two indicators.

Water Quality

The NCPN exceedences of state water quality standards for the measures were reported only if they occurred for more than 10% of samples for each reporting period. This approach minimized reported exceedences of short duration changes in water chemistry that may be associated with natural factors such as weather. The results were compared with Utah Division of Environmental Quality (DEQ), Department of Water Quality standards (Utah DEQ 2016). Water resources sampled in Bryce Canyon NP are grouped into three designated beneficial use classes (Utah—DEQ 2016). The classes are: 2B (protected for infrequent primary contact recreation), 3C (protected for nongame fish and other aquatic wildlife), and 4 (protected for agricultural uses). When criteria differ by designated beneficial use, or within a use class by aquatic-life stage, the more stringent standard was used as the basis for comparison.

The State of Utah does not have a water quality standard for total phosphorus (Tom Toole, pers. comm. 12/20/07 as cited in Thoma et al. 2008). Rather, the value of 0.05 mg/L is used as an indication of impairment meant to be considered with other parameters, such as dissolved oxygen. If low dissolved oxygen concentrations were observed commensurate with elevated total phosphorus concentrations (above 0.05 mg/L), the collective results might then indicate an impairment due to eutrophication. Corroborating evidence may include other chemical parameters associated with eutrophication—such as elevated nutrient concentrations or low dissolved oxygen concentrations—and bioassessments.

Contaminants of Emerging Concern

In most cases, because of their emerging status, no water quality benchmarks or standards apply to contaminants of emerging concern. In addition to possible direct toxicity, many of the analytes included in the analysis suite are known or suspected endocrine disruptors, which can have harmful effects on aquatic vertebrates. Analytes included in the tested suite may also be ecologically benign but serve as indicators of persistent synthetic compounds in the natural environment. The ecological effects of these compounds are often uncertain. A range of known effect levels can be represented by (1) the lowest observed effect level (LOEL) for freshwater organisms (which can include effects not only on mortality, but also on ecologically relevant variables, such as biochemistry, behavior, and morphology), and (2) the acute toxicity rating at which 50% of tested organisms die (lethal concentration for 50% of organisms, LC_{50}).

Table 4.6.3-1. Reference conditions used to assess water resources.

Indicator	Good	Moderate/Significant Concern
Water Quality[1]	Water quality thresholds established by the State of Utah were not exceeded for more than 10% of samples for an individual attribute.	Water quality thresholds established by the State of Utah were exceeded for more than 10% of samples for an individual attribute.
Contaminants of Emerging Concern[2]	Analytes were below the lowest observed effect level (LOEL) and/or are below the lethal concentration for 50% of tested organisms (LC_{50}).	Analytes exceeded the lowest observed effect level (LOEL) and/or exceeded the lethal concentration for 50% of tested organisms (LC_{50}).

[1] See Utah DEQ (2016) for State of Utah water quality standards.

[2] LOEL and L_{50} values for analytes found in NCPN waters can be found in Weissinger et al. (2013), Weissinger (2015), and Weissinger et al. (2016a).

The LOEL and L_{50} values were derived from a variety of sources, including the Pesticide Action Network, Environmental Protection Agency, the World Health Organization, and peer-reviewed literature (see Weissinger et al. 2013, Weissinger 2015, and Weissinger et al. 2016 for the LOEL and L_{50} values for analytes found in NCPN parks). However, endocrine-disrupting chemicals, in particular, can be bio-active at very low concentrations that may not be captured by an LOEL. Due to the large number of analytes, only the thresholds for detected analytes were presented in the above-mentioned reports.

4.6.4. Condition and Trend

Core Parameters

Water-quality standards were exceeded for only one core attribute for water years 2013 to 2015. Tropic Ditch exceeded the pH standard for secondary-contact recreation, non-game fish, and agricultural use for 10% of evaluations for two of 20 samples. A pH of 9.04 was recorded on August 5, 2014, and a pH of 9.01 was recorded on September 4, 2014. The geochemical components of watersheds throughout the Northern Colorado Plateau naturally cause the pH of surface water to be slightly basic. Measurements taken later in 2014 and in 2015 were within the acceptable pH range. Thus, there is no immediate management concern. The condition for core parameters of water is good and confidence is high. We could not report on trends since an analysis of the long-term data has not been completed.

Major Ions

During the 2009 to 2012 water years, total dissolved solids exceeded standards at Sheep Creek (below the spring) but for less than <10% of site visits. No other attributes of major ions were exceeded in the park. In part, Sheep and Yellow creeks were included in the NCPN monitoring plan because they contribute flow to segments of the Paria River, which is on the State of Utah's 303(d) list of impaired water bodies for this attribute of water quality. Total dissolved solids exceedences are common on these streams below the park boundary (Judd and Adams 2006 as cited in Van Grinsven et al. 2010), but were rare in the park (Thoma et al. 2008, Van Grinsven et al. 2010, Hackbarth and Weissinger 2013, and Hackbarth and Weissinger 2016). The condition for this measure is good and confidence is high. We could not report on trends since an analysis of the long-term data has not been completed.

Nutrients

During the 2009 to 2012 water years, Mossy Cave Spring exceeded the indication of impairment for total phosphorus but during less than 10% of site visits. Sheep Creek (below the spring) and Yellow Creek (below the spring) exceeded the indication of impairment for total phosphorus for warm-water game fish for 10% and 13% of site visits, respectively. Total phosphorus exceedences may result from rock weathering, airborne deposition, or soil erosion. Phosphorus comes in several forms, including a form in soil particles that may be transported to water bodies where dissolution can occur, resulting in bioavailable phosphorus. Trespass cattle in and around Sheep and Yellow Creeks may contribute to soil erosion and increased total phosphorus levels. It is also possible that the phosphorus has a geologic origin and is naturally occurring at high levels due to weathering. A better understanding of phosphorus source, transport, and biological effect in these watersheds would help determine potential management actions for restoration, including the possibility of reclassifying or providing site-specific classifications for water bodies based on natural conditions. Since only one attribute of nutrients exceeded the indication for impairment, the condition for this measure is good and confidence is high. We could not report on trends since an analysis of the long-term data has not been completed.

Trace Elements

Thresholds for trace elements were not exceeded at any of the six sites during the sampling period. The condition for this measure is good and confidence is high. We could not report on trends since an analysis of the long-term data has not been completed.

Fecal Indicator Bacteria

The chronic *E. coli* standard for the State of Utah was exceeded during 2006-2015 at Yellow Creek (below the spring) and Sheep Creek (below the spring), and at Mossy Cave and Tropic Ditch during 2006-2008 but on less than 10% of site visits. The acute *E. coli* standard was not exceeded. Possible sources of contamination include wildlife, human use, and trespass cattle, which have been an infrequent but reoccurring issue in Bryce Canyon NP. Fresh cow tracks and manure were observed at these sites and on at least one occasion, cattle were at the Sheep and Yellow Creek monitoring sites (Van Grinsven et al. 2010). The infrequent *E. coli* exceedences that occurred during the study period do not warrant concern from a human-health perspective. Thus, the condition for this measure is good and confidence is high. We could not report on trends since an analysis of the long-term data has not been completed.

Pesticides

None of the 73 pesticide analytes were detected in waters sampled during 2010-2015 (Weissinger et al. 2013, Weissinger 2015, and Weissinger et al. 2016). The condition for this measure is good and confidence is high. We could not report on trends since an analysis of the long-term data has not been completed.

Wastewater Indicators

A total of 11 wastewater indicators were detected among the four sites located along Sheep and Yellow Creeks during 2010-2015 (Table 4.6.4-1). No wastewater indicators were detected at Mossy Cave Spring during the single site visit in 2010. All concentrations were below the LOEL except for carbaryl and estrone, which were detected at Yellow Creek (below the spring) on one occasion in 2010. Neither of these analytes were detected during subsequent sampling periods. The condition for this measure is good and confidence is high. We could not report on trends since an analysis of the long-term data has not been completed.

Pharmaceutical and Personal Care Products

Caffeine was detected in Yellow Creek (below spring) during July and August of 2012 and during May and September of 2015, but concentrations did not exceed LOEL (Table 4.6.4-2). DEET was detected at Sheep Creek (at park boundary) during May 2014 and at Yellow Creek (at park boundary) during May and September of 2015. As with caffeine, concentrations of deet were below the LOEL. Therefore, the condition for this measure is good and confidence is high. Analysis of the long-term data has not been completed to determine trend.

Overall Condition, Trend, Confidence Level, and Key Uncertainties

Overall, we consider water quality at Bryce Canyon NP to be in good condition. This condition rating was based on two indicators with a total of eight measures, which are summarized in Table 4.6.4-3. In sum, all water quality measures and CECs were within the range that was considered good except for two wastewater contaminants that were over the LOEL, but this was during only one site visit and these chemicals

Table 4.6.4-1. Wastewater analytes detected.

Location	Year	Analyte	Concentration (µg/L)
Sheep Creek (below spring)	2010	Bisphenol A	0.105 (November)
	2010	Isoquinoline	0.230[1] (November)
	2010	Metachlor	0.210 (November)
	2014	Camphor	0.101
	2014	Tri(dichloroisopropyl) phosphate	0.116
Sheep Creek (at park boundary)	2014	Camphor	0.101 (September)
	2014	Tri(dichloroisopropyl) phosphate	0.116 (May)
Yellow Creek (below spring)	2010	Bisphenol A	0.170 (November)
	2010	Carbaryl	0.1602 (November)
	2010	Estrone	0.1902 (November)
	2010	Isoquinoline	0.190 (November)
	2010	Metolachlor	0.220 (November)
	2010	p-Cresol	0.210 (November)
	2010	Tri(2-chloroethyl) phosphate	0.160 (November)
	2010	Tributyl phosphate	0.170 (November)
	2012	Bisphenol A	0.107[1] (July)
	2012	Nonylphenol	0.12[1] (July)
	2012	Tributyl phosphate	0.114[1] (July)
Yellow Creek (at park boundary)	2015	Camphor	0.020[1]

[1] Estimated value.

[2] Exceeded the LOEL.

Table 4.6.4-2. Pharmaceutical and personal care product analytes detected.

Location	Year	Analyte	Concentration (µg/L)
Sheep Creek (at park boundary)	2014	DEET	0.0112
Yellow Creek (below spring)	2012	Caffeine	0.0122* (July), 0.0439* (August)
	2015	Caffeine	0.04.6* (May), 0.025 (September)
Yellow Creek (at park boundary)	2015	DEET	0.0261* (May), 0.0284* (September)

* Estimated value.

Table 4.6.4-3. Summary of water quality indicators, measures, and condition rationale.

Indicators of Condition	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Water Quality	Core Parameters		Water-quality standards were exceeded for only one attribute for water years 2013 to 2015. Tropic Ditch exceeded the pH standard for secondary-contact recreation, non-game fish, and agricultural use for 10% of evaluations for two of the 20 samples. Measurements taken later in the year and in 2015 were within the acceptable pH range. There is no immediate management concern and these fluctuations may reflect natural variability. The condition for this measure is good and confidence is high. Trend could not be determined.
	Major Ions		During the 2009 to 2012 water years, total dissolved solids (TDS) exceeded standards at Sheep Creek (below the spring) for less than <10% of site visits. TDS exceedences are common on these streams below the park boundary, but were rare in the park. None of the other attributes of this measure exceeded standards. The condition for this measure is good and confidence is high. Trend could not be determined.
	Nutrients		During the 2009 to 2012 water years, Mossy Cave Spring exceeded the indication of impairment for total phosphorus during less than 10% of site visits, while Sheep Creek (below the spring) and Yellow Creek (below the spring) exceeded the indication of impairment for total phosphorus for warm-water game fish for 10% and 13% of site visits, respectively. The cause for these exceedences is unknown, but is not cause for immediate concern. No additional indicators of impairment were observed. The condition for this measure is good and confidence is high. Trend could not be determined.
	Trace Elements		Thresholds for trace elements were not exceeded at any of the sites during the sampling period. The condition for this measure is good and confidence is high. Trend could not be determined.
	Fecal Indicator Bacteria		The chronic *E. coli* standard for the State of Utah was exceeded during 2006-2015 at Yellow Creek (below the spring) and Sheep Creek (below the spring), and at Mossy Cave and Tropic Ditch during 2006-2008 but on less than 10% of site visits. The acute *E. coli* standard was not exceeded. The infrequent *E. coli* exceedences do not warrant concern from a human-health perspective. The condition for this measure is good and confidence is high. Trend could not be determined.
Contaminants of Emerging Concern	Pesticides		No pesticides were detected in waters sampled during 2010-2015. The condition for this measure is good and confidence is high. Trend could not be determined.
	Wastewater Indicators		A total of 11 wastewater indicators were detected among the four sites located along Sheep and Yellow Creeks. No wastewater indicators were detected at Mossy Cave Spring during the single site visit in 2010. All concentrations were below the LOEL except for carbaryl and estrone, which were detected at Yellow Creek (below spring) on one occasion. Neither of these indicators were detected in later years. The condition for this measure is good and confidence is high. Trend could not be determined.
	Pharmaceutical and Personal Care Products		Caffeine was detected in Yellow Creek (below spring) during July and August of 2012 and during May and September of 2015, but concentrations did not exceed LOEL. DEET was detected at Sheep Creek (at park boundary) during May 2014 and at Yellow Creek (at park boundary) during May and September of 2015. As with caffeine, concentrations of DEET were below the LOEL. The condition for this measure is good and confidence is high. Trend could not be determined.
Overall Condition, Trend, and Confidence Level			Overall, water quality at Bryce Canyon NP is in good condition with an unknown trend. Confidence in the condition rating is high. Virtually all attributes and analytes were within the range that was considered good. *E. coli* and pH standards were occasionally exceeded and only two wastewater contaminants were over the LOEL, but this was during only one site visit and these chemicals were not detected on subsequent site visits.

were not detected on subsequent site visits. While pH also exceeded reference thresholds for good condition at Tropic Ditch, this may be due to the geology of the region and is not a cause for concern.

Confidence in the overall condition rating is high. 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 of the park. The data used in this assessment were collected recently, are repeatable, and are part of a long-term monitoring effort. We could not determine trend since an analysis of the long-term data has not been done.

A key uncertainty is that LOEL and LC_{50} are standardized tests that can be misleading because (1) the values are usually developed based on laboratory tests with static water conditions, rather than flowing natural environments, (2) information is often not available for every taxonomic group (e.g., amphibians, fish, invertebrates including zooplankton, vascular plants, non-vascular plants including phytoplankton), (3) some of the values are derived from thousands of studies while others are derived from only a handful, and (4) the LOEL is highly dependent on instrument sensitivity.

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

During monthly monitoring visits, signs of cattle trespass were observed in the park along the riparian corridors of Sheep and Yellow creeks. Potential physical and biological damage to the riparian corridor and degradation of water quality from cattle trespass is not being measured but may be a resource-management concern. There has been continued effort to maintain the boundary fences at Sheep Creek and Yellow Creek, but high water damages these fences during the summer monsoon season. Re-construction of the boundary fence on Sheep Creek—destroyed by flood in 2007, repaired in 2008, and maintained in 2009—should eliminate any potential impacts caused by trespass cattle in the biologically rich riparian area along the stream. There is also possible contamination of water resources from tourism development and septic systems in Bryce Canyon City via natural geologic fracturing.

Of all the threats to water resources in the park, climate change has the greatest potential to alter the structure and function of springs, seeps, and streams. 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 Bryce Canyon NP were summarized in Monahan and Fisichelli (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 (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 and stream flow (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). As noted earlier, Bryce Canyon NP does not hold all water rights for waters originating within or flowing through the park (Utah Division of Water Rights 2017).

Altered hydrologic patterns may, in turn, alter water chemistry and concentrations of environmental contaminants. Continued sampling of water resources in Bryce Canyon NP will help establish a baseline for the range of natural variability expected for the park.

4.6.5. Sources of Expertise

Significant portions of the NCPN water quality and contaminants reports were excerpted in this assessment. Assessment authors are William Battaglin (USGS), Paul Bradley (USGS), Kenneth Dahlin (U.S. EPA), Carolyn Hackbarth (NCPN), Kristen Keteles (U.S. EPA), Matt Malick (NPS), Mary Moran (NPS), David Thoma (NCPN), Matt Van Grinsven (NCPN), Rebecca Weissinger (NCPN), and Lisa Baril (Utah State University). Subject matter review experts are listed in Appendix B.

4.7. Upland Vegetation

4.7.1. Background and Importance

Variable topography, differences in soil moisture attributes, and fire history drive plant distribution patterns in Bryce Canyon National Park (NP) (Tendick et al. 2011). The park's plant communities have been broadly classified into three vegetation belts (Buchanan 1992 as cited in Tendick et al. 2011). From highest to lowest elevations the vegetation belts are as follows: mixed coniferous forests in the montane forest belt (Figure 4.7.1-1), ponderosa pine (*Pinus ponderosa*) woodlands interspersed with sagebrush shrublands (*Artemisia* spp.) in the submontane forest belt, and sparse woodlands in the lowest vegetation belt (Tendick et al. 2011). Sparse woodlands are further divided into pinyon pine-Utah juniper (*Pinus edulis-Juniperus osteosperma*) woodlands on mesic north-facing slopes and bristlecone pine (*Pinus longaeva*) woodlands on xeric south-facing slopes (Tendick et al. 2011).

This assessment focuses on vegetation composition and structure of upland forest and woodland communities in each of the three vegetation belts. Uplands are plant communities that are not associated with riparian areas or wetlands (Tendick et al. 2011). Non-native plants and rare and distinctive vegetation were addressed as separate assessments in this report.

4.7.2. Data and Methods

Five indicators with a total of nine measures were used to assess the current condition of upland vegetation in Bryce Canyon NP.

From 2010 to 2016, NCPN staff monitored upland vegetation in each of forty-five 50 x 50 m (164 x 164 ft) plots (Witwicki 2012). Plots were distributed across pinyon-juniper (PJ) woodlands (25) and mixed conifer (MC) forests (20) (Figure 4.7.2-1). 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 2010 to 2014 (i.e., 8 or 10 plots per year) to complete one round of surveys. The second round of surveys began in 2015. For the following two measures, data from the first round of sampling were averaged across years (i.e., 2010–2014) with data from 2015 and 2016 listed in Appendix G. Refer to Witwicki et al. (2013) for further details on monitoring protocol for each of the measures listed below. Data were provided by D. Witwicki, NCPN vegetation ecologist.

<u>Tree Density (#/ha)</u>

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

Figure 4.7.1-1. Mixed coniferous forest with aspen. Photo Credit: © Ashley Tai.

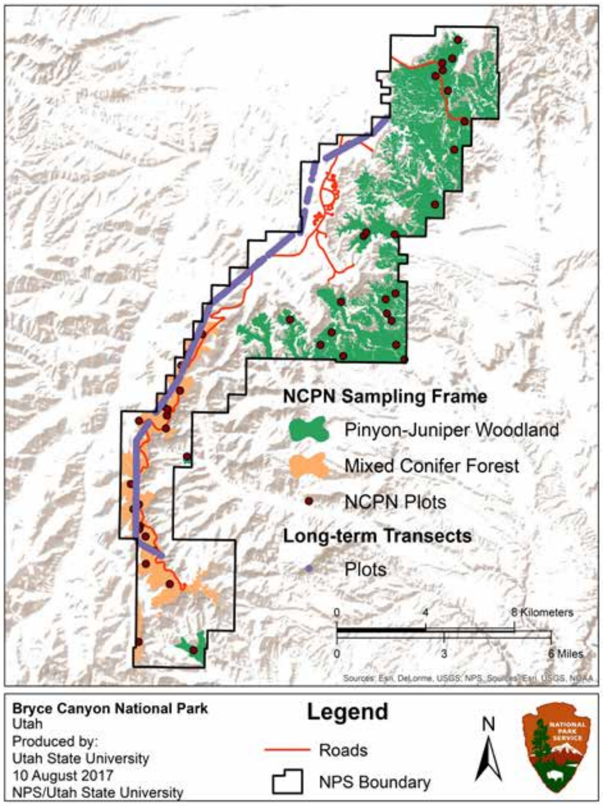


Figure 4.7.2-1. Upland vegetation monitoring plots and transects in Bryce Canyon NP.

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 species.

Crown Health (% live)

For each tree in mixed coniferous forests 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). For PJ woodlands trees were recorded as live or standing dead (i.e., crown health classes of live foliage were not recorded). Data were summarized by species.

Soil Aggregate Stability (class)

In each of the 25 PJ plots, soil aggregate stability was measured at 18 random sample points along the three transects (6 per transect) (Witwicki et al. 2013). Soil stability was not measured in MC plots. Soil stability classes range from 1 to 6, with 1 representing very unstable soils and 6 representing very stable soils (Herrick et al. 2005).

In 1957-1959, nine permanent transects were established across a 400 m (1,312 ft) elevation gradient along the western edge of the park (Figure 4.7.2-1) (Buchanan 1960). Along each transect Buchanan (1960) established 1 m^2 (11 ft^2) quadrats spaced approximately 91 m (299 ft) apart for a total of 266 quadrats. Transects were resampled in 1969-1970, 1978-1980, 1990-1992, and in 2007, but not all quadrats could be located every year and there were several issues with the 1978-1980 tree data (Ironside et al. 2008). Therefore, only those quadrats (n = 221) that were sampled in all years except 1978-1980 were included in the analysis of long-term trends for trees (Ironside et al. 2008). All years were used in the analysis of understory cover, but not all quadrats were used (see Ironside et al. 2008 for more details).

Quadrats were grouped into stands based on dominant species composition, structure, and disturbance history. Stands were then grouped into one of three forest types. From lowest to highest elevation the three forest types were as follows: ponderosa pine-grassland savanna (n = 5 stands), ponderosa pine-Douglas-fir (*Pseudostuga menziesii*) forest (n = 6 stands), and white fir (*Abies concolor*)-ponderosa pine-Douglas-fir forest (n = 21 stands for trees and 23 stands for understory cover) (Ironside et al. 2008). The latter forest community identified by Ironside et al. (2008) was described as mixed coniferous forest by the NCPN and is referred to as such hereafter. Following the 1991 survey, prescribed fire has been used as a management tool in all ponderosa pine-grassland savanna stands, four ponderosa pine-Douglas-fir stands, and in two mixed coniferous forest stands. A brief description of the two measures used in this assessment follow, but see Ironside et al. (2008) for further details.

Relative Importance of Trees

Density for seedlings (<2.5 cm DBH [1.0 in DBH]), saplings (2.5–10 cm DBH [1.0–4.0 in DBH]), and trees (>10 cm DBH [>4.0 in DBH]) were recorded in each quadrat (note that these size classes differ slightly from NCPN size classes). Cover was defined as a measure of basal area (also referred to as dominance) and was recorded at a height of 1.4 m (4.5 ft) for all trees. Basal area was then multiplied by the absolute density for each species and divided by the total cover for all species to arrive at relative cover. Relative frequency was calculated as the percentage of sample points at which a species occurred divided by the total frequency of all species. Relative measures of density, cover, and frequency were summed to determine overall relative importance (RI) and RI for each tree species by forest type. The authors then tested for significant differences in RI over time using paired t-tests for normally distributed data and the Mann-Whitney test otherwise. Estimates of density and other measures used to calculate RI were also reported for some species to better illustrate changes over time. Because actual estimates of RI were rarely reported, we focus on presenting trends over time.

Understory Cover

Plant presence and cover by life form (grasses, shrubs, forbs, and rushes/sedges) were recorded in each quadrat. Ocular estimates of cover were made and the number of individuals of each species was noted. All survey years were used in the analysis, but missing data from 1969-1970 prevented comparisons among time periods in a few cases. The authors then tested for significant differences in cover over time for each forest type using ANOVA for normally distributed data and the Kruskal-Wallis test otherwise. As with RI, the authors rarely presented actual cover estimates. Therefore, we focused on presenting trends over time.

Bark Beetle Infestation (ha)

Insect detection survey (IDS) geospatial data for Utah State were downloaded from the United States Forest Service's (USFS) Forest Health Monitoring (FHM) program website 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 surveys and ground survey efforts by FHM staff and State of Utah staff (USFS 2016). The shapefiles were clipped to Bryce Canyon NP'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.

Fuels Volume (tonnes/ha)

In both PJ and MC plots, woody fuels were measured along four 15-m (50-ft) transects that extended beyond the plot on two corners (Witwicki et al. 2013). 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 was also recorded along the four fuels 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.

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

Normalized Difference Vegetation Index (NDVI)

NDVI (Normalized Difference Vegetation Index) 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 analyzed NDVI in 658 forested polygons (Tendick et al. 2011) greater than 6.25 ha (15.44 ac), which is an area greater than the resolution of a single MODIS image pixel. Following the naming convention in Tendick et al. (2011), the six coarse scale vegetation types were blue spruce (*Picea pungens*) forest complex, Douglas fir forest complex, Gambel oak (*Quercus gambelii*) shrubland complex, pinyon pine-juniper woodlands, ponderosa pine savanna, ponderosa pine-Douglas fir forest, and white fir forest. After grouping forest types into six coarse classes (Figure 4.7.2-2) each polygon was classified as either unburned or high-severity burned if it burned during the study period (Figure 4.7.2-3). Other burn severity classes have been mapped and additional burn-severity analyses are possible but were not presented here.

For each of the six 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 at a point in time 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 productivity 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

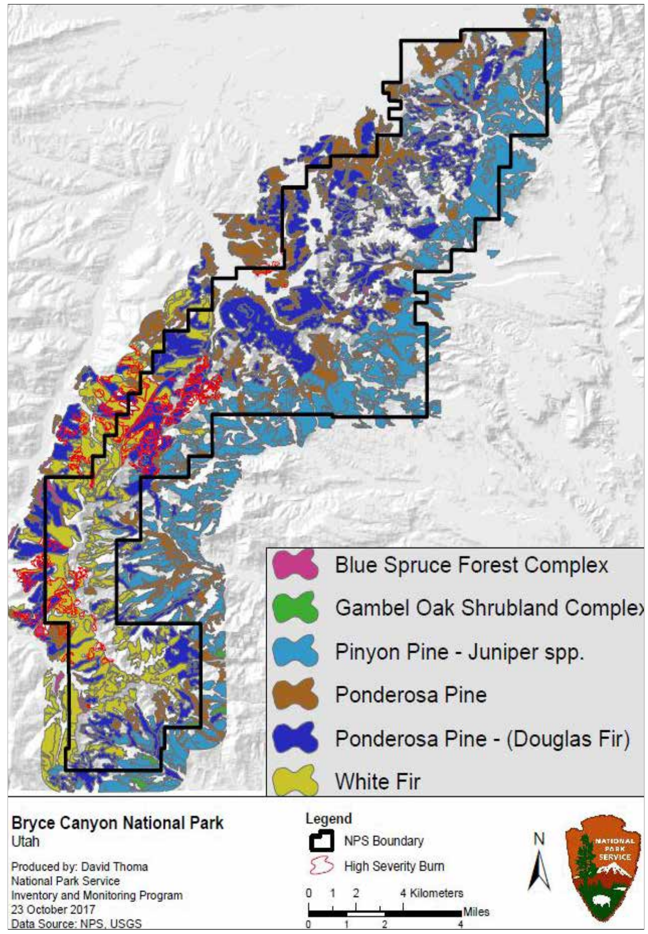


Figure 4.7.2-2. A map of the polygons in six forest types used to assess NDVI (productivity) in Bryce Canyon NP.

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 productivity 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 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 for pre-settlement (i.e., before 1900) forests in the southwest, particularly those in southern Utah. Furthermore, those studies that estimated pre-settlement conditions often reported such wide ranges that their utility was limited. Lastly, the available

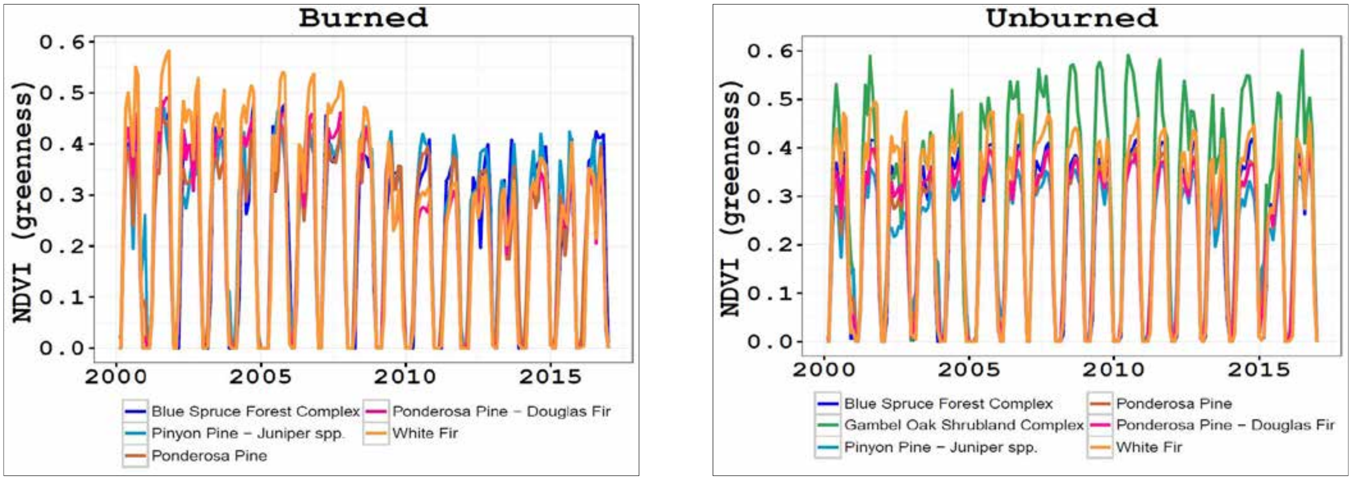


Figure 4.7.2-3. Gap-filled and smoothed monthly normalized difference vegetation index averaged across coarse forest types and grouped by either high severity burn (top) or unburned (bottom). Only forested polygons >6.25 ha were analyzed for the period 2000-2016.

studies may not apply to forests in Bryce Canyon NP. Therefore, a majority of the reference conditions were necessarily qualitative and were based on descriptions of historic conditions in Utah's forests or similar forests (Abella and Denton 2009, Battaglia and Shepperd 2007, Baker et al. 2007, Fulé et al. 2004, Fulé et al. 1997, Margolis 2014, Miller et al. 2008, and others).

No reference conditions were developed for fuels volume because fuel loads were 1) historically variable, especially in mixed coniferous forests, and 2) dependent on time since the last fire and other disturbances, such as bark beetle-killed trees and windthrow (Baker et al. 2007, Battaglia and Shepperd 2007, Covington and Moore 1994, Tausch and Hood 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 for context (Jarvis and Kulakowski 2015, Morris and Brunelle 2012). Finally, no reference conditions were developed for NDVI. Rather, NDVI data provide a baseline for which to compare future NDVI results.

4.7.4. Condition and Trend

Pinyon-juniper woodlands tree density (#/ha)

Four species dominated PJ woodlands with a total tree density of 239 trees/ha (97 trees/ac) during 2010-2014. Utah juniper exhibited the highest tree density with 101 trees/ha (41 trees/ac), while Rocky Mountain juniper exhibited the lowest tree density at 21 trees/ha (9 trees/ac). Seedling density was highest for two-needle pinyon (217 seedlings/ha [88 seedlings/ac]) and lowest for Rocky Mountain juniper (87 seedlings/ha [35 seedlings/ac]) (Figure 4.7.4-1). At least some individuals within all size classes were represented for each species, and all species exhibited a greater number of seedlings than saplings or trees. These results indicate a stable or growing population for all four species. Condition was good and confidence was high, but trend could not be determined based on a single round of sampling.

Mixed coniferous forests tree density (#/ha)

Five species of tree were encountered in MC forests. The species were white fir, ponderosa pine, quaking aspen, Douglas-fir, and limber pine. Total tree density for the five species was 171 trees/ha (69 trees/ac) during 2010 to 2014. Because limber pine was so rarely encountered, it was excluded from the following density estimates. White fir exhibited the highest tree density (93 trees/ha [38 trees/ac]), while aspen exhibited the lowest tree density (1 trees/ha [0.4 trees/ac]) (Figure 4.7.4-2). White fir also exhibited far more seedlings than the other three species (2,516 seedlings/ha [1,019 seedlings/ac]). Density of ponderosa pine seedlings and saplings was relatively low, and sapling density was very low for quaking aspen but with relatively high seedling density (640 seedlings/ha [259 seedlings/ac]). These results suggest a low but persistent population of ponderosa pine and quaking aspen and dominance by white fir. Historically, mixed coniferous forests were dominated several conifer species whose densities varied by elevation, slope, and

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

Indicator	Strata	Measure	Good	Moderate / Significant Concern
Community Composition and Structure	Pinyon-juniper, Mixed Conifer	Tree Density (#/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.	A declining population for one or more species as indicated by few or no seedlings, saplings, and young mature trees. In addition, for mixed coniferous forests density indicates possible dominance by one or two species rather than a forest composed of multiple species.
	Pinyon-juniper, Mixed Conifer	Crown Health	Trees exhibited more live foliage than standing dead, and the majority of the foliage was within crown health class 1 or 2 (50-100% live foliage).	Trees exhibited more standing dead than live foliage, or the majority of the foliage was in crown health class 3 or 4 (0.1-49% live foliage).
Soil Stability	Pinyon-juniper	Soil Aggregate Stability (class)	Over all plots, soil stability averaged ≥ class 3 (moderately stable to very stable).	Over all plots, soil stability averaged < class 3 (unstable to very unstable).
Forest Community Changes (1957-2007)	Ponderosa pine savanna, Ponderosa pine-Douglas-fir, Mixed Conifer	Relative Importance of Trees (RI)	Changes in RI over time reflected a trend toward historical vegetation conditions. Ponderosa pine dominated lower elevations but was co-dominant with other conifers in mixed coniferous forests.	Changes in RI over time reflected a trend that departed from historical vegetation conditions. Ponderosa pine was not the dominant species at low elevations and was out-competed by other conifers in the absence of natural disturbances, especially at higher elevations.
	Ponderosa pine savanna, Ponderosa pine-Douglas-fir, Mixed Conifer	Understory Cover	Changes over time reflected a trend toward improving conditions of a grass-dominated understory at all elevations, although mixed coniferous forest understory was also characterized by a moderate amount of shade-intolerant shrub cover.	Changes over time reflected a trend that departed from historical vegetation conditions. The understory at all elevations was dominated by a shade-tolerant shrub understory rather than a predominantly grass understory.
Forest Health	Park-wide	Bark Beetle Infestation (ha)	No reference conditions developed.	No reference conditions developed.
	Pinyon-juniper, Mixed Conifer	Fuels Volume (tonnes/ha)	No reference conditions developed.	No reference conditions developed.
	Park-wide	Vegetation Condition Class	A majority (>70%) of the park was mapped as Low to Moderate departure, and no areas of the park were mapped as High or Very High departure.	Less than 70% of the park was mapped as Low to Moderate Departure, and areas mapped as Moderate to High departure or higher were common.
Forest Productivity	Forested Areas Park-wide	Normalized Difference Vegetation Index	No reference conditions developed.	No reference conditions developed.

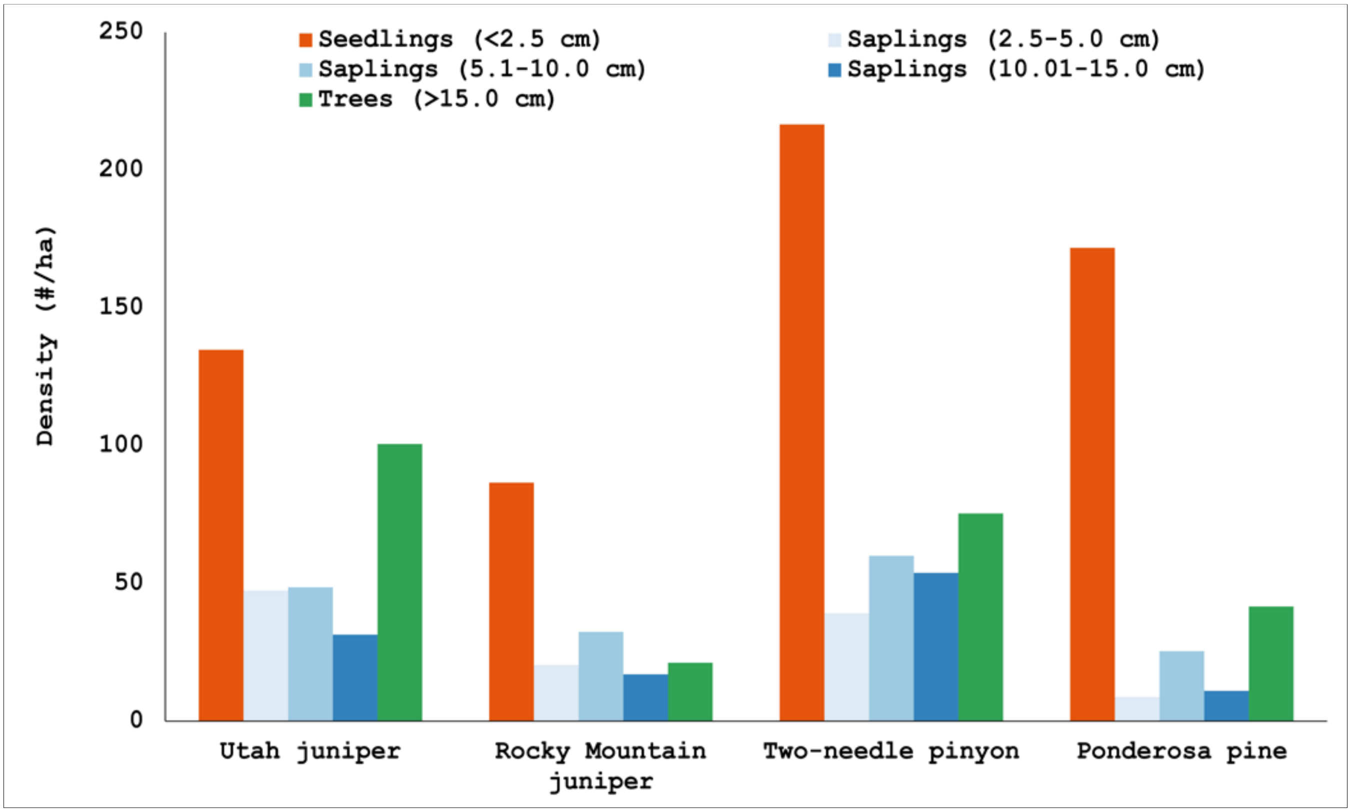


Figure 4.7.4-1. **Tree density by size class in pinyon-juniper woodlands.**

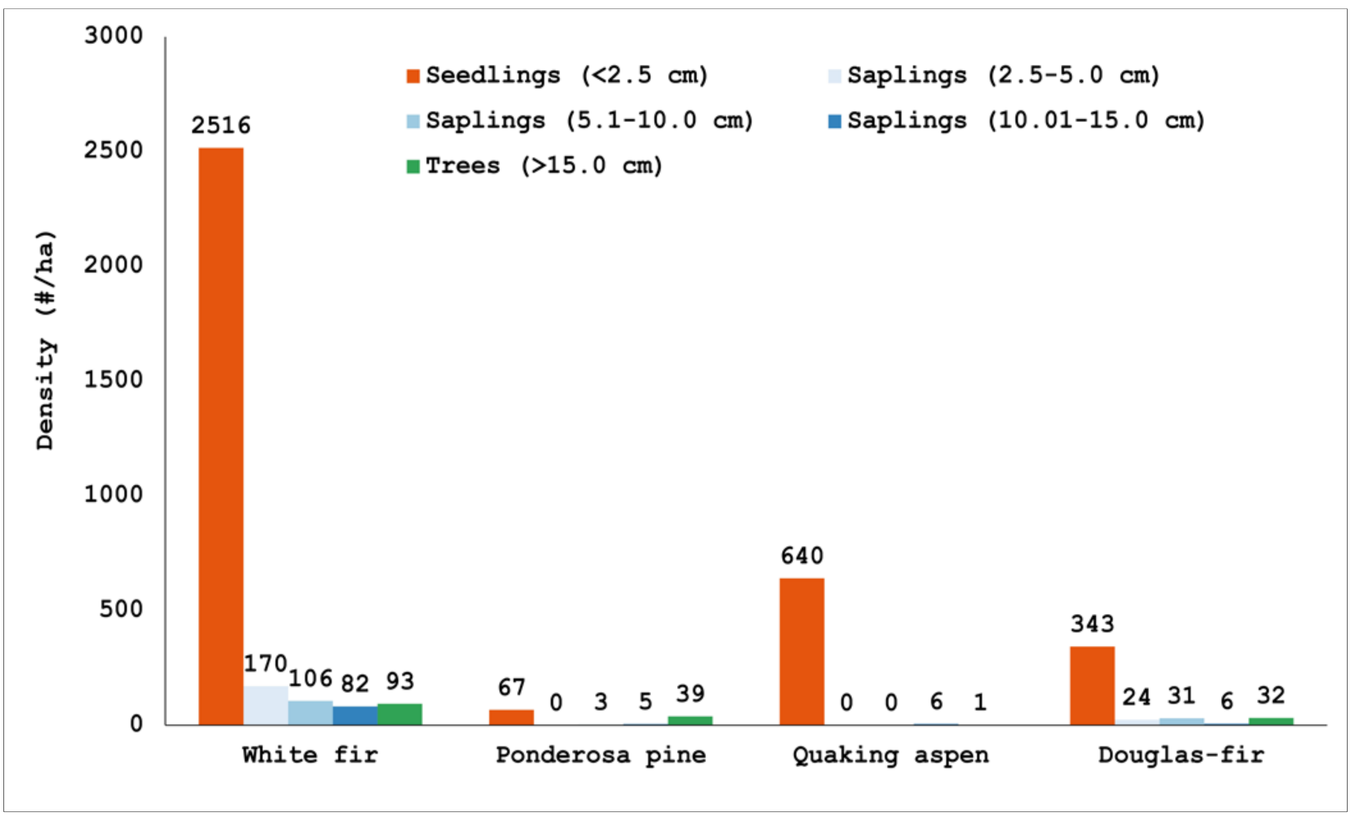


Figure 4.7.4-2. **Tree density by size class in mixed coniferous forests.**

aspect (Battaglia and Shepperd 2007). At elevations greater than 2,591 m (8,500), as sampled in this study, white fir tends to dominate with limber pine and Douglas fir (Battaglia and Shepperd 2007). The results presented here suggest that forest composition and density generally reflects historical conditions. Therefore, condition is good. Confidence was high, but trend could not be determined based on a single round of sampling.

Crown Health (% live)

Pinyon-juniper woodlands exhibited mostly live trees with few standing dead trees during 2010 to 2014 (Figure 4.7.4-3). All four tree species exhibited at least 90% cover. These data indicate good condition for this measure. Although the second round of sampling has not been completed, data for 2015 and 2016 (Appendix G) indicate high crown health with values similar to the results presented here. Confidence in the condition rating is high, but trend could not be determined based on one round of sampling.

Mixed coniferous forests

Approximately half of white fir and ponderosa pine trees were in crown health classes 1 and 2, or were ≥50% live (Figure 4.7.4-4). Approximately, 25% of all Douglas fir trees were classified as ≥50% live, while 59% were classified as standing dead. No quaking aspen trees were classified as ≥50% live and 83% were classified as standing dead. These results indicated mostly live white fir and ponderosa pine, but a large number of standing dead Douglas fir and aspen trees. Although these results suggest moderate to significant concern based on aspen and Douglas fir, the condition is unknown at this time since plots were not stratified based on fire activity. Fire was likely responsible for at least some standing dead trees and is a natural process in this community type. Because of the unknown condition, confidence is low. Trend could not be determined based on this single round of monitoring.

Soil Aggregate Stability (class)

During 2010 to 2014, total soil aggregate stability averaged 2.7. Based on reference conditions, these results warrant moderate/significant concern; however, soils in the park may be naturally less stable in pinyon-juniper woodlands than in other areas of the park since this plant community tends to occur in naturally erosive areas (e.g., hoodoos). Because of this uncertainty, confidence in the condition rating is low. This first round of NCPN data may serve as a baseline for which to evaluate future soil samples

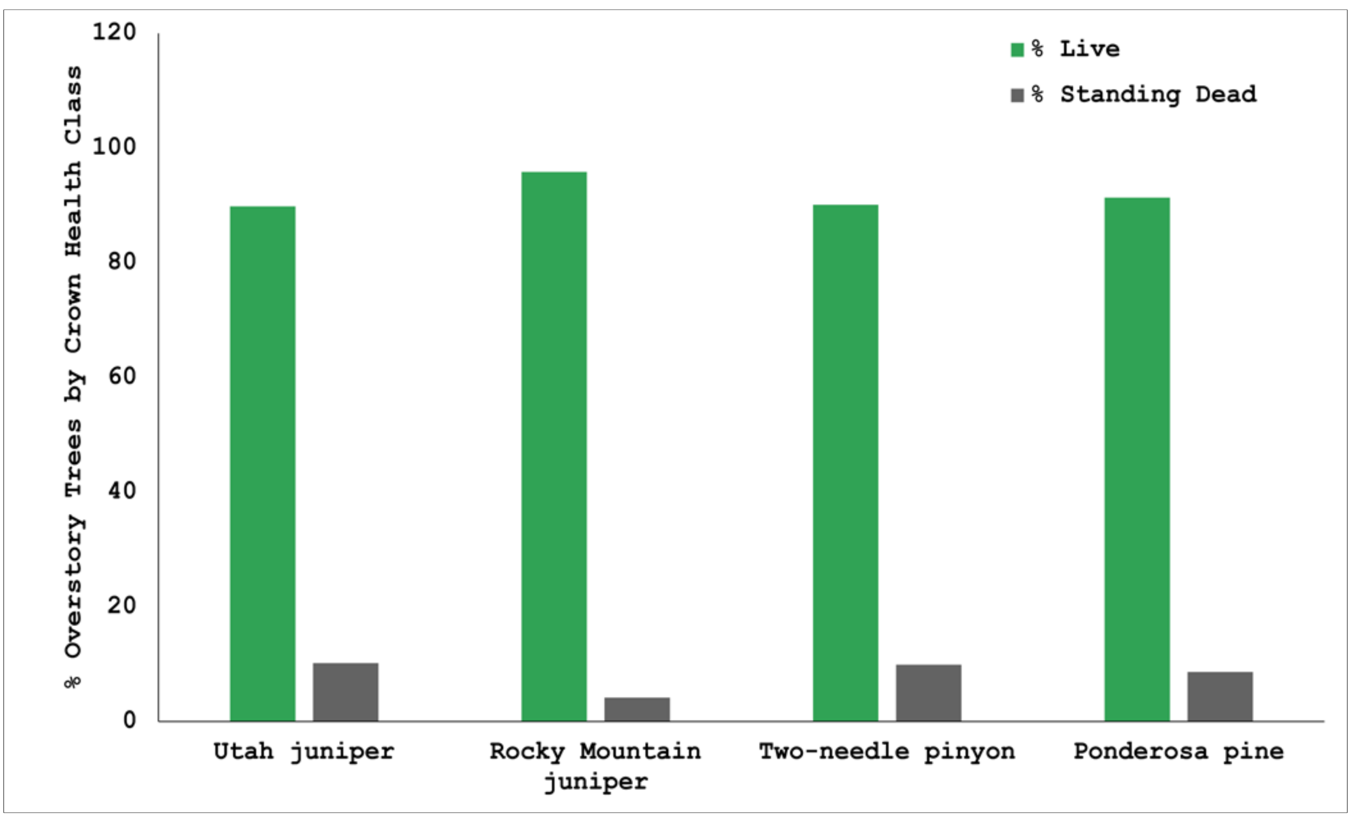


Figure 4.7.4-3. Crown health in pinyon-juniper woodlands.

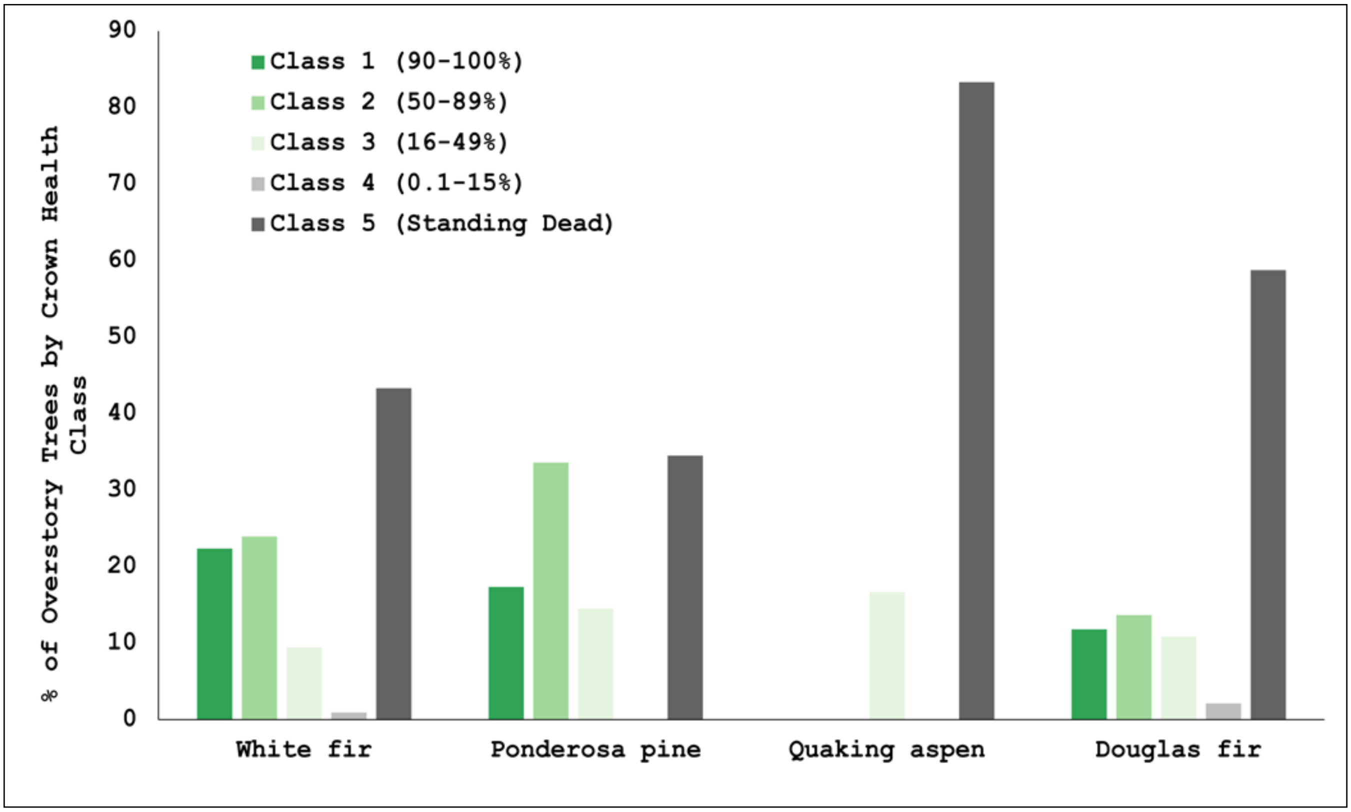


Figure 4.7.4-4. Crown health in mixed coniferous forests.

from this plant community. Erosion, was addressed in the geology assessment in this report. Trend for this measure was unknown.

Relative Importance of Trees

Ponderosa Pine-Grassland Savanna Forest

Ponderosa pine was the dominant tree species in this community type. When transects were first established in 1957-1959, ponderosa pine savanna exhibited low densities of trees and high densities of seedlings and saplings (Ironside et al. 2008). Many of these seedlings and saplings recruited into larger size classes over time. The RI value for species dominance increased significantly from 1957-1959 to 2007 ($p = 0.027$). However, the authors note that because this forest type is composed almost exclusively of ponderosa pine, RI values that use relative measures of cover, density, and frequency were less meaningful than if the absolute values of these measures were used (Ironside et al. 2008). Thus, the authors reported key measures used to calculate RI that were responsible for changes over time.

Absolute tree density more than doubled between 1957-1959 (75.3 trees/ha [30.5 trees/ac]) and 1991 (199.8 trees/ha [80.9 trees/ac]) ($p = 0.016$). Between 1991 and 2007, tree density declined somewhat to 143 trees/ha (57.9 trees/ac), but this change was not significant ($p = 0.221$). Basal area between 1957-1959 and 2007 did not change (Mann-Whitney test significance level 0.403). The authors suggested that the large increase in tree density but no changes in basal area may be an artifact of sampling methods (Ironside et al. 2008).

Sapling and seedling density increased slightly between the first two surveys, but changes were not significant ($p > 0.05$). However, both size classes significantly declined between 1991 and 2007 to densities less than what was observed in 1957-1959. In 1991, sapling density was 159 saplings/ha (64 saplings/ac) and in 2007 sapling density was 47.1 saplings/ha (19 saplings/ac) ($p = 0.011$). In 1991, seedling density was 127.5 seedlings/ha (51.7 seedlings/ac) and in 2007 seedling density was 31.1 seedlings/ha (12.6 seedlings/ac) ($p = 0.025$). These data indicate low recruitment of seedlings and saplings into the tree size class after 1991, which was directly attributed to a prescribed fire specifically targeted at reducing ponderosa pine densities and maintaining the open park-like savanna that is characteristic of this community type (Ironside et al. 2008).

A literature search revealed a general lack of studies on pre-settlement ponderosa pine-densities for southern Utah. However, several studies reported density estimates for other areas. Pre-settlement estimates of southwestern ponderosa pine tree density averaged approximately 99-148 trees/ha (40-60 trees/ac) (Battaglia and Shepperd 2007). Baker et al. (2007) reported pre-settlement ponderosa pine densities ranging from 28 to 3,052 trees/ha (11-1,236 trees/ac) for Colorado. In northern Arizona pre-settlement densities were between 5 and 99 trees/ha (2-40 trees/ac) (Abella and Denton 2009). Abella and Denton (2009) found considerable inherent variation in ponderosa pine forest structure within and across regions depending on soil type and climatic variables. These considerable differences make determining whether Bryce Canyon NP's ponderosa pine savannas were within the natural range of historical variability difficult, although there is general agreement that ponderosa pine densities were historically much lower in southwestern savannas than in southern and central Rocky Mountain savannas (Kaufmann et al. 2000). Furthermore, inconsistencies in size classes designated as trees can lead to variable densities that make comparing studies difficult.

Overall however, the results presented in Ironside et al. (2008) indicate densification of mature trees, reduced seedling and sapling density, and lack of encroachment of other tree species. Because of the densification of mature trees, the condition warrants moderate/significant concern but with an improving trend as a result of reduced seedling and sapling densities and the restoration of fire. Confidence was medium because the sample size was small (n = 5 stands).

Relative Importance of Trees
Ponderosa Pine-Douglas-fir Forest

There were no significant differences in pair-wise comparisons of RI for any species between the three surveys ($p > 0.05$). By this measure, ponderosa pine-Douglas-fir forest has not changed significantly over the 50 years of surveys. As previously noted, prescribed fire was used as a management tool in four out if six stands between 1991 and 2007. Although the sample size was small, a paired t-test between burned and unburned stands showed no significant differences in RI ($p = 0.877$). However, prescribed fire significantly reduced overall sapling density ($p = 0.038$) but not the density of seedlings or trees ($p > 0.05$). Sapling density averaged 102 saplings/ha (41 saplings/ac) in 1991 and 83 saplings/ha (34 saplings/ac) in 2007.

Although this forest type has changed little since 1957-1959, the initial sampling period probably does not reflect pre-settlement conditions. The authors did not present density estimates for trees so we could not compare these results to other studies. However, in Colorado estimates for pre-settlement tree densities ponderosa pine-Douglas-fir forests varied between 39 and 3,410 trees/ha (16-1,381 trees/ac) (Baker et al. 2007). For these reasons, the condition for this measure was unknown with an unchanging trend. Confidence was low because the condition was unknown.

Relative Importance of Trees
Mixed Coniferous Forest

Analyses revealed that this forest type has drifted from a mixed coniferous forest with several codominant species to a forest dominated primarily by white fir. The RI for white fir trees increased significantly between each time period ($p < 0.05$). Density in 1957-1959 averaged 134 trees/ha (54 trees/ac). By 1991 tree density averaged 226 trees/ha (91 trees/ac). The authors did not report tree density for 2007. These estimates were somewhat higher than what was reported for the same size classes by NCPN during 2010 to 2014, which was 175 trees/ha (71 trees/ac) (note these data were corrected to correspond to the same size class reported by Ironside et al (2008). The RI for white fir saplings significantly increased from 1957-1959 to 1991 ($p < 0.001$), but there was no difference in sapling RI between 1991 and 2007 ($p > 0.05$). The RI for white fir seedlings did not change significantly between any of the surveys. The authors suggested that because seedling density had not changed, seedlings and saplings recruited into sapling and tree size classes (Ironside et al. 2008).

RI for Douglas-fir trees declined from 1957-1959 to 2007 (Mann-Whitney test significance level 0.037), although pair-wise comparisons between each of three survey periods were not significant. Douglas-fir sapling RI decreased significantly from the first survey to the 1991 survey ($p = 0.001$), but there were no differences between 1991 and 2007 ($p > 0.05$). Seedling RI, however, significantly declined ($p = 0.006$) between the first two surveys and then significantly increased by 2007 ($p = 0.040$). However, changes in Douglas-fir were small.

The authors did not report RI significance tests for ponderosa pine, but did report absolute density data. Tree density increased only slightly between 1957-1959 (79 trees/ha [32 trees/ac]) and 1991 (98 trees/ha [40 trees/ac]) (p = 0.045), but there were no significant differences between 1991 and 2007. Sapling density did not change significantly over time. Similar to ponderosa pine, limber pine tree density increased but increased only between the first two survey periods (p = 0.035). Sapling density, however, declined over all time periods from 80 saplings/ha (32 saplings/ac) in 1957-1959 to 44 saplings/ha (18 saplings/ac) by 2007 (p < 0.05). Although other species, including pinyon pine, juniper, aspen, and blue spruce also occurred in this forest type, they were too infrequent to calculate RI or density values.

The overall trend in this forest type indicates the conversion of mixed conifer forest to a white fir-dominated forest. These results warrant moderate/significant concern for this forest type and are consistent with NCPN data from mixed coniferous forests in the park. Trend has deteriorated over time. Confidence is high due to the high number of stands in this forest type (n = 21).

Understory Cover

Ponderosa Pine-Grassland Savanna Forest

Cover of shrubs significantly declined over time, while grass cover increased (Figure 4.7.4-5). By 2007 grass cover was greater than shrub cover. Sedge/rush cover has significantly increased. Overall, grass cover did not change significantly over time (p = 0.302), but data showed that grass cover had declined somewhat by 1991 and then increased slightly thereafter. Data on forb cover indicate a slight decline over time, but this relationship was not significant. These results indicate good condition overall and an improving trend of greater grass cover and lower shrub cover, which was attributed to prescribed fire and reseeding in a portion of the area surveyed (Ironside et al. 2008). Confidence was medium because of the small sample size (n = 5). Historic estimates of understory vegetation were not available for this or the remaining forest types.

Ponderosa Pine-Douglas-fir Forest

As with trees, there were few changes in the understory of this forest type (Figure 4.7.4-6). Only sedges/rushes had significantly increased over time (p = 0.021). However, forbs, grasses, and shrubs declined somewhat over time, but trends were not significant.

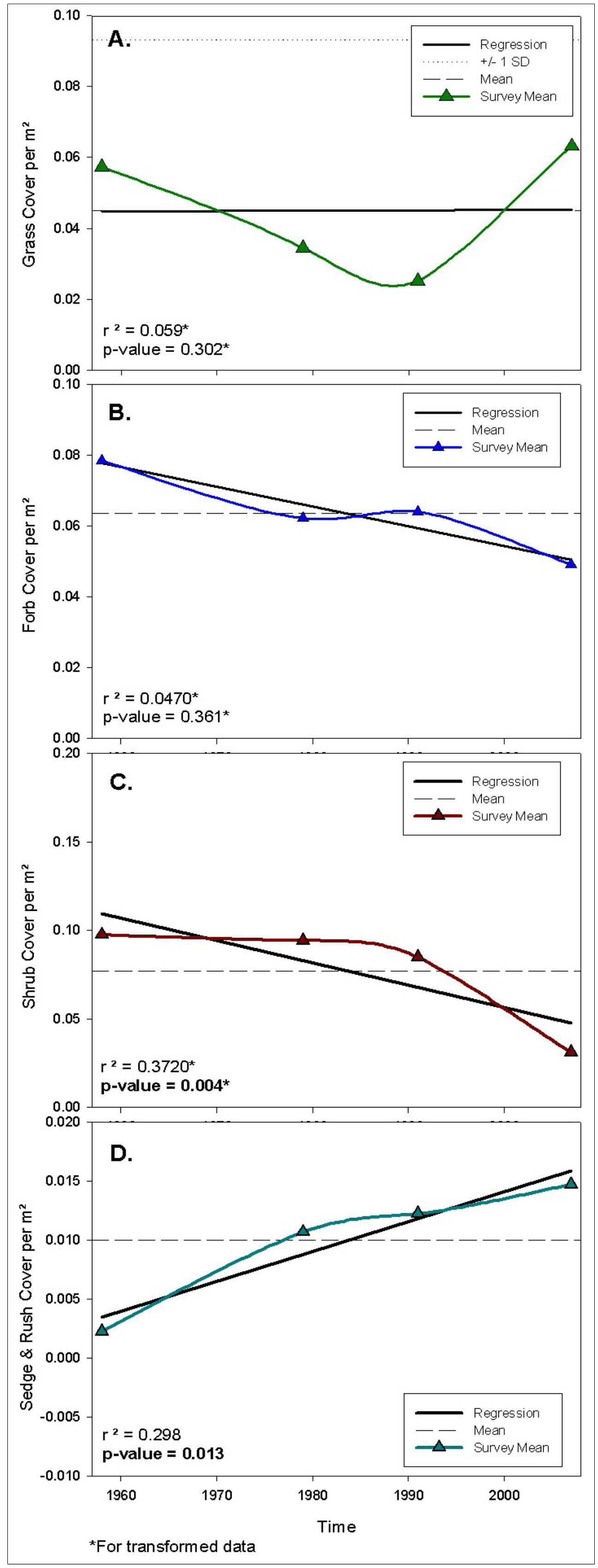


Figure 4.7.4-5. Changes in understory cover in ponderosa pine savanna. Figure Credit: © Ironside et al. (2008).

The authors speculated that because this community type occurs in relatively dry areas, productivity is low and changes occur slowly (Ironside et al. 2008). Due to lack of reference conditions for this forest type, the condition was unknown. Trend was considered unchanging. Confidence was low since the condition was unknown.

Mixed Coniferous Forest
Grass cover significantly decreased over time (Kruskal-Wallis test *p*-value = 0.02) (Figure 4.7.4-7). While forb cover also declined, the trend was not significant. Shrub cover exhibited the greatest changes of the four life forms. During the first half of the time period, shrub cover declined by half, from 17% cover in 1958 to just 8% in 1980. Afterwards, shrub cover increased to 13% cover. Because of the initial decline then increase, the overall trend was not significant (Kruskal-Wallis *p*-value = 0.078). Sedges/rushes significantly increased over time (p = 0.000). Although trends in shrub cover were not significant, the pattern of change warrants moderate/significant concern as does the decline in grass cover. Changes in shrub cover over time were attributed to a shift in species composition from mostly shade-intolerant species to shade-tolerant species as the overstory canopy densified (Ironside et al. 2008). Trend has deteriorated. Confidence was high due to the high number of stands in this forest type (n = 24).

Bark Beetle Infestation (%)
A total of 2,270 ha (5,610 ac), or about 16% of the park, were mapped as affected by bark beetles during 1997 to 2015 (Figure 4.7.4-8). Pinyon ips (*Ips confusus*) and fir engravers (*Scolytus ventralis*) were the two most common disturbance agents. This value excludes areas that were mapped in multiple years. Less than 3% of the survey area was mapped as infested in any given year except for 2004-2005 when 13% and 18% were mapped, respectively (Table 4.7.4-1). In most years less than 1% of the park was mapped as affected. Insect activity occurred regularly in the park's history with numerous disturbance events between 1955 and 1976 (Hansen 1997). Activity between 1977 and 1996 had apparently not been documented (Hansen 1997). Since no reference conditions were developed, condition was unknown and confidence was low. Trend appears unchanging, with pulses of outbreaks, however we consider this unknown as well since a longer time period is likely need to establish trends with confidence.

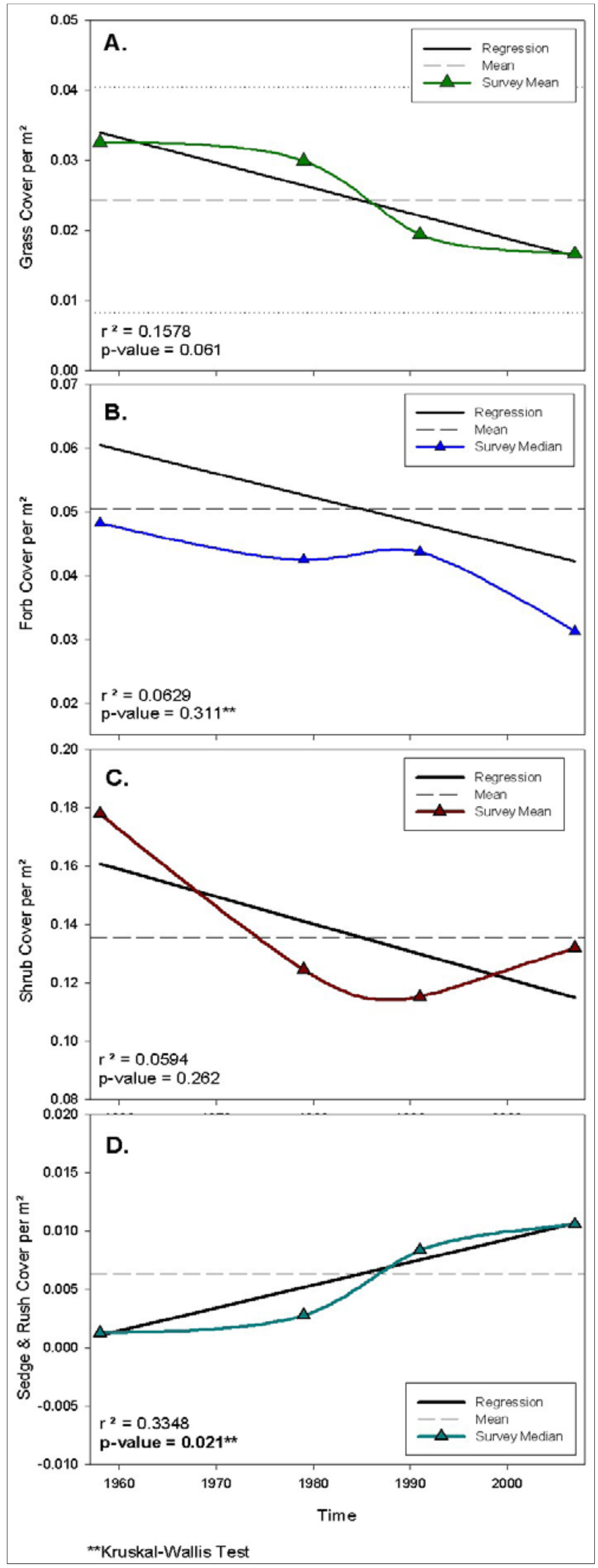


Figure 4.7.4-6. Changes in understory cover in ponderosa pine-Douglas-fir forest. Figure Credit: © Ironside et al. (2008).

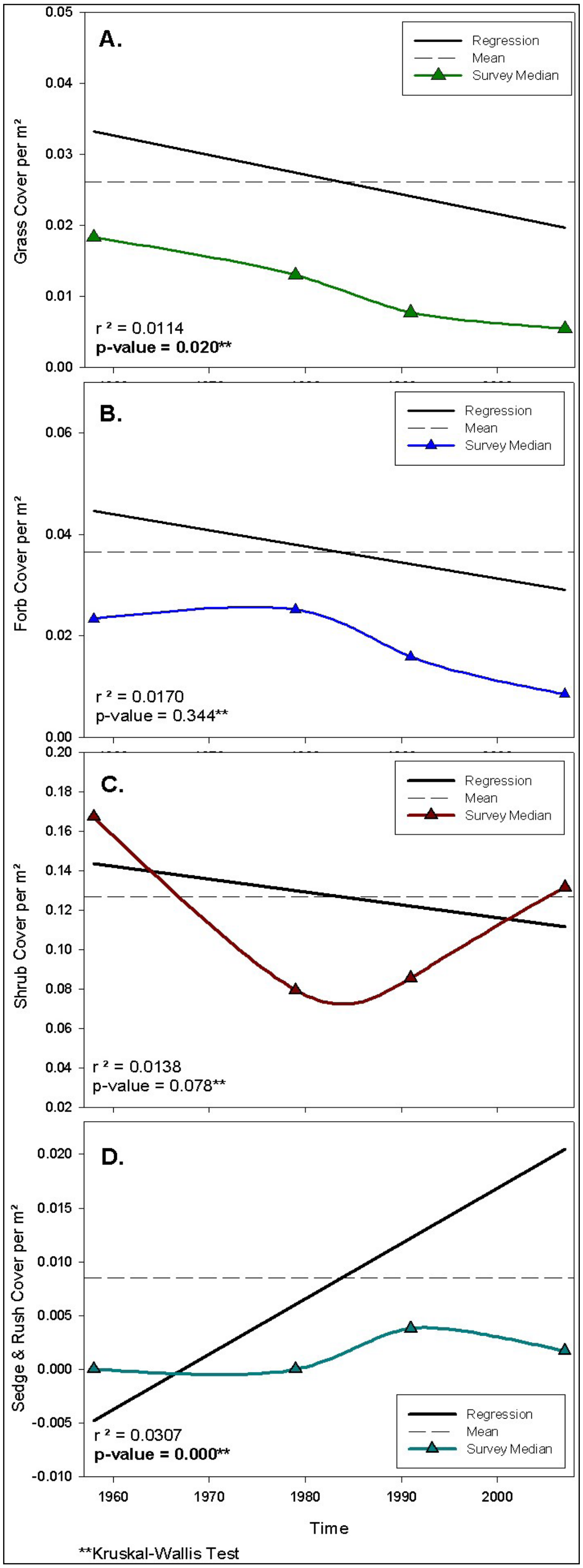


Figure 4.7.4-7. Changes in understory cover in mixed coniferous forest. Figure Credit: © Ironside et al. (2008).

Table 4.7.4-1. Forest insect damage and survey area mapped by year.

Year	Affected Area ha (ac)	Total Surveyed Area ha (ac)	% Area Affected
1997	15.5 (38.3)	No Data	–
1998	15.5 (38.3)	No Data	–
1999	12.1 (29.8)	10,940 (27,034)	0.11
2000	4.1 (10.2)	14,084 (34,802)	0.03
2001	28.1 (69.6)	6,492 (16,043)	0.43
2002	0.0 (0.0)	12,624 (31,196)	0.00
2003	357.1 (882.4)	13,935 (34,434)	2.56
2004	1,774.9 (4,385.8)	13,399 (33,110)	13.25
2005	518.9 (1,282.3)	2,938 (7,259)	17.66
2006	10.1 (24.9)	1,378 (3,406)	0.73
2007	104.2 (257.4)	14,563 (35,987)	0.72
2008	3.2 (8.0)	14,470 (35,758)	0.02
2009	4.0 (10.0)	13,432 (33,191)	0.03
2010	0.0 (0.0)	13,339 (32,963)	0.00
2011	4.0 (10.0)	13,938 (34,443)	0.03
2012	1.0 (2.5)	13,759 (33,999)	0.01
2013	1.0 (2.5)	14,366 (35,501)	0.01
2014	5.9 (14.5)	14,162 (34,996)	0.04
2015	7.4 (18.3)	14,563 (35,987)	0.05

Source: USFS Forest Health Protection Program (2015).

Fuels Volume (tonnes/ha)
Pinyon-juniper woodland

Total woody fuels averaged 15.38 tonnes/ha (6.87 tons/ac) during 2010 to 2014 (Table 4.7.4-2). Approximately, 76% of the fuels were comprised of 10-hr and 1,000-hr sound fuels. Litter and duff depth averaged 1.41 cm (0.56 in) and 0.35 cm (0.14 in), respectively. Fuel loads were generally low probably because productivity is low in this community type. Since no reference conditions were developed, condition was unknown and confidence was low. Trend was unknown.

Fuels Volume (tonnes/ha)
Mixed coniferous forests

Total woody fuels averaged much higher in MC forests than in PJ woodlands (Table 4.7.4-2). Total woody fuels during 2010 to 2014 averaged 70.85 tonnes/ha (31.63 tons/ac), most of which was composed of sound 1,000-hr fuels (56.63 tonnes/ha [25.28 tons/ac]) (4.7.4-2). Litter and duff depth averaged 1.22 cm (0.48 in) and 0.42 cm (0.17 in), respectively. Since no reference conditions were developed, condition was unknown and confidence was low. Trend was unknown.

Table 4.7.4-2. Mean fuel volume and litter and duff depth.

Average (2010-2014)	Fuel Volume (tonnes/ha)						Depth (cm)	
	Total	1-hr	10-hr	100-hr	1,000-hr Sound	1,000-hr Rotten	Litter	Duff
Pinyon-juniper Woodlands	15.38	0.35	1.69	1.65	7.41	4.28	1.41	0.35
Mixed coniferous forest	70.85	1.11	4.49	8.62	50.86	5.77	1.22	0.42

Source: NCPN data.

Vegetation Condition Class (% area)

Of all the mapped areas, 47% of the park was mapped as Moderate to Low vegetation departure (Table 4.7.4-3; Figure 4.7.4-8). Another 18% was mapped as Moderate to High departure and 13% was mapped as Low to Moderate departure. None of the park was mapped as Very High departure. Most areas mapped as Moderate to High departure occurred in mixed coniferous forests in the southwestern part of the park and the areas mapped as Low to Moderate departure occurred in pinyon-juniper woodlands in the northeastern part of the park. Fires tended to occur in areas mapped as Moderate to Low and Moderate to High vegetation departure. When considering only the classified areas, 22% of the park was mapped as Moderate to High departure and 28% was mapped as High departure. Therefore, the condition warrants moderate/significant concern. Trend has deteriorated. Confidence is medium since these results were extracted from a national database that has an unknown classification error at the park. Although several of the previous measures support these results.

Table 4.7.4-3. Proportion of Bryce Canyon NP in each vegetation condition class.

Class Description	Proportion of Park	Proportion of Classified Areas
Low to Moderate	13	16
Moderate to Low	47	61
Moderate to High	18	22
High	1	1
Very High	0	0
Non-burnable Urban	1	n/a
Burnable Urban	1	n/a
Barren	14	n/a
Sparsely Vegetated	5	n/a

Source: USFS LANDFIRE Program (2014).

Normalized Difference Vegetation Index (NDVI)
Recent Condition and Trends in NDVI

Recent condition assessed as a percentile of long-term NDVI anomaly at the end of 2016 indicated all forest types were above the median percentile (0.50) except white fir, which was well below at 0.18 (Table 4.7.4-4). Rate of greening or increase in production was greater in the lower elevation forest types (i.e., Gambel oak shrubland complex, pinyon pine – juniper, and ponderosa pine) than higher elevation forests. Confidence is high because anomalies were calculated from monthly data (n = 12 months * 17 years) (Figure 4.7.4-9).

Table 4.7.4-4. Anomaly trends, or trends in the difference from long-term average annual production in vegetation types where trends were statistically significant (p<0.1).

Coarse Forest Type	Trend	2016 Mean NDVI Percentile*
Blue Spruce Forest Complex	Positive	0.65
Gambel Oak Shrubland Complex	Positive	0.65
Pinyon Pine - Juniper spp.	Positive	0.88
Ponderosa Pine	Positive	0.76
Ponderosa Pine - Douglas Fir	Positive	0.65
White Fir	Negative	0.18

* Percentiles are equal for some coarse forest types because they were based on rank order among a sample size of 17 for each forest type. Since forest types were influenced by similar temporal patterns in climate, the productivity rank of year 2016 was similar across some types.

Variability in annual production was high among the coarse forest types with set-backs and recovery in years 2004-2006 and in 2007-2008, respectively. In general, there was an upward trend in forest productivity for all forest types except white fir, which was the forest most affected by fire (Figure 4.7.4-9). The effects of fire were seen in white fir beginning in 2008 when wildland and prescribed fires in this forest type dramatically reduced productivity. This is supported by RI data presented earlier, which indicated a significant increase in white fir density by 2007. Although the authors do not report tree density in 2007, density in 1991 was substantially higher than what was found in NCPN monitoring

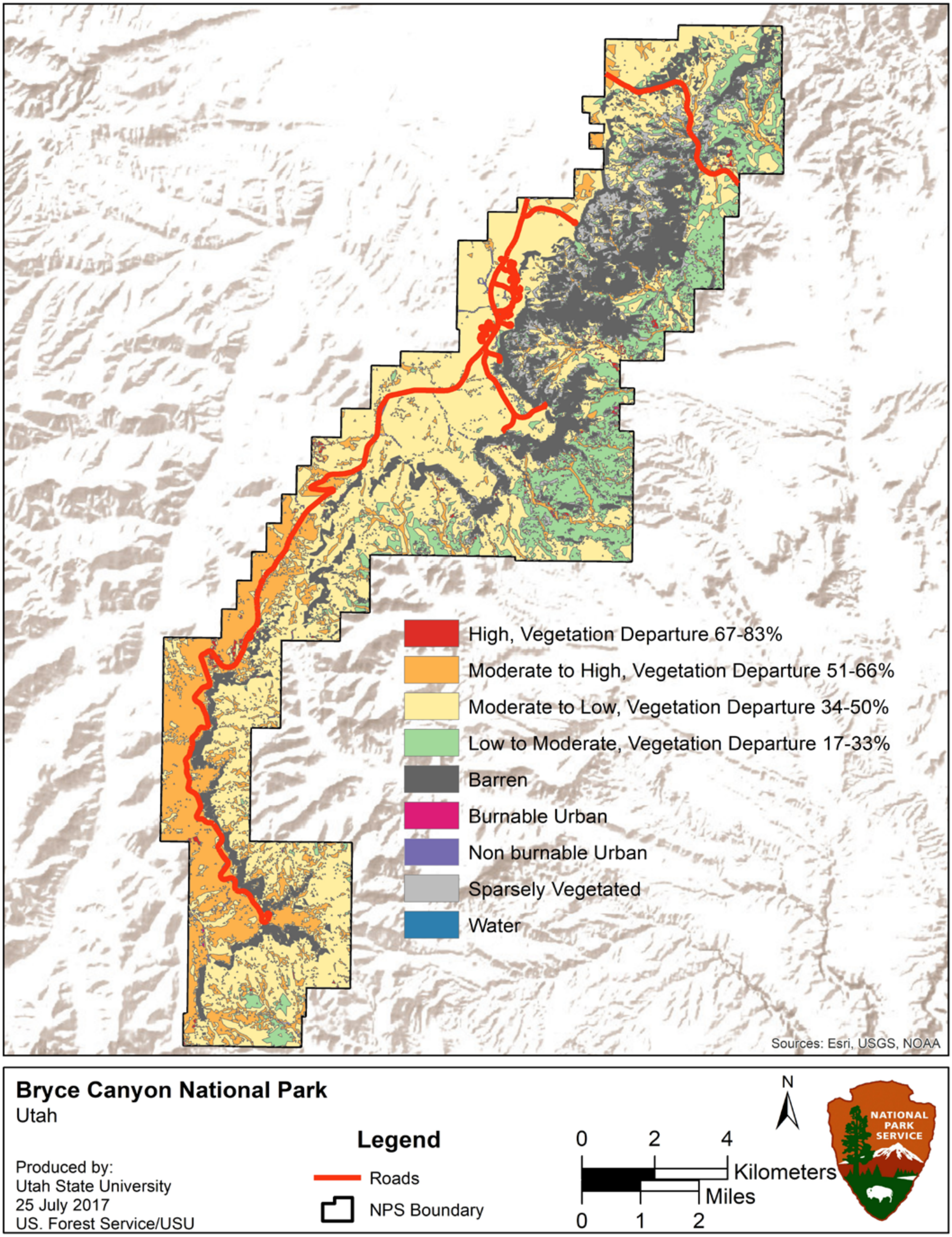


Figure 4.7.4-8. Areas affected by bark beetles and vegetation condition class.

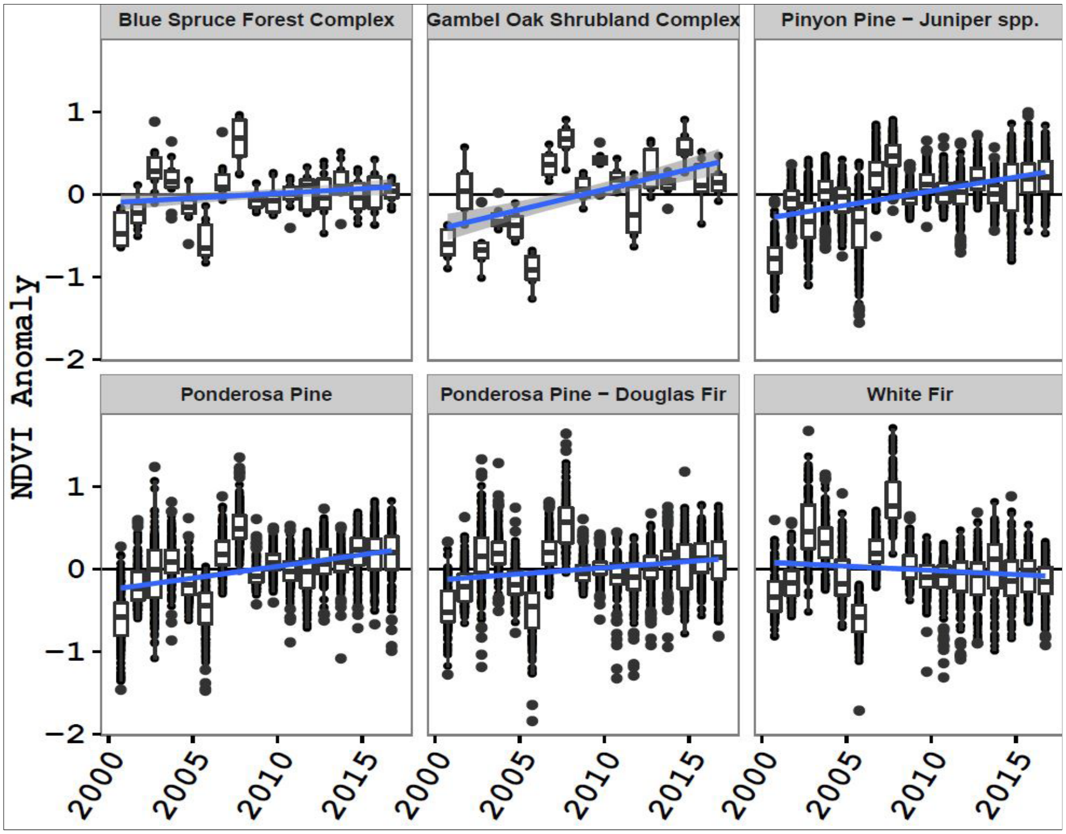


Figure 4.7.4-9. Anomaly (difference from long-term mean NDVI) trends by coarse forest type. All trends shown are statistically significant (p < 0.10).

plots surveyed during 2010 to 2014. Productivity trend in unburned polygons of the white fir forest type were statistically significant and positive ($p < 0.10$). Since no reference conditions were developed for NDVI, the condition is unknown with an unknown trend. While confidence in the analysis is high, the confidence in the condition rating is low as a result of unknown condition.

Spatial Pattern in NDVI Trends

No significant mean annual NDVI trend was observed in 54% of park area analyzed, while 32.6% increased and 13.4% decreased in production (Figure 4.7.4-10). The largest decrease in production occurred in white fir and the largest increase occurred in ponderosa pine and blue spruce followed closely by Gambel oak shrubland (Table 4.7.4-5). This seems to contradict the findings of Ironside et al. (2008), which found an increase in white fir, but a spatially explicit comparison would be required to determine how the same areas changed between the two studies. Differences could also be a matter of scale. Confidence in mean trend is high for each polygon (n = 12 months*17 years).

No significant maximum NDVI trend was observed in 70% of park area analyzed, while 14.8% increased and 15.2% decreased. The largest decrease in maximum monthly productivity occurred in white fir and the largest increase in peak productivity occurred ponderosa pine (Table 4.7.4-5). Confidence in maximum NDVI trend is low due to variability and small sample size (n = 17 years).

Correlations between Climate and NDVI

Correlations indicate which climate variables were most strongly related to vegetation production on an annual basis and whether the effect on vegetation was positive or negative. At Bryce Canyon NP measures of temperature and precipitation were important but elevation dependent (Figures 4.7.4-11 and 4.7.4-12). That is, the effect of temperature and precipitation on vegetation production depended on elevation where forest types occurred. However, there was no elevation dependency on the production relationship with actual evapotranspiration as all forest types responded positively to this climate variable.

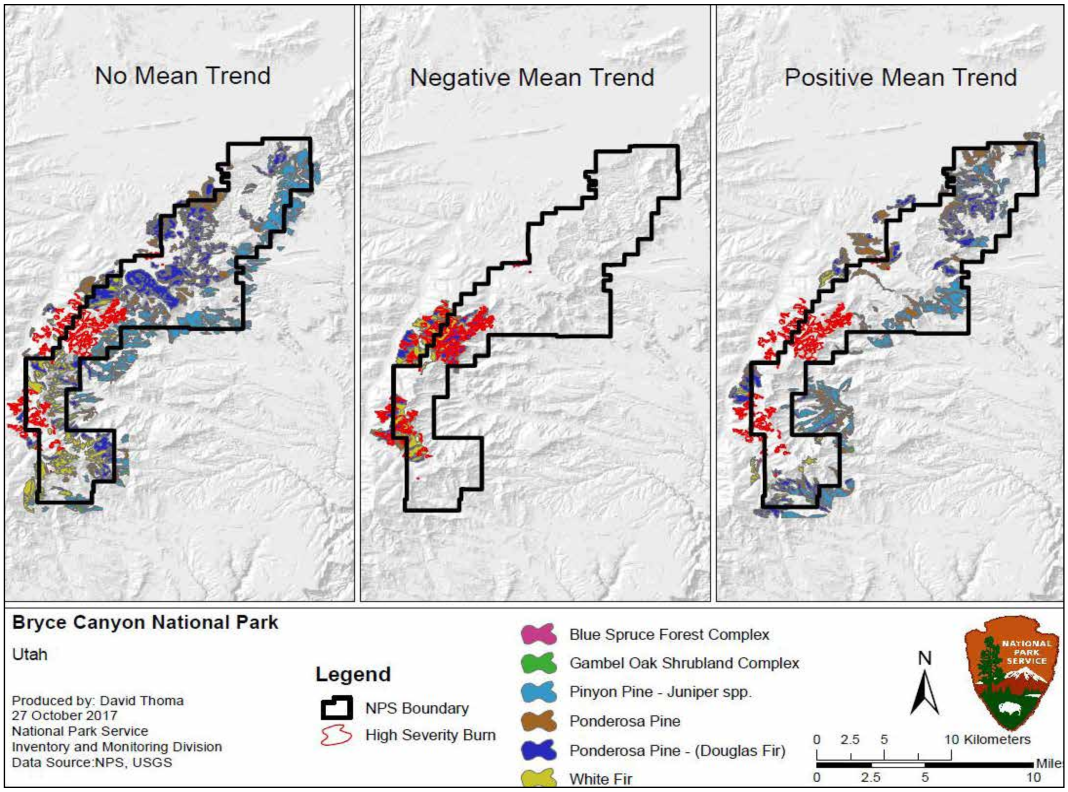


Figure 4.7.4-10. Spatial pattern of trends in forest productivity assessed by change in mean annual NDVI over time. Only polygons with statistically significant trends ($p < 0.1$) are shown.

From these elevation dependent relationships it follows that lower elevation drier forest types were limited by precipitation and thus responded positively to precipitation and other measures of water availability (soil moisture, rain, snow and water) and higher elevation, wetter forest types were limited by temperature and responded positively to warmer temperatures (average temperature, maximum temperature and potential evapotranspiration). However, all forest types responded positively to actual evapotranspiration (ET in this report). Actual evapotranspiration integrates effects of temperature, precipitation, slope, aspect and soil properties that control water storage for growth when temperatures are suitable. Actual evapotranspiration is a metric that is positively correlated with growth at all elevations in Bryce Canyon NP, which simplifies understanding the effects of climate.

Although positive relationships between actual evapotranspiration and NDVI occur in all forest types, this does not mean these forests were immune from drought stress which may occur in some years, typically later in the growing season. Warmer temperatures

Table 4.7.4-5. Trends in maximum and mean NDVI from 2000 to 2016.

Vegetation Type	Area Analyzed (ha)	Polygon Count	NDVI Max Increase ha (%)	NDVI Max Decrease ha (%)	NDVI Mean Increase ha (%)	NDVI Mean Decrease ha (%)
Blue Spruce Forest Complex	103	10	0 (0%)	12 (11%)	50 (49%)	12 (11%)
Gambel Oak Shrubland Complex	55	6	0 (0%)	0 (0%)	25 (46%)	0 (0%)
Pinyon Pine - Juniper spp.	4379	185	631 (14%)	51 (1%)	1624 (37%)	0 (0%)
Ponderosa Pine	2626	174	710 (27%)	123 (5%)	1275 (49%)	107 (4%)
Ponderosa Pine - Douglas Fir	4391	160	562 (13%)	823 (19%)	1361 (31%)	789 (18%)
White Fir	2459	123	159 (6%)	1112 (45%)	221 (9%)	968 (39%)
Park Area Totals	14014	658	2062 (15%)	2121 (15%)	4556 (33%)	1876 (13%)

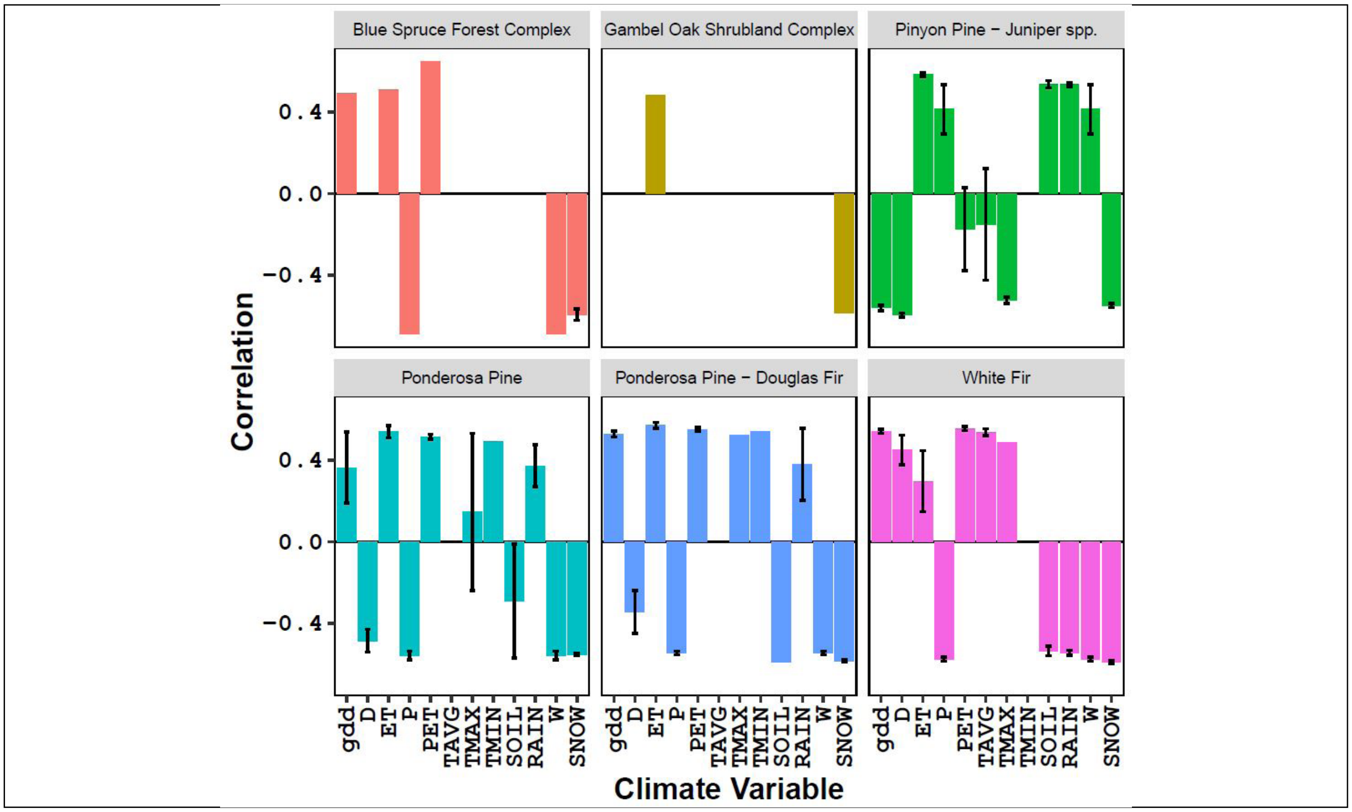


Figure 4.7.4-11. Correlation between climate variables and forest type productivity for the period 2000-2016.

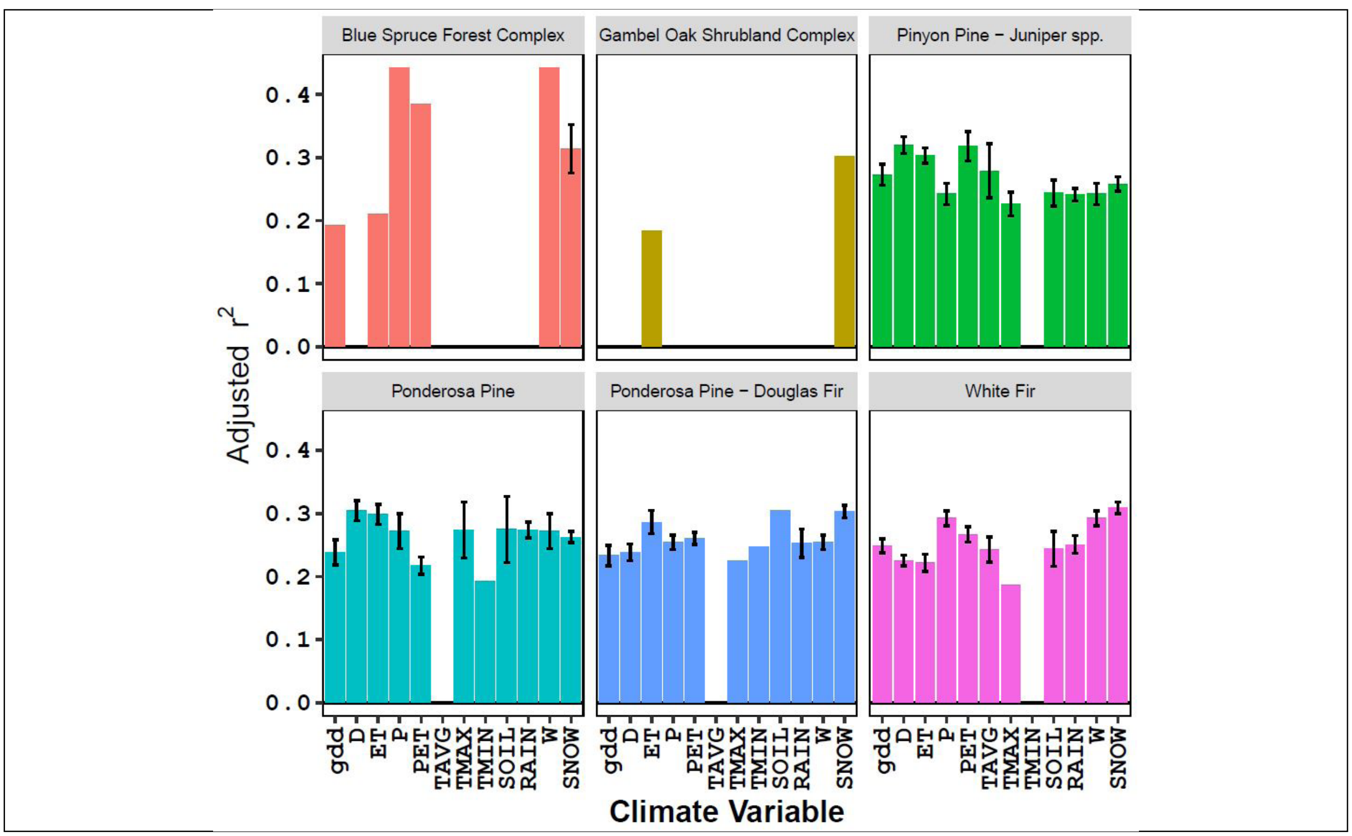


Figure 4.7.4-12. Coefficient of determination (adjusted r^2), which is the percent of variation in annual production explained by the climate variable.

are often associated with forest disease and wildfire, so warmer temperatures may have indirect effects on forest condition and trend that could limit temperature induced increases in productivity in higher elevation forests (Allen et al. 2015).

Overall Condition, Trend, Confidence Level, and Key Uncertainties

The overall condition for upland vegetation warrants moderate concern with medium confidence in the condition rating (Table 4.7.4-6). No overall trend was assigned because of variable trajectories for several measures. Based on the measures used in this assessment ponderosa pine savanna appears to be in good condition with improving condition. Pinyon juniper woodlands also appear in generally good condition but with an unknown trend. Ponderosa pine-Douglas fir forest condition could not be determined based on the available data, but the data used suggests unchanging conditions for this forest type. Finally, measures used for mixed coniferous forests suggest moderate concern with a deteriorating trend. Throughout the assessment there were several measures that were unknown because reference conditions have not been developed or the data were insufficient. Previously published studies offer some insights to historical conditions, but estimates of pre-settlement conditions vary widely and may not apply to vegetation in the park. However, given current climate change scenarios a return to historical vegetation conditions is unlikely (Settele et al. 2014). Given the high variability in NDVI anomaly over time,

Table 4.7.4-6. Summary of upland vegetation indicators, measures, and condition rationale.

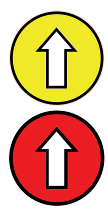
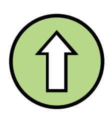
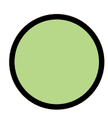
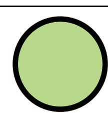
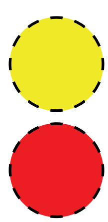
Indicators of Condition	Vegetation Type	Measures	Condition/ Trend/ Confidence	Rationale for Conditions
Forest Community Changes (1957-2007)	Ponderosa Pine Savannah	Relative Importance of Trees (RI)		The RI value for species dominance increased significantly from 1957-1959 to 2007. The increase in RI was attributed to a more than doubling of tree density from 1991 to 2007. Sapling and seedling density significantly declined during this same period. Because of the densification of mature trees, the condition warrants moderate/ significant concern but with an improving trend as a result of reduced seedling and sapling densities and the restoration of fire. Confidence was medium because the sample size was small.
	Ponderosa Pine Savannah	Understory Cover		Cover of shrubs significantly declined over time, while sedge/rush cover significantly increased. Overall, grass cover did not change over time, but grass cover had declined somewhat by 1991 and then increased slightly thereafter. Data on forb cover indicate a slight decline over time, but this relationship was not significant. These results indicate good condition and an improving trend of greater grass cover and lower shrub cover, which can be attributed to prescribed fire. Confidence was medium because of the small sample size.
Community Composition and Structure	Pinyon-juniper Woodlands	Tree Density (#/ha)		At least some individuals within all size classes were represented for each species, and all species exhibited a greater number of seedlings than saplings or trees. These results indicate a stable or growing population for all four species. Condition was good and confidence was high, but trend could not be determined based on a single round of sampling.
	Pinyon-juniper Woodlands	Crown Health		All four species exhibited at least 90% live crowns. These results indicate good condition for all four species. Trend could not be determined. Confidence was high.
Soil Stability	Pinyon-juniper Woodlands	Soil Aggregate Stability (class)		During 2010 to 2014, total soil aggregate stability in pinyon-juniper plots averaged 2.7. Based on reference conditions, these results warrant moderate/significant concern, but soils in pinyon-juniper woodlands may be naturally less stable than soils elsewhere. Because of this uncertainty, confidence is low. Trend is unknown.

Table 4.7.4-6 continued. ***Summary of upland vegetation indicators, measures, and condition rationale.***

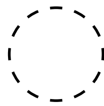
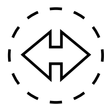
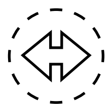
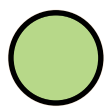
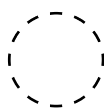
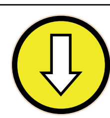
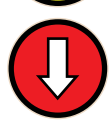
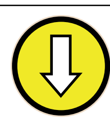
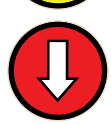
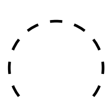
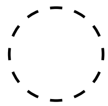
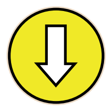
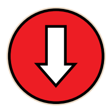
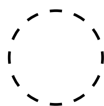
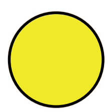
Indicators of Condition	Vegetation Type	Measures	Condition/ Trend/ Confidence	Rationale for Conditions
Forest Health	Pinyon-juniper Woodlands	Fuels Volume (tons/ha)		Total woody fuels averaged 15.38 tonnes/ha during 2010 to 2014. Approximately, 76% of the fuels were comprised of 10-hr and 1,000-hr sound fuels. Litter and duff depth averaged 1.41 cm and 0.35 cm, respectively. Fuel loads were low probably because productivity is low in this community type. Since no reference conditions were developed, condition was unknown and confidence was low. Trend was unknown.
Forest Community Changes (1957-2007)	Ponderosa pine-Douglas-fir Forest	Relative Importance of Trees (RI)		Although this forest type has changed little since 1957-1959, the initial sampling period probably does not reflect pre-settlement conditions. For these reasons, the condition for this measure was unknown with an unchanging trend. Confidence was low because the condition was unknown.
Forest Community Changes (1957-2007)	Ponderosa pine-Douglas-fir Forest	Understory Cover		There were few changes in understory vegetation. Sedges/rushes significantly increased over time. Forbs, grasses, and shrubs declined, but trends were not significant. Due to lack of reference information for his forest type, condition was unknown. Trend is unchanging, but confidence is unknown since the condition is unknown.
Community Composition and Structure	Mixed Coniferous Forest	Tree Density (#/ha)		Forests at the elevations sampled in this study (762 m [2,600 ft]) were historically dominated by a mix of conifers including ponderosa pine, Douglas fir and especially white fir. In this study, white fir density was far greater than ponderosa pine and Douglas fir. Aspen was also present in low densities. These results suggest dominance by white fir with low but persistent populations of the other species, which seems to reflect natural conditions. Therefore, the condition is good. Confidence is high but trend could not be determined based on one round of sampling.
	Mixed Coniferous Forest	Crown Health		These results indicated mostly live white fir and ponderosa pine, but a large number of standing dead Douglas fir and aspen trees. Although these results suggest moderate to significant concern based on aspen and Douglas fir, the condition is unknown at this time since plots were not stratified based on fire activity. Fire was likely responsible for at least some standing dead trees and is a natural process in this community type. Because of the unknown condition, confidence is low. Trend could not be determined based on this single round of monitoring.
Forest Community Changes (1957-2007)	Mixed Coniferous Forest	Relative Importance of Trees (RI)	 	The overall trend in this forest type has been a homogenization of a mixed conifer forest to a white fir-dominated forest. These results warrant moderate/significant concern for this forest type and are consistent with NCPN data from mixed coniferous forests in the park. Trend has deteriorated over time. Confidence is high due to the high number of stands in this forest type.
	Mixed Coniferous Forest	Understory Cover	 	Shrub cover initially declined and then increased to similar levels. These changes were attributed to a shift in species composition from mostly shade-intolerant species to shade-tolerant species as the overstory canopy densified. Grass cover significantly declined over time, while forbs declined only slightly. Sedges and rushes significantly increased over time. Trend has deteriorated. These results warrant moderate/significant concern. Confidence is high due to the high number of stands.
Forest Health	Mixed Coniferous Forest	Fuels Volume (tons/ha)		Total woody fuels during 2010-2014 averaged 70.85 tonnes/ha, most of which was composed of sound 1,000-hr fuels (56.63 tonnes/ha). Litter and duff depth averaged 1.22 cm and 0.42 cm, respectively. Since no reference conditions were developed, condition is unknown and confidence is low. Trend is unknown.

Table 4.7.4-6 continued. ***Summary of upland vegetation indicators, measures, and condition rationale.***

Indicators of Condition	Vegetation Type	Measures	Condition/ Trend/ Confidence	Rationale for Conditions
Forest Health	Park-wide	Bark Beetle Infestation (ha)		About 16% of the park was mapped as affected during 1997 to 2015. Pinyon ips and fir engravers were the two most common disturbance agents. Less than 3% of the survey area was mapped as infested in any given year except for 2004-2005 when 13% and 18% were mapped, respectively. Since no reference conditions were developed, condition is unknown and confidence is low. Trend appears unchanging, with pulses of outbreaks, however trend is unknown as well since a longer time period is likely needed to establish trends with confidence.
	Park-wide	Vegetation Condition Class	 	When considering only the classified areas, 22% of the park was mapped as Moderate to High departure and 28% was mapped as High departure. Therefore, the condition warrants moderate/significant concern. Trend has deteriorated. Confidence is medium since these results were extracted from a national database that has an unknown classification error at the park, although several of the previous measures support these results.
Forest Productivity	Park-wide	Normalized Difference Vegetation Index		NDVI anomaly increased in all six forest types during the 17-year period except in burned white fir forest. Of the park area analyzed 54% did not change in mean NDVI, 33% increased in NDVI, and 13% decreased in NDVI. The largest decrease occurred in white fir forests and the largest increase occurred in ponderosa pine forests followed by Gambel oak shrublands. Measures of temperature were most important in predicting NDVI at high elevations, while measures of precipitation were the limiting factor at low elevations. Actual evapotranspiration was correlated with all six forest types regardless of elevation.
Overall Condition, Trend, and Confidence Level				The various forest types exhibited different trajectories. Ponderosa pine savannas and pinyon-juniper woodlands were considered in good condition with improving trends for the former forest type. There were not enough data to asses ponderosa pine-Douglas-fir forest condition. Mixed coniferous forests warranted moderate concern, and the trend has deteriorated. The reintroduction of fire has had beneficial effects on vegetation in the park, especially ponderosa pine savannas. However, three of five trends were deteriorating. Thus, we did not assign an overall trend. Confidence in the condition rating is medium.

measures that included a trend determination could be biased depending on climatic conditions when measurements were made. Therefore, trends should be interpreted with caution.

Threats, Issues, and Data Gaps

Historically, much of the park was characterized by frequent fires that maintained an open forest structure and low fuel loads, at least for mixed coniferous and ponderosa pine forests (NPS 2004b). Mixed severity fires created a mosaic of different aged stands and dynamic forest structure (NPS 2004b). With fire suppression beginning in the early 1900s, the fire regime has been significantly altered (NPS 2004b, NPS 2011c). The long-term suppression of fire has had the most dramatic impacts on mixed coniferous forests in the park (Ironside et al. 2008, NPS 2004b). Results from the long-term transects in this forest type indicate that the lack of fire and other disturbances has created a forest structure composed predominantly of white fir with a shift in understory species composition toward more shade-tolerant species (Ironside et al. 2008). Encroachment of conifers into aspen stands is also of concern as a result of fire exclusion (Ironside et al. 2008). Fire could be beneficial in this forest type provided there remains a viable soil seed bank of Douglas-fir, ponderosa pine, limber pine, and other conifers (Ironside et al. 2008).

A major goal of the fire management program in the park is to restore fire as a natural ecosystem process that is consistent with historic fire regimes (NPS 2011c). This is accomplished through allowing natural wildland fires to burn when and where appropriate and through prescribed fire management in certain areas (NPS 2011c). The park's prescribed fire program was initiated in 1990, but by that time most of changes to tree density, species composition, and understory cover had already occurred (Ironside et al. 2008). However, some forest stands have shown improving trends as a result of prescribed fire, especially at lower elevations. Prescribed fire may not be possible in dense mixed coniferous forests due to the risk of escaped fires as a result of high fuel loads and ladder fuels (Fulé et al. 2004). High tree density and ladder fuels provided by saplings have increased the potential for stand-replacing fire in mixed coniferous forests, which may be undesirable (Ironside et al. 2008).

The total area of beetle-killed trees represents 16% of the park, and the majority of that area was mapped during 2003-2005 and 2007. Over the 17 years for which the proportion of survey area affected could be determined, only a small percentage of the total area was mapped as affected in most years. A 1995 survey of forest health in the park indicated that bark beetles were rare, although many of the park's trees were considered at risk of infection based on basal area, average stand age, and average DBH (Hansen 1997). Hansen (1997) also found that dwarf mistletoe (*Arceuthobium douglasii*) occurred on half of all Douglas-fir trees in the park. Other mistletoe species that parasitize ponderosa pine, white fir, and limber pine were rare (Hansen 1997).

Although bark beetles and mistletoe are native to western forests, these types of disturbances have become more severe and widespread in recent decades, bark beetles in particular (Raffa et al. 2008). The scale of the recent beetle-kill in the western U.S. has raised concerns regarding increased 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, one study found that the amount of area burned in the western U.S. in recent decades has not increased as a result of widespread mountain pine beetle (*Dendrocotonus 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 time since outbreak and beetle type (Meigs et al. 2016).

Region-wide drought, rising temperatures, and long-term fire suppression resulting in dense and over-mature forests, are all factors that have increased the susceptibility of coniferous forests to bark beetle infestations (Hebertson and Jenkins 2008, Hart et al. 2014, Raffa et al. 2008). The western U.S., and especially the Southwest, has experienced increasing temperatures and decreasing rainfall (Prein et al. 2016). Since 1974 there has been a 25% decrease in precipitation, a trend that is partially counteracted by increasing precipitation intensity (Prein et al. 2016). While there were no apparent changes in total precipitation in the park, 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). Warmer temperatures also increase the rate of evaporation, leaving less water in the soil for plants.

The protective cover of snow and about 200 days of frost per year (NPS 2014f) limit the growing season for non-native species in Bryce Canyon NP. 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). Only one non-native species was detected along the nine transects surveyed from 1957 to 2007, and this species (smooth brome [*Bromus inermis*]) was only detected in one quadrat during the 1991 survey (Ironside et al. 2008). Smooth brome has, however, encroached into upland meadows and is commonly found along roadsides and in developed areas (Dewey and Anderson 2005a). Pinyon-juniper woodlands may also be susceptible to non-native species. Once established, invasive plants can be extremely difficult to control and most will never be completely eradicated (Mack et al. 2000).

4.7.5. Sources of Expertise

Assessment authors were Lisa Baril, science writer, Utah State University, and David Thoma, hydrologist, NPS. Dana Witwicki, vegetation ecologist, NCPN, provided data for several measures and expertise in interpretation of data. Subject matter review experts are listed in Appendix B.

4.8. Unique and Distinctive Vegetation

4.8.1. Background and Importance

Variable topography, soil moisture attributes, and fire history drive plant distribution patterns in Bryce Canyon National Park (NP) (Tendick et al. 2011). The park's plant communities have been broadly classified into three vegetation belts (Buchanan 1992 as cited in Tendick et al. 2011). From highest to lowest elevation of 1,859–2,774 m (6,099-9,101 ft) the vegetation belts are: dense mixed coniferous forests in the montane forest belt, ponderosa pine (*Pinus ponderosa*) woodlands interspersed with sagebrush shrublands (*Artemisia* spp.) in the submontane forest belt, and sparse woodlands in the lowest vegetation belt (Tendick et al. 2011). Sparse woodlands are further divided into pinyon pine-Utah juniper (*Pinus edulis-Juniperus osteosperma*) woodlands on mesic north-facing slopes and bristlecone pine (*Pinus longaeva*) woodlands on xeric south-facing slopes (Tendick et al. 2011).

Many of the park's rare and endemic plants are restricted to the pinyon pine-Utah juniper vegetation belt within the Claron formation, which is one of the harshest environments in the park (Fertig and Topp 2009). This area is characterized by poorly developed soils, rapid erosion, and continuous freeze-thaw cycles during winter (Tendick et al. 2011). Rare and endemic plants include Bryce Canyon Indian paintbrush (*Castilleja revealii*) (Figure 4.8.1-1a) and Red Canyon beardtongue (*Penstemon bracteatus*) (Figure 4.8.1-1b).

These broad plant communities have been mapped into 126 unique associations based on dominant species (Tendick et al. 2011). Of the 126 plant associations mapped in 2005 and 2006, 29 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 plant associations occur outside the park but have yet to be mapped (Tendick et al. 2011). Only one plant association mapped in the park was considered critically imperiled by NatureServe, which ranks plant communities by risk of elimination across their ranges (NatureServe 2017). Six additional communities were considered imperiled, and 55 were ranked as vulnerable to secure. The remaining 62 associations were not ranked because there were few data with which to assess their status (Tendick et al. 2011). Lastly, two associations were considered provisional (i.e., not confirmed). Although few of the 126 plant associations mapped in the park were considered imperiled by NatureServe, Tendick et al. (2011) caution that because so little is known about many of them, particularly those considered park specials, their status remains unclear.

Figure 4.8.1-1a. Bryce Canyon Indian paintbrush. Photo Credit: NPS.

Figure 4.8.1-1b. Red canyon penstemon. Photo Credit: NPS

4.8.2. Data and Methods

A list of rare plants of conservation concern for Bryce Canyon NP 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 the park (Fertig and Topp 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 conservation status rank (G-Rank) for each species (NatureServe 2017). NatureServe's G-Ranks reflect the condition of a species across its entire range on a scale of 1–5 (1 = critically imperiled and 5 = secure) for full species (G) and varieties or subspecies (T). Rank qualifiers "?" and "Q" indicate inexact numeric rank and questionable taxonomy, respectively. "NR" was used to denote species that were not ranked. 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 plant communities ranked as critically imperiled and imperiled by NatureServe and the 26 park specials mapped during 2005-2006 (Tendick et al. 2011).

There have been numerous botanical studies in Bryce Canyon NP (Fertig and Topp 2009), few of which were specifically targeted at unique and distinctive vegetation (but see Graybosch and Buchanan 1983, Schelz 1990, Peabody 1995, and NPS 2016d). Two additional studies focused on single species surveys, including one on Jones' false goldenaster (*Heterotheca jonesii*) (Hreha 1982) and Paria River Indian breadroot (*Pediomelum pariense*) (Hallsten and Roberts no date), both of which were proposed for listing under the U.S. Fish and Wildlife (USFWS) Endangered Species Act (ESA) at the time surveys were conducted. However, neither species was ultimately listed (USFWS 2017a). We used two of the most current datasets and reports to evaluate unique and distinctive vegetation in the park: a 1997-2016 study targeted at eight species of concern (Peabody 1995, NPS 2016d) and the 2005-2006 NPS vegetation classification and mapping project data (Tendick et al. 2011).

The prevalence indicator included two measures, change in density and percent frequency, which are described below.

<u>Change in Density</u>

During 1991 to 1993, eight rare species of conservation concern were surveyed across 27 plots, with between two and 10 plots established per species (Peabody 1995) (Table 4.8.2-1). Plots were of variable size so that they contained approximately 100 individuals of a target species. Some plots contained more than one target species by chance, resulting in a lower number of initial individuals for secondary target species (NPS 2016d). Thus, not all plots began with 100 individuals of each target species. Most plots were established in the main amphitheater of the breaks (NPS 2016d).

Plots were re-surveyed in 1997, 2006, 2011/2012, and 2016, but not all plots could be located each year (NPS 2016d). Fifteen of the original 27 plots were surveyed during all monitoring periods according to Table 2 in NPS (2016d). Of the remaining 12 plots, nine were either not relocated or monitoring was discontinued there. In the remaining three plots, surveys were not conducted during all sampling years. In 1997, five new plots were established but only one of them was surveyed during all subsequent monitoring years. For each year a plot was sampled, observers recorded the number of individuals by species. Change in density was calculated from the first year a plot was monitored (i.e., 1991-1993 or 1997) to 2016.

Table 4.8.2-1. Rare species of conservation concern surveyed from 1991-2016.

Scientific Name	Common Name
Castilleja revealii	Bryce Canyon Indian paintbrush
Cryptantha ochroleuca	Yellowish cryptanth
Heterotheca jonesii	Jones' false goldenaster
Oxytropis oreophila var. jonesii	Jones' locoweed
Pediomelum pariense	Paria River Indian breadroot
Penstemon bracteatus	Red Canyon beardtongue
Silene petersonii	Plateau catchfly
Townsendia alpigena var. minima	Wyoming Townsend daisy

Source: NPS (2016d).

Frequency (%)

Frequency was determined for the eight species surveyed in Peabody (1995) and NPS (2016d) in addition to those ranked as Extremely High and High Priority by UNPS (2016) using the NPS vegetation classification and mapping project data (Tendick et al. 2011). Field data were collected in 357 plots distributed throughout the park during 2005 and 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). Frequency by species was calculated by summing the number of plots containing the target species and dividing by the total number of plots. The vegetation map classes in which target species occurred were also summarized. We did not calculate frequency by plant association because of high variability in sample size.

Flowered (%)

For each of the eight target species surveyed in the 20 sensitive species plots during 2016, observers recorded the proportion of individuals that had flowered or were in flower by plot (NPS 2016d). Data were summarized by determining the total number of individuals per species across all plots and then dividing by the total number of that species that flowered. The timing of surveys was not reported in NPS 2016d.

4.8.3. Reference Conditions

Table 4.8.3-1 summarizes the thresholds for measures in good condition, moderate concern condition, and significant concern condition.

4.8.4. Condition and Trend

Table 4.8.4-1 lists the 37 rare plants of special concern in Bryce Canyon NP along with their UNPS priority 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). UNPS (2016) ranked two species as High Priority, 21 species were ranked as Watch, and 13 species were ranked as Medium Priority. The two species ranked as High Priority were Bryce Canyon Indian paintbrush and rambling fleabane (*Erigeron vagus* var. *madsenii*). Eighteen of the 37 species were ranked as G1 (critically imperiled), G2 (imperiled), or G3 (vulnerable), excluding species with mixed ranks of lower values. Among the most imperiled were yellowish cryptanth (*Cryptantha ochroleuca*) and abajo daisy (*Erigeron abajoensis*). The two ranking systems were consistent for some species but not others. For example, rambling fleabane was considered High Priority by UNPS (2016) but apparently secure (G4) by NatureServe (2017). Differences in the ranking systems are expected since the NatureServe accounts for the condition of a species throughout its range, while the UNPS ranking system considers state status only.

Table 4.8.4-2 shows the 29 park special plant communities and the seven critically imperiled (1) and imperiled (6) plant communities as ranked by NatureServe (none of the park special were ranked) (Tendick et al. 2011). All of the park special plant associations occurred in the uplands, particularly as shrublands, and three of these contained non-native plants. Upland shrublands also contained four of the seven imperiled and critically imperiled plant communities.

Change in Density

Percent change was calculated for all eight species, but for some species, change in density was based on only one or a few plots (Table 4.8.4-3). Because of the low number of plots per species (i.e., 8 or fewer)

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

Indicator	Measure	Good	Moderate Concern	Significant Concern
Prevalence	Change in Density (%)	The density of targeted rare plants has remained stable or has increased over time.	The density of targeted rare plants has declined over time.	The density of targeted rare plants has declined over time.
	Frequency (%)	Targeted rare plans were common in appropriate habitat.	Targeted rare plants were uncommon or absent from appropriate habitat.	Targeted rare plants were uncommon or absent from appropriate habitat.
Reproduction	Flowered (%)	A majority of the targeted rare plants were either in flower or exhibited evidence of flowering.	Less than half of the targeted rare plants were in flower or had not flowered.	Less than half of the targeted rare plants were in flower or had not flowered.

Table 4.8.4-1. Rare plants of conservation concern in Bryce Canyon NP.

Scientific Name	Common Name	UNPS Priority Rank	NatureServe G-Rank*
Aquilegia scopulorum	Rock columbine	Watch	G3?
Asclepias hallii	Hall's milkweek	Medium	G3
Astragalus limnocharis var. *limnocharis*	Cedar Breaks milkvetch	Watch	G2T1
Carex scirpoidea ssp. *scirpoidea*	Slender sedge	Watch	G5T5
Castilleja revealii	Bryce Canyon Indian paintbrush	High	G2
Caulanthus major	Slender wild cabbage	Medium	G4
Cryptantha cinerea var. *arenicola*	Sand cryptanth	Medium	G5T3?
Cryptantha ochroleuca	Yellowish cryptanth	Watch	G1?
Cymopterus minimus	Cedar Breaks springparsley	Watch	G1G2Q
Ericameria zionis	Subalpine goldenbush	Watch	G3
Erigeron abajoensis	Abajo daisy	Medium	G1G2
Erigeron vagus var. *madsenii*	Rambling fleabane	High	G4T1
Eriogonum aretioides	Red Canyon buckwheat	Watch	G2
Gentianella tortuosa	Jones' gentian	Medium	G3?
Hesperodoria scopulorum var. *hirtellus*	Spindly goldenbush	Medium	G4
Heterotheca jonesii	Jones' false goldenaster	Watch	G2
Lepidium montanum var. *claronense*	Claron pepperwort	Watch	G5?T1?
Lesquerella arizonica	Arizona bladderpod	Watch	G3?
Lesquerella rubicundula	Breaks bladderpod	Medium	G3
Lomatium minimum	Little desertparsley	Medium	G3
Lupinus kingii var. *argillaceus*	King's lupine	Medium	G3G4TNR
Lupinus sericeus ssp. *marianus*	Marysvale lupine	Watch	G5T3
Oxytropis oreophila var. *jonesii*	Jones' locoweed	Watch	G5T3
Packera hartiana	Hart's groundsel	Watch	G3G4
Packera werneriifolia var. *barkleyi*	Barkley's groundsel	Watch	G5
Pediomelum pariense	Paria River Indian breadroot	Watch	G2G3
Penstemon bracteatus	Red Canyon beardtongue	Watch	G3
Penstemon caespitosus var. *desertipicti*	Painted penstemon	Medium	G5T3?
Phacelia mammillarensis	Nipple Bench phacelia	Watch	G3
Physaria chambersii var. sobolifera	Claron twinpod	Watch	G5
Physaria lepidota var. lepidota	Kane County twinpod	Medium	G3T2?
Potentilla plattensis	Platte River cinquefoil	Medium	G4
Primula incana	Silvery primrose	Watch	G5
Sphaeromeria capitata	Cluster-head chicken-sage	Medium	G4
Symphyotrichum foliaceum var. *apricum*	Spruce aster	Watch	G5T4T5
Thelypodium sagittatum var. ovalifolium	Palmer's thelypody	Watch	G4T2
Townsendia alpigena var. minima	Wyoming Townsend daisy	Watch	G4T3

Note: Plant list is based on the Utah Native Plant Society Rare Plant Committee list (2016).

* NatureServe's global 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 range of uncertainty. NR indicates that the species was not ranked.

Table 4.8.4-2. Park special, critically imperiled, and imperiled plant associations in Bryce Canyon NP.

Plant Association Group	Plant Association
Upland Forest	*Abies concolor / Purshia tridentata* Forest
	Picea pungens / Bromus inermis Forest
	Populus tremuloides / Acer grandidentatum Forest
Upland Woodland	*Pinus ponderosa - Pseudotsuga menziesii / Arctostaphylos patula* Colorado Plateau Woodland
	Pinus ponderosa / Cercocarpus ledifolius / Arctostaphylos patula Woodland
	Pinus ponderosa / Elymus elymoides - (*Elymus* spp.) Woodland
	Pinus ponderosa / Hesperostipa comata Colorado Plateau Woodland
	Pinus ponderosa / Petradoria pumila Woodland
	Pinus ponderosa / Seeded Grasses Semi-natural Woodland
	Pinus ponderosa Sparse Woodland
Upland Shrubland	*Amelanchier (utahensis, alnifolia) - Cercocarpus montanus* Shrubland[1]
	Artemisia nova / Leymus salinus Shrub Herbaceous Vegetation[2]
	Artemisia pygmaea Dwarf-shrubland
	Artemisia tridentata ssp. tridentata / Agropyron cristatum Semi-natural Shrubland
	Artemisia tridentata ssp. wyomingensis / Elymus lanceolatus Shrubland
	Atriplex canescens / Elymus (elymoides, salinus) Shrubland
	Atriplex canescens / Psathyrostachys juncea Seeded Shrubland
	Ceanothus martinii / Elymus trachycaulus Seeded Roadcut Shrub Herbaceous Vegetation
	Cercocarpus montanus Desert Wash Shrubland
	Chrysothamnus viscidiflorus / Mixed Grasses Shrubland
	Ericameria nauseosa / Achnatherum lettermanii Shrubland
	Eriogonum corymbosum / Leymus salinus Dwarf-shrubland[1]
	Purshia tridentata / Hesperostipa comata Shrub Herbaceous Vegetation[1]
	Purshia tridentata / Leymus salinus Shrubland
	Purshia tridentata Desert Wash Shrubland
	Tetradymia canescens / Poa pratensis Shrubland
	Tetradymia canescens Badlands Sparse Vegetation
	Tetradymia canescens Shrubland
Upland Herbaceous	*Carex vallicola* Herbaceous Vegetation
	Elymus elymoides Herbaceous Vegetation
	Elymus trachycaulus Herbaceous Vegetation
	Hesperostipa comata Great Basin Herbaceous Vegetation[1]
	Heterotheca villosa / Mixed Grass Shrub Herbaceous Vegetation
	Leymus salinus Herbaceous Vegetation
Riparian and Wetland Forest and Woodland	*Populus angustifolia / Symphoricarpos (albus, occidentalis, oreophilus)* Woodland[1]
	Picea pungens / Betula occidentalis Woodland[1]

Source: Tendick et al. (2011).

[1] Ranked as imperiled by NatureServe.

[2] Ranked as critically imperiled by NatureServe.

Table 4.8.4-3. Change in rare plant density from the 1990s to 2016.

Plot ID	Species	1991-1993	1997	2006	2011/2012	2016	% Change
18	Bryce Canyon Indian paintbrush	90	200	171	61	152	69
27	Bryce Canyon Indian paintbrush	25	39	1	19	1	-96
28	Bryce Canyon Indian paintbrush	35	18	26	26	48	37
32	Bryce Canyon Indian paintbrush	–	100	72	24	17	-83
18	Yellowish cryptanth	120	175	463	140	557	364
25	Jones' false goldenaster	50	>100	69	63	84	68
26	Jones' false goldenaster	30	>60	32	23	16	-47
33	Jones' locoweed	–	115	74	n/a	44	-62
3	Paria River Indian breadroot	67	132	106	85	80	19
4	Paria River Indian breadroot	21	35	19	22	26	24
5	Paria River Indian breadroot	400	400	293	85	188	-53
6	Paria River Indian breadroot	1000	2042	317	602	1114	11
13	Paria River Indian breadroot	90	>100	104	44	96	7
14	Paria River Indian breadroot	90	125	46	49	56	-38
15	Paria River Indian breadroot	90	88	102	96	117	30
29	Paria River Indian breadroot	–	100	59	111	60	-40
32	Red Canyon beardtongue	–	55	11	15	66	20
23	Plateau catchfly	44	>100	51	38	40	-9
24	Plateau catchfly	50	150	3	26	1	-98
31	Plateau catchfly	–	140	–	–	0	-100
17	Wyoming Townsend daisy	90	350	109	95	78	-13
19	Wyoming Townsend daisy	90	140	85	55	97	8
30	Wyoming Townsend daisy	–	100	33	–	0	-100
33	Wyoming Townsend daisy	–	250	132	n/a	167	-33

Source: NPS (2016).

it was difficult to make inferences about changes in population density for a given species; however, most species appear to show an overall decline (NPS 2016d). Plateau catchfly (*Silene petersonii*) declined in all three plots with complete eradication in one of the plots. Wyoming Townsend daisy (*Townsendia alpigena* var. *minima*) exhibited declines in three of four plots, and Bryce Canyon Indian paintbrush declined more than it increased in four plots. Change in density for Paria River Indian breadroot (*Pediomelum pariense*) varied considerably among plots but exhibited an overall decline.

According to NPS (2016d), populations located within the Amphitheater were in particular decline, possibly as a result of social trails, trampling, natural erosion, and other impacts. There were a number of issues regarding these studies, however, primarily related to the original protocol, plot loss over time, and low sample size for target species (NPS 2016d). Furthermore, the original species chosen may not reflect current monitoring needs. For example, plateau catchfly was not listed as rare species of concern in Table 4.8.4-1, and while the remaining species were on this list, others with the same or higher UNPS ranking are not currently being monitored (e.g., rambling fleabane). For these reasons, the condition for this measure was considered unknown and confidence was low. Trend could not be determined given the low sample size (i.e., # of plots) for individual species.

Frequency (%)

Six of the nine target NPS (2016d) and UNPS High Priority (UNPS 2016) species were encountered across six of the 126 vegetation associations during the 2005/2006 mapping project (Table 4.8.4-4). Not surprisingly, overall frequency by species was low park-wide. *Pinus longaeva* woodlands contained all six species, while the remaining five associations contained one or two species. Some species such as Yellowish cryptanth, Wyoming Townsend daisy, and Bryce Canyon Indian paintbrush appear locally

Table 4.8.4-4. Frequency and vegetation associations of rare plants in Bryce Canyon NP.

Common Name	Overall Frequency (%)	Plant Associations and Frequency (occurrence of total plots)
Wyoming Townsend daisy	5	*Pinus ponderosa / Arctostaphylos patula* Woodland (4 of 67), *Pinus longaeva* Woodland (12 of 20), *Pinus ponderosa / Leymus salinus* Woodland [Provisional] (1 of 16)
Yellowish cryptanth	3	*Arctostaphylos patula* Shrubland (1 of 5), *Pinus ponderosa / Arctostaphylos patula* Woodland (1 of 67), *Pinus ponderosa / Cercocarpus ledifolius / Arctostaphylos patula* Woodland [Park Special] (1 of 3), *Pinus longaeva Woodland* (7 of 20)
Bryce Canyon Indian paintbrush	2	*Pinus longaeva* Woodland (7 of 20), *Arctostaphylos patula* Shrubland (1 of 5)
Jones' locoweed	1	*Abies concolor / Arctostaphylos patula* Forest (1 of 31), *Pinus longaeva* Woodland (4 of 20)
Plateau catchfly	1	*Pinus longaeva* Woodland (2 of 20), *Pinus ponderosa / Leymus salinus* Woodland [Provisional] (1 of 16)
Red Canyon beardtongue	<1	*Pinus longaeva* Woodland (1 of 20)
Rambling fleabane	0	n/a
Jones' false goldenaster	0	n/a
Paria River Indian breadroot	0	n/a

Source: Tendick et al. (2011).

abundant in *Pinus longaeva* woodlands (i.e., >30% of plots). Red Canyon beardtongue, plateau catchfly, and Jones' locoweed (*Oxytropis oreophila* var. *jonesii*) however, appear rare regardless of vegetation type. These results suggest good condition for only three of the nine species and moderate to significant concern for the remaining six species, particularly those not found in any of the 357 plots. Therefore, the condition for this measure warrants moderate to significant concern. Confidence is low given the age of the data (i.e., greater than 10 yrs), because sample sizes varied considerably among associations, and because rare plants are expected to be rare and therefore may require targeted surveys to effectively monitor them. Trend is unknown.

<u>% Flowered</u>

The number of plots in which a target species was found was variable and ranged by species from one to seven (Table 4.8.4-5). The percent of individuals that had flowered or were in flower varied considerably within across plots by species. On average 85% of total individual Bryce Canyon Indian paintbrush plants and 73% of Jones' false goldenaster plants had flowered. None of the 44 Jones' locoweed had flowered and only 3% of Red Canyon beardtongue had flowered. These results suggest good condition for Bryce Canyon Indian paintbrush and Jones' false goldenaster, but the low rate of flowering for the remaining species suggests moderate to significant concern condition. However, confidence was low due to the low number of plots in which a given species occurred. Since data were collected during only one year, trend could not be determined.

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

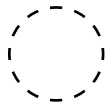
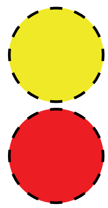
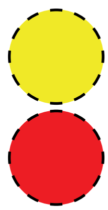
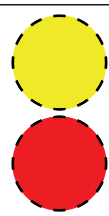
Overall, the condition of unique and distinctive vegetation in Bryce Canyon NP warrants moderate to significant concern, but confidence in the condition rating was low (Table 4.8.4-6). The confidence was low because there were few data with which to asses this resource, NPS vegetation mapping data were collected greater than 10 years ago, and rare plant survey plots exhibited several issues regarding sampling design and loss of plots over time. Trend could not be determined.

Table 4.8.4-5. Rare species of conservation concern that flowered during 2016.

Species	# of Plots	% Flowered of Total Individuals
Bryce Canyon Indian paintbrush	4	85% of 218
Jones' false goldenaster	2	73% of 100
Yellowish cryptanth	2	30% of 628
Paria River Indian breadroot	7	20% of 623
Wyoming Townsend daisy	3	18% of 342
Plateau catchfly	2	10% of 41
Red Canyon beardtongue	1	3% of 66
Jones' locoweed	1	0% of 44

Source: NPS (2016).

Table 4.8.4-6. Summary of unique and distinct vegetation indicators, measures, and condition rationale.

Indicators of Condition	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Prevalence of Rare Plants	Change in Density		Most species appear to show an overall decline, especially within the Amphitheater, possibly as a result of social trails, trampling, and natural erosion. There are a number of issues regarding these studies, primarily related to the original protocol, plot loss over time, and low sample size for target species. Furthermore, the original species chosen may not reflect current monitoring needs. Therefore, the condition for this measure is unknown and confidence is low. Trend could not be determined.
	Frequency (%)		Six of nine sensitive plants were found in NPS vegetation mapping plots almost exclusively in *Pinus longaeva* woodlands. Three species were not found at all and three species were rare. The condition for this measure warrants moderate to significant concern. Confidence is low given the age of the data (i.e., >10 years) and because rare plants are expected to be rare and therefore may require targeted surveys to effectively monitor them. Trend is unknown.
Reproduction	% Flowered		On average 85% of total individual paintbrush plants and 73% of Jones' false goldenaster flowered. None of the 44 Jones' locoweed flowered and only 3% of Red Canyon beardtongue flowered. These results suggest good condition for Bryce Canyon Indian paintbrush and Jones' false goldenaster, but the low rate of flowering for the remaining six species suggests moderate to significant concern condition. However, confidence is low due to the low number of plots in which a given species occurred. Furthermore climate conditions and timing of the surveys could have influenced these results Since data were collected during only one year, trend could not be determined.
Overall Condition, Trend, and Confidence Level			Overall, the condition of unique and distinctive vegetation in Bryce Canyon NP warrants moderate to significant concern based on two of the three measures, but confidence in all three measures was low. The confidence was low because there were few data with which to asses this resource, NPS vegetation mapping data were collected >10 years ago, and rare plant survey plots exhibited several issues regarding sampling design and loss of plots over time. Trend could not be determined.

There are 37 rare species of conservation concern and 29 distinct plant community associations in Bryce Canyon NP. 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). In contrast, areas of high species richness, or "hotspots", may lack rare or endemic species (e.g., springs and seeps), but these areas play a critical role for birds, invertebrates, and mammals in arid regions (Stohlgren et al. 2005). Wetland habitats also support many plant species that are not necessarily rare throughout their ranges but are sparsely distributed (Springer et al. 2006). Efforts that focus on both "hotspots" and areas of high endemism will protect the greatest variety of unique and distinctive vegetation.

Threats, Issues, and Data Gaps

Since there were few current data with which to assess unique and distinctive vegetation, the resource topic itself represents a data gap. Only one of the two studies used in this assessment was focused specifically on rare plants. By their very nature, rare plants are observed infrequently often within narrow ranges. Studies that are specifically targeted at rare plants may be necessary to monitor them effectively. Since 2001 NPS staff have conducted annual butterfly counts that provide information on the abundance and diversity of pollinators (NPS unpublished data). Linking pollinators to rare plants and phenological data would help fill data gaps regarding this resource.

Many of the park's rare plants occur near areas of high visitor use (i.e., in the amphitheater and along cliff edges near the rim), and visitation to the park continues to grow. In 2017, an estimated 2.5 million people visited Bryce Canyon NP (NPS Public Use

Statistics Office 2018). Increasing visitation contributes to the establishment of social trails, which leads to soil compaction, increased runoff, and trampling of native vegetation (NPS 2016e). From 1994 to 1998, a study on visitor impacts at high use areas showed that social trails were common, and that the area of bare ground as a result of foot traffic had increased over time (Ames-Curtis 1997, Mitton 1999). Although boundary fences and barriers have been erected in some areas to discourage the use of social trails and to protect native vegetation, visitors sometimes ignore them, but once social trails have become established they can be difficult to rehabilitate (NPS 2010e). However, at least a portion the park's rare plant populations are naturally protected because they occur in areas that are hard to reach (i.e., the breaks) (Tendick et al. 2011).

Trampling by livestock trespass and horses or mules also has the potential to affect native plants. Livestock grazing is no longer permitted in the park, but there is limited park access for cattle drives, and in most years livestock wander across the boundary (NPS 2014a), particularly near some springs (Warren and Haas 2012). Springs and seeps support wetland plant communities that are rare in the park; only 33 springs and seeps are known to exist in Bryce Canyon NP, many of which are located on the steep slopes of the breaks (NPS 1996, Thornberry-Ehrlich 2005). However, there is little information on plant communities at springs.

Livestock trespass and visitor use may influence the spread of non-native species (Abella and Tendick 2013). One study found that meadows and shrubland communities in the park were the most heavily invaded of all community types, primarily by smooth brome (*Bromus intermis*) (Abella and Tendick 2013). Once established, invasive plants can be extremely difficult to control and most will never be completely eradicated (Mack et al. 2000). However, climate change may facilitate the spread of non-native species in the park.

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). Climate data for the park indicate a trend toward warmer but not necessarily drier conditions within the park (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 200 days of frost per year (NPS 2014e) limits the growing season for non-native species, but climate change 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). However, how climate change will affect rare plant communities in the park is unknown.

4.8.5. Sources of Expertise

Assessment author is Lisa Baril, science writer, Utah State University. Subject matter review experts are listed in Appendix B.

4.9. Non-native Invasive Plants

4.9.1. Background and Importance

Vegetation in Bryce Canyon National Park (NP) occurs within three broadly defined vegetation belts (Tendick et al. 2011). The vegetation belts are: montane forests, submontane forests, and pinyon-juniper (*Pinus edulis-Juniperus osteosperma*) woodlands. Montane forests occur at the highest elevations while pinyon-juniper woodlands occur at the lowest elevations. At middle elevations, the sub-montane vegetation belt is further divided into ponderosa pine (*Pinus ponderosa*) woodlands and sagebrush (*Artemisia* spp.) shrublands. Non-native plants are found in all elevation zones and vegetation types throughout the park, but some vegetation types and areas are more heavily invaded than others (Abella and Tendick 2013). According to NPS Management Policies (2006), non-native plants are "those species that occupy or could occupy park lands directly or indirectly as the result of deliberate or accidental human activities." For example, many of the park's developed areas, including around buildings, along roads, and at observation points, are prone to the establishment of non-native plants due to the high visitor use (Dewey and Anderson 2005a).

Smooth brome (*Bromus inermis*), cheatgrass (*Bromus tectorum*), and thistles (*Cirsium* spp., *Carduus* spp., *Onopordum* spp.) are some of the most invasive non-native plants in the park (NPS 2016e). According to Executive Order No. 11312, 3 C.F.R. (1999), an invasive species is "a species whose introduction does or is likely to cause economic or environmental harm or harm to human health." Non-native invasive 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, which it is mandated to manage (Executive Order No. 11312, 3 C.F.R. (1999)), present a significant challenge to the preservation of the agency's natural resources "unimpaired for the enjoyment of future generations" (NPS 2006). National parks, like land managed by

Figure 4.9.1-1. Bull thistle found in Bryce Canyon NP. Photo Credit: © K. A. Anderson.

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). 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, with a total of four measures, to determine current condition of non-native plants at Bryce Canyon NP. There have been several efforts over the years to document non-native plant presence in the park. Roberts and Jean published one of the first lists of non-native plants found during their two-year study during 1988-1989 (Roberts and Jean 1989). In 1997 staff from Zion NP conducted a survey of non-native plants in the park (Mason and LaBarre 1997), and in 2004-2005 Dewey and Anderson (2005a,b) mapped non-native plants in areas considered vulnerable to invasion. 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 across the park (Tendick et al. 2011). Based on the above-mentioned surveys (and additional surveys), a review of museum specimens, and field work in 2005-2007, non-native plants were compiled in an annotated checklist in 2009 (Fertig and Topp 2009) and in an update to the checklist in 2012 (Fertig et al. 2012). Finally, Northern Colorado Plateau Network (NCPN) staff began long-term monitoring of upland vegetation in 2010, including cover and frequency of non-native plants (Witwicki 2012).

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

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 plant (ecological impact, current distribution and abundance, trend in distribution and abundance, and management difficulty) for a total of 20 questions (Morse et al. 2004). A subrank score is developed for each category then an overall Invasive Species Impact Rank or I-Rank score is developed for each species. Based upon the I-Rank value, each species is then placed into one of four categories: species that cause high, medium, low, or insignificant negative impacts to native biodiversity within the area of interest (Morse et al. 2004). 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).

<u>New Non-native Plants Detected</u>

During 2005-2007, Fertig and Topp (2009) reviewed existing literature and museum specimens to develop a list of vascular plants in the park. The museum and literature review was supplemented by field work during 2005-2007 to verify existing reports and to locate new species (Fertig and Topp 2009). Appendix A in Fertig and Topp (2009) lists all plants known to occur in the park, including non-native species and the year in which they were first documented. In 2012, Fertig et al. (2012) published an update to the original annotated checklist, which included additional species identified during studies conducted from 2008 to 2011. We cross-referenced these lists with data collected during the subsequent NCPN upland plant surveys (2012-2015) and Bryce Canyon NP's vegetation crew annual reports (NPS 2012c; NPS 2013b; NPS 2014h; NPS 2015b; NPS 2016e). 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 and Topp (2009) and NPSpecies (NPS 2017a). These species were not included in this assessment because they have never been documented in the park but occur in the vicinity.

<u>Frequency (%) and Cover (%)</u>

We used three datasets to evaluate non-native plant frequency and cover: 2004-2005 NCPN non-native plant inventory and mapping data (Dewey and

Anderson 2005a,b), 2005-2006 NPS vegetation classification and mapping project data (Tendick et al. 2011), and 2010-2015 NCPN upland plant data (unpublished NCPN data) (Figure 4.9.2-1).

NCPN Non-native Plant Inventory and Mapping

In August 2004 and 2005, Dewey and Anderson (2005) surveyed 3,570 ha (8,821 ac) for non-native plants. The target area included nearly all uplands with emphasis on areas of management concern, including main roads, parking areas, campgrounds, service roads, housing areas, burned areas, plateaus, riparian zones, and hiking trails (Dewey and Anderson 2005a,b). A total of 28 units ranging in size from 15 ha (38 ac) to 401 ha (990 ac) were inventoried. Twelve non-native plants were targeted as high priority for inventory and mapping, only some of which were known to occur in the park at the time surveys were conducted (Table 4.9.2-1). Additional non-native plants were documented if found but not necessarily mapped. Within each unit observers walked transects spaced 23-91 m (75-300 ft) apart depending on the terrain. Plant infestations were recorded as point features for patches less than 0.4 ha (1 ac) and as either point, polygon, or line features for patches greater than 0.4 ha (1.0 ac) depending on which method best represented the infestation. Patch size was estimated visually by class as follows: 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), 1.01 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.

NPS Vegetation Classification and Mapping Project

In support of the NPS vegetation classification and mapping project, field data were collected in 357 plots distributed throughout the park during 2005 and 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 categories, 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

Table 4.9.2-1. Non-native plants targeted for inventory and mapping during 2004 and 2005.

Species	Common Name
Bromus inermis	Smooth brome
Bromus tectorum	Cheatgrass
Carduus nutans	Musk thistle
Centaurea diffusa	Diffuse knapweed
Centaurea maculosa	Spotted knapweed
Centaurea repens	Russian knapweed
Centaurea virgata v. squarrosa	Squarrose knapweed
Cirsium arvense	Canada thistle
Cirsium vulgare	Bull thistle
Elaeagnus angustifolia	Russian olive
Onopordum acanthium	Scotch thistle
Tamarix ramosissima	Saltcedar

Source: Dewey and Anderson (2005a).

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.

NCPN Uplands Plant Monitoring

NCPN upland plant monitoring occurred in each of 45, 50 x 50 m (164 x 164 ft) plots during 2010-2015 (Witwicki 2012). Plots were distributed across pinyon-juniper woodlands (25 plots) and mixed coniferous forests (20 plots) (data provided by D. Witwicki, NCPN vegetation ecologist). Each plot was sampled for two consecutive years during the 6-year sampling period (i.e., 8 or 10 plots per year). Several plots were sampled three times. 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 by vegetation type. 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 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

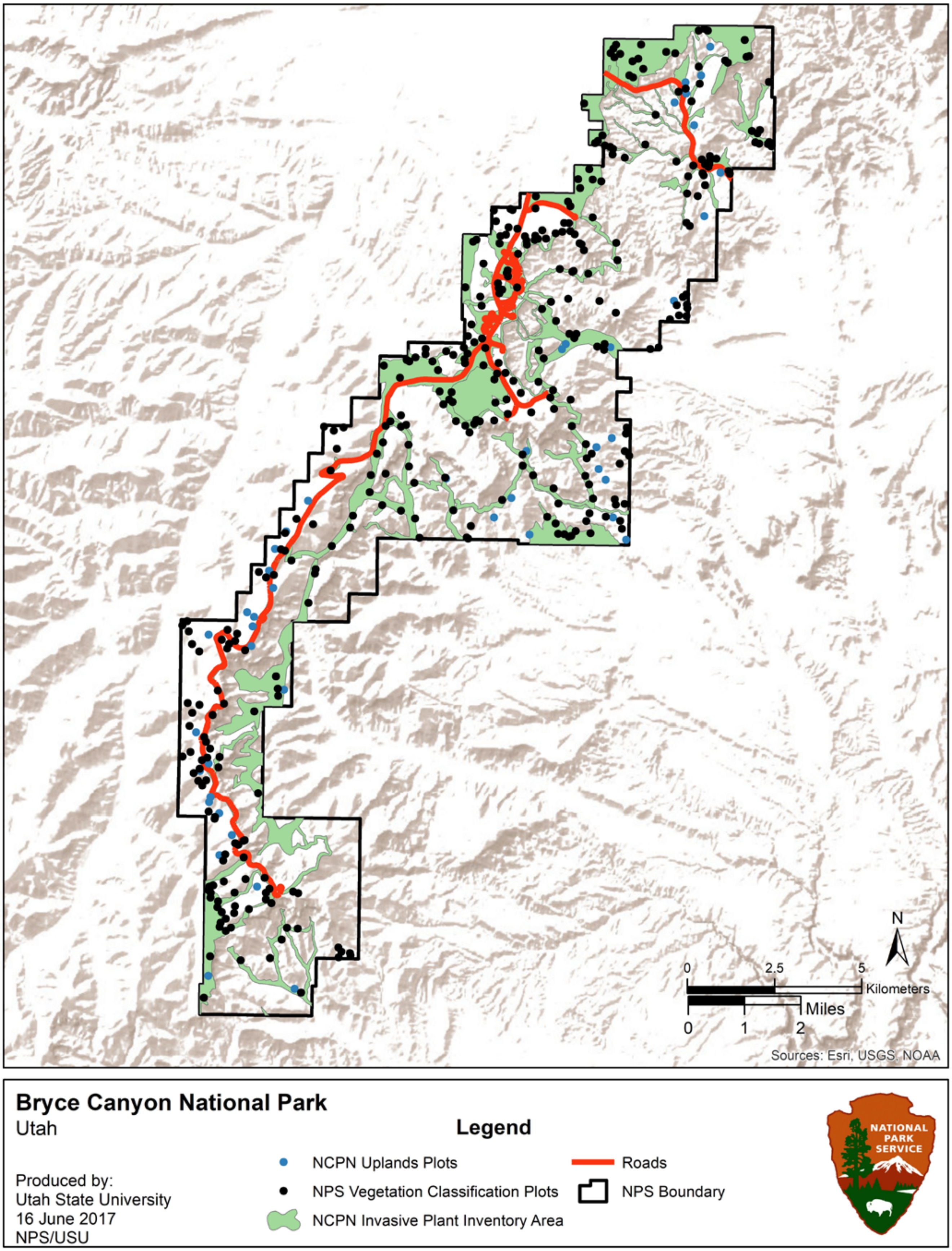


Figure 4.9.2-1. **Locations of vegetation monitoring plots and target survey areas in Bryce Canyon NP.**

by the total number of plots by vegetation type. Average plot frequency was calculated 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 (NRCA) staff, Bryce Canyon NP staff, and NCPN staff.

4.9.4. Condition and Trend

NatureServe Invasive Species Impact Rank

Table 4.9.4-1 lists the 66 non-native plant species known to occur in Bryce Canyon NP. Leafy spurge (*Euphorbia esula*) was noted as occurring in the park in Fertig and Topp (2009), but the source they use states that the species occurred adjacent to the park rather than mapped in the park (Dewey and Anderson 2004a), nor has this species been reported since that time. Of the 66 non-native species, 17 (26%) have not been assessed by NatureServe. Of the remaining species, 11 (22%) species were given a low or insignificant ranking, 24 (49%) species were given at least a medium ranking (some with mixed ranks), and 14 (29%) species were given a high ranking (some with mixed ranks). Nine species shown in table 4.9.4-1 are considered noxious by the state of Utah (Utah Department of Agriculture and Food 2017). Species with the highest rank included smooth brome, cheatgrass, spotted knapweed (*Centaurea maculosa*), and Canada thistle (*Cirsium arvense*), among others.

Fifteen of the 38 species with a medium or high invasive risk had mixed ranks. Only two of those 15 are targeted in Bryce Canyon NP's management. Many of the others have not been managed because they are not deemed as problematic (i.e., invasive) in natural habitats at the park (Eric Vasquez, Vegetation Crew Leader, Bryce Canyon NP, pers. comm). Furthermore, *Phragmites australis* (ranked as high) may be inaccurately listed in table 4.9.4.1 as non-native; more information is needed to determine if populations at the park are of the native lineage.

NCPN conducts invasive plant monitoring at Black Canyon of the Gunnison National Park, Curecanti National Recreation Area, Fossil Butte National Monument, Colorado National Monument, Capitol Reef National Park, Zion National Park, Golden Spike National Historic Site, and Dinosaur National Monument. All of these parks have developed a priority list specific to their park of the 30 or so species that are most damaging to their park. An additional column "Priority Invasive Species in at Least one NCPN park" was added to Table 4.9.4-1 (NPS NCPN 2017). Since these other parks surround Bryce Canyon NP, this would likely indicate that the high priority species at other parks that are present at Bryce may also be of management concern (D. Perkins, NCPN Program Manager, pers. comm., 2017).

Because the majority of medium or high ranked species are not problematic at the park and/or actively managed, we consider, this measure to be in good

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%

Table 4.9.4-1. List of non-native plant species documented in Bryce Canyon NP.

Scientific Name	Common Name	NatureServe Invasive Species Impact Rank	Priority Invasive Species in at Least one NCPN Park	Year Documented
Agropyrun cristatum	Crested wheatgrass	Medium	–	1956
Agrostis stolonifera	Redtop	Medium	–	1956
Arctium minus	Burdock	Medium/Insignificant	X	1998
Asparagus officinalis	Asparagus	Medium/Insignificant	–	1980
Bassia scoparia	Summer-cypress	Low	X	2006
Berula erecta	Cutleaf waterparsnip	Not Assessed	–	1987
Brassica nigra[1]	Black mustard	High/Low	–	1932
Bromus inermis	Smooth brome	High	–	1942
Bromus japonicus	Japanese chess	Not Assessed	–	1980
Bromus tectorum	Cheatgrass	High	–	1932
Capsella bursa-pastoris	Shepherd's purse	Insignificant	–	1980
Cardaria draba[2]	Whitetop	Not Assessed	X	1998
Carduus nutans[2]	Musk thistle	High/Low	X	1998
Centaurea maculosa	Spotted knapweed	High	X	1998
Centaurea repens	Russian knapweed	High	X	1980
Chenopodium album[3]	Lambsquarters	Not Assessed	–	2005
Chorispora tenella	Crossflower	Insignificant	X	2011
Cichorium intybus	Chicory	Medium/Insignificant	–	1998
Cirsium arvense[2]	Canada thistle	High	X	1998
Cirsium vulgare	Bull thistle	Medium/Low	X	1998
Conringia orientalis	Hare's-ear mustard	Medium/Low	–	1980
Convolvulus arvensis[2]	Field bindweed	Medium	X	1980
Cynoglossum officinale[2]	Common hound's-tongue	Medium	X	1998
Dactylis glomerata	Orchard grass	Medium/Insignificant	–	1942
Descurainia sophia	Tansy mustard	Medium	X	1957
Elaeagnus angustifolia[2]	Russian olive	High	X	2004
Elymus hispidus	Intermediate wheatgrass	Medium/Insignificant	–	1980
Elymus junceus	Russian wildrye	Low	–	1980
Erodium cicutarium	Storksbill	Medium	X	1998
Eschscholzia californica	California poppy	Not Assessed	–	1956
Festuca pratensis	Meadow fescue	High/Low	–	1942
Halogeton glomeratus	Halogeton	High	–	2004
Lactuca serriola	Prickly lettuce	Low	–	1980
Lepidium perfoliatum	Clasping pepperwort	Low	–	1998
Malcolmia africana	African mustard	Not Assessed	–	1980
Malus pumila	Paradise apple	Medium/Insignificant	–	1998
Malva neglecta	Common mallow	Medium/Insignificant	–	1998
Marrubium vulgare	Horehound	Medium	–	1932
Medicago lupulina	Black medick	Medium/Insignificant	–	1958
Medicago sativa[1]	Alfalfa	Insignificant	–	1931

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

[2] Species that have been confirmed with a voucher specimen and have been relocated and treated within the past 5-10 years.

[3] More information is needed on Bryce Canyon NP's specific populations of *P. australis*, but Eric Vasquez suspects it may be the native lineage.

[4] Species listed as potentially occurring in Fertig and Topp (2009) and mapped in the park by Dewey and Anderson (2005).

[5] Species in bold are considered noxious by the state of Utah (UDAF 2017).

Note: X = Present.

Table 4.9.4-1 continued. **List of non-native plant species documented in Bryce Canyon NP.**

Scientific Name	Common Name	NatureServe Invasive Species Impact Rank	Priority Invasive Species in at Least one NCPN Park	Year Documented
Melilotus officinalis	Yellow sweetclover	Medium	X	1959
Onopordum acanthium[2]	Scotch thistle	Not Assessed	X	2013
Phleum pratense	Timothy grass	Medium	–	1980
Phragmites australis[4]	Common reed	High	–	1980
Plantago lanceolata	Lanceleaf plantain	High/Low	–	1980
Poa bulbosa	Bulbous bluegrass	Not Assessed	–	2011
Poa compressa	Canada bluegrass	High/Low	–	1980
Poa pratensis	Kentucky bluegrass	Medium	–	1931
Polygonum aviculare	Knotweed	Low	–	1932
Polygonum convolvulus	Black bindweed	Low	–	Unknown
Rumex crispus	Curly dock	Low	–	1932
Salsola tragus [S. kali]	Prickly Russian thistle	Not Assessed	X	1931
Setaria viridis	Green bristlegrass	Not Assessed	–	1998
Sisymbrium altissimum[4]	Tumble mustard	Not Assessed	X	2005
Solanum rostratum	Buffalobur	Not Assessed	–	1998
Solanum sarrachoides	Ground-cherry nightshade	Not Assessed	–	1998
Sonchus asper	Spiny-leaf sow-thistle	Not Assessed	–	1998
Sonchus uliginosus	Marsh sow-thistle	Not Assessed	–	1998
Tamarix chinensis	Five-stamen tamarisk	Not Assessed	X	1980
Tamarix ramosissima[2]	Saltcedar	High	X	1980
Taraxacum officinale	Dandelion	Not Assessed	–	1980
Thlaspi arvense	Field pennycress	Low	–	1974
Tragopogon dubius	Common salsify	Medium	X	1957
Trifolium repens	White clover	Medium	–	1957
Ulmus pumila	Siberian elm	Medium	X	2006
Verbascum thapsus	Common mullein	Medium	X	1980

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

[2] Species that have been confirmed with a voucher specimen and have been relocated and treated within the past 5-10 years.

[3] More information is needed on Bryce Canyon NP's specific populations of *P. australis*, but Eric Vasquez suspects it may be the native lineage.

[4] Species listed as potentially occurring in Fertig and Topp (2009) and mapped in the park by Dewey and Anderson (2005).

[5] Species in bold are considered noxious by the state of Utah (UDAF 2017).

Note: X = Present.

condition. Confidence is high. Trend does not apply to this measure.

New Non-native Plants Detected

By 1932, eight non-native species had been documented in Bryce Canyon NP, which represented 4.7% of the total documented species at the time (Figure 4.9.4-1). The proportion of total species considered non-native was stable during the 1950s through the 1970s and then increased thereafter. During the 1980s a significant pulse of 19 new non-native species were added to the park's plant list. Eighteen of these species were documented during a 1980 survey of the main amphitheater in the breaks (Graybosch 1981). During the park's first weed survey in 1990s an additional 17 species were discovered (Dewey and Anderson 2005, Fertig and Topp 2009). By 2000, much of the park had been surveyed and the majority of non-native plants had been documented. However, there continue to be new discoveries with nine new non-native species since 2000. The 2013 discovery of Scotch thistle (*Onopordum acanthium*) was the most recent (NPS 2013b) (Table 4.9.4-1). Although the rate of total species added to the park plant list has slowed in recent years, the proportion of documented non-native plants has remained stable at

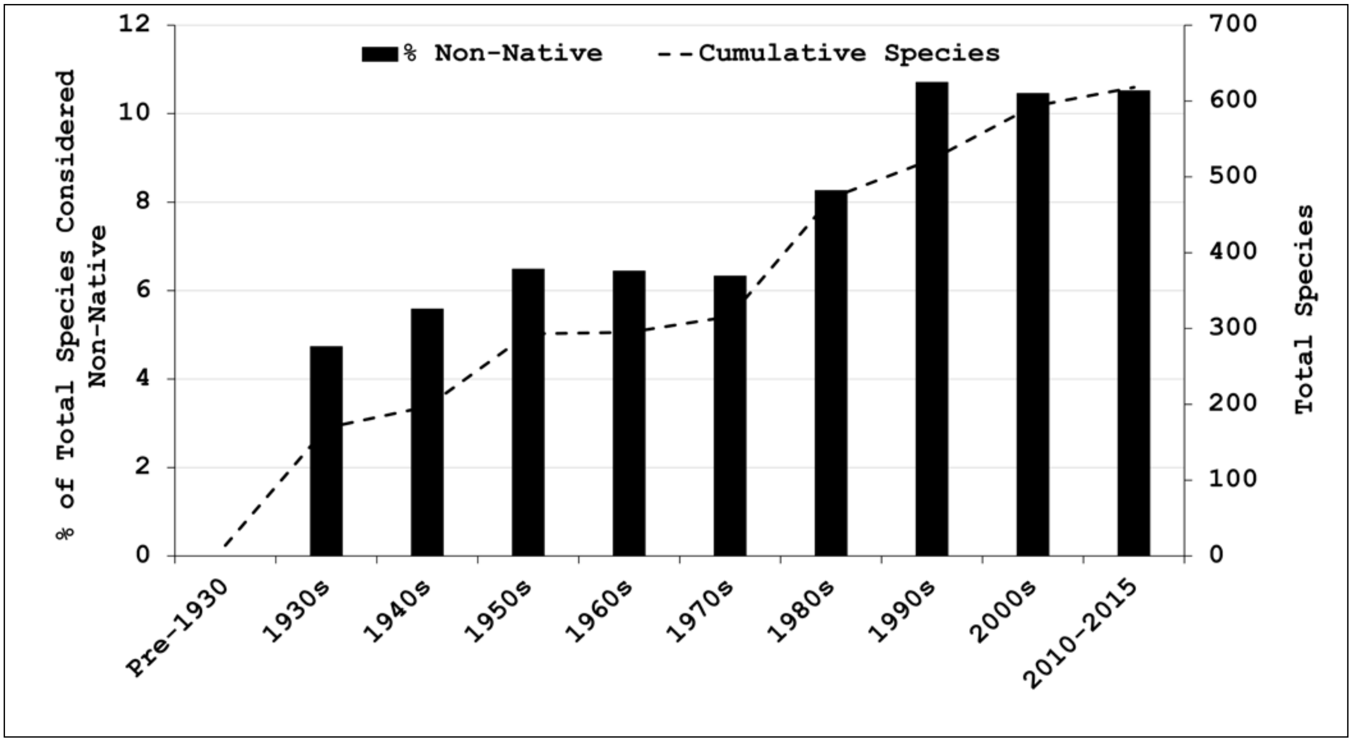


Figure 4.9.4-1. Number of non-native plants documented in Bryce Canyon NP by decade.

about 10% since 1990 (note that Figure 4.9.4-1 excludes 11 species without a date of documentation, including one non-native species). Since the rate of invasion is high and has increased over time, the condition for this measure warrants significant concern. Confidence is medium since the date of documentation does not necessarily reflect the date of introduction. Trend is deteriorating.

Frequency (%)

NPS Vegetation Classification and Mapping Project

At least one non-native species was detected in 95 (27%) of the 357 NPS vegetation classification and mapping project plots. Fifteen non-native species were detected in all (Table 4.9.4-2). Kentucky bluegrass (*Poa pratensis*) (10%), dandelion (*Taraxacum officinale*) (9%), and common salsify (8%) were the three most common non-native species. Smooth brome, cheatgrass, and prickly lettuce (*Lactuca serriola*) each occurred in 3% of plots. The remaining nine species occurred in ≤2% of plots.

At least one non-native species occurred in plots sampled in 23 of the 40 map classes (Table 4.9.4-2). Both dandelion and Kentucky bluegrass were widespread and were found in 16 and 13 map classes, respectively. Kentucky bluegrass and smooth brome were so abundant in some areas that they were included in the perennially disturbed grassland complex where these species represented the dominant plant cover (Tendick et al. 2011). The most heavily invaded map classes include meadows, ponderosa pine/mixed herbaceous woodlands, and shrublands. Overall frequency (27%) warrants moderate concern, but individual species frequency did not exceed 25%, which is considered good condition. 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 uplands, no non-native species were observed in pinyon-juniper plots, but nine non-native species were observed in mixed coniferous forest plots during the six years of surveys (2010-2015) (Table 4.9.4-3). At least one non-native species was observed in 12 of the 20 coniferous forest plots for 60% frequency. Dandelion (22.2%) was widely distributed across plots, followed by prickly lettuce (16.1%), Kentucky bluegrass (9.0%), and smooth brome (8.3%). The remaining species occurred only rarely. Average quadrat frequency was low for all species indicating a clumped distribution within plots. Based on overall plot frequency data, the condition for warrants significant concern. By species, the condition is good. Confidence is high since data were recently collected

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

Species	Total Plot Frequency (%)	Vegetation Map Classes
Kentucky bluegrass	10	Bottomland Shrubland Complex, Gambel Oak Shrubland Complex, Blue Spruce Forest Complex, White Fir Forest Complex, White Fir/Mixed Grass Forest, Willow spp. Temporarily Flooded Shrubland Complex, Viscid Rabbitbrush Shrubland Complex, Ponderosa Pine/ Mixed Herbaceous Woodland Complex, Ponderosa Pine/Mixed Mountain Shrub Woodland Complex, Dry Meadow Mixed Herbaceous Vegetation Mosaic, Perennial Distrubed Grassland Complex, Black Sagebrush Shrubland Complex, Sedge and Rush Wet Meadow Herbaceous Vegetation Mosaic
Dandelion	9	Gambel Oak Shrubland Complex, White Fir Forest Complex, White Fir/Mixed Grass Forest, Viscid Rabbitbrush Shrubland Complex, Ponderosa Pine/Mixed Herbaceous Woodland Complex, Black Sagebrush Shrubland Complex, Mixed Mountain Shrubland Complex, Ponderosa Pine-(Douglas Fir)/Manzanita Woodland Complex, Aspen Forest Complex, Roadside Restored Herbaceous Complex, Bottomland Shrubland Complex, Blue Spruce Forest Complex, Perennial Disturbed Grassland Complex, Sedge and Rush Wet Meadow Herbaceous Vegetation Mosaic, Ponderosa Pine/Mixed Mountain Shrub Woodland Complex, Dry Meadow Mixed Herbaceous Vegetation Mosaic
Common salsify	8	White Fir/Mixed Grass Forest, Mixed Mountain Shrubland Complex, Roadside Restored Herbaceous Complex, Bottomland Shrubland Complex, Blue Spruce Forest Complex, Sedge and Rush Wet Meadow Herbaceous Vegetation Mosaic, Manzanita Shrubland Complex, White Fir/Manzanita-Mixed Shrub Forest, Viscid Rabbitbrush Shrubland Complex, Perennial Disturbed Grassland Complex, Ponderosa Pine/Mixed Herbaceous Woodland Complex, Ponderosa Pine/Mixed Mountain Shrub Woodland Complex, Black Sagebrush Shrubland Complex, Dry Meadow Mixed Herbaceous Vegetation Mosaic
Smooth brome	3	Sedge and Rush Wet Meadow Herbaceous Vegetation Mosaic, Black Sagebrush Shrubland Complex, Manzanita Shrubland Complex, Mixed Mountain Shrubland Complex, Ponderosa Pine/Mixed Mountain Shrub Woodland Complex, Perennial Disturbed Grassland Complex, Dry Meadow Mixed Herbaceous Vegetation Mosaic
Cheatgrass	3	Dry Meadow Mixed Herbaceous Vegetation Mosaic, Black Sagebrush Shrubland Complex, Mixed Mountain Shrubland Complex, Mixed Desert Shrubland Complex, Gambel Oak Shrubland Complex, Viscid Rabbitbrush Shrubland Complex, Ponderosa Pine/Mixed Herbaceous Woodland Complex, Bottomland Shrubland Complex
Prickly lettuce	3	Mixed Mountain Shrubland Complex, Dry Meadow Mixed Herbaceous Vegetation Mosaic, Mixed Desert Shrubland Complex, Viscid Rabbitbrush Shrubland Complex, Ponderosa Pine/ Mixed Herbaceous Woodland Complex, Manzanita Shrubland Complex, Big Sagebrush Shrubland Complex, Ponderosa Pine-(Douglas Fir)/Manzanita Woodland Complex, Bottomland Shrubland Complex
White clover	2	Ponderosa Pine/Mixed Herbaceous Woodland Complex, Ponderosa Pine/Mixed Mountain Shrub Woodland Complex, Black Sagebrush Shrubland Complex
Crested wheatgrass	1	Ponderosa Pine/Mixed Herbaceous Woodland Complex, Bottomland Shrubland Complex, Mixed Desert Shrubland Complex
Redtop	1	Perennial Disturbed Grassland Complex, Sedge and Rush Wet Meadow Herbaceous Vegetation Mosaic
Prickly Russian thistle	1	Mixed Desert Shrubland Complex, Siltbush Sparse Vegetation
Cutleaf waterparsnip	< 1	Sedge and Rush Wet Meadow Herbaceous Vegetation Mosaic
Japanese chess	< 1	Dry Meadow Mixed Herbaceous Vegetation Mosaic
Russian olive	< 1	Mixed Mountain Shrubland Complex
Knotweed	< 1	Pinyon Pine-Juniper spp./Sparse Understory Woodland
Curly dock	< 1	Sedge and Rush Wet Meadow Herbaceous Vegetation Mosaic

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.

Year	Kentucky bluegrass	Dandelion	Smooth brome	Common salsify	Prickly lettuce	Lambsquarter	Bull thistle	Cheatgrass	Orchard grass
2010	n/a (0)	n/a (0)	n/a (0)	n/a (12.5)	n/a (0)	n/a (0)	n/a (0)	n/a (0)	n/a (0)
2011	0.8 (25.0)	1.7 (25.0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (12.5)
2012	0.8 (12.5)	2.1 (25.0)	0 (0)	0 (0)	5.0 (62.5)	0 (0)	0 (0)	0 (0)	0 (0)
2013	0 (0)	8.3 (25.0)	5.4 (50)	0.4 (12.5)	1.7 (50)	1.3 (12.5)	0 (0)	0 (12.5)	0 (0)
2014	0 (0)	4.2 (25.0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (12.5)	0 (0)	0 (0)
2015	2.2 (16.7)	8.9 (33.3)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Average	0.8 (9.0)	4.2 (22.2)	0.9 (8.3)	0.07 (4.2)	1.1 (16.1)	0.2 (1.8)	0 (1.8)	0 (1.8)	0 (1.8)

Note: Frequency is shown as quadrat frequency followed by plot frequency in parentheses. Quadrat frequency data were not collected in 2010.

Source: NCPN unpublished data.

and are part of a long-term monitoring effort. Trend could not be determined since these data represent the first round of sampling.

Summary

Between these two studies, 18 of the 66 known non-native species in the park were observed. Together, these data indicate that the majority of non-native plants known to occur in the park are rare, at least across the plots sampled. Of the 18 species observed, smooth brome, cheatgrass, and Russian olive (*Elaegnus angustifolia*) were all ranked high by NatureServe. Russian olive was rare but Kentucky bluegrass, dandelion, prickly lettuce, and smooth brome exhibited moderate to high frequency. For these reasons, the condition for this measure is warrants moderate concern. Confidence is medium. Trend is unknown.

Cover (%)

NCPN Non-native Plant Inventory and Mapping

In the 3,570 ha (8,821 ac) surveyed for non-native plants during 2004 and 2005, 19 ha (47 ac), or about 0.5% of the total area was infested (Table 4.9.4-4). Eight of the 12 target species and an additional 15 species were mapped for a total of 23 species. Smooth brome was by far the most widespread, infesting a 13.01-ha (32.16-ac) area, which represents only 0.33% of the total survey area but 68% of the total infested area. The vast majority of smooth brome was mapped in dense patches in open meadows (Dewey and Anderson 2005a,b). Cheatgrass exhibited the second most cover, comprising only 0.06% of the total survey area and 12.58% of the total infested area. Yellow sweetclover (*Melilotus officinalis*) (0.05%) exhibited similar cover to cheatgrass. The remaining species were very low in cover. Several additional species were found but not mapped, such as lambsquarters (*Chenopodium album*) and crested wheatgrass (*Agropyrun christatum*) (Dewey and Anderson 2005a,b). Thus, these data do not represent a complete assessment of non-native plant cover in the inventoried area. Based on reference

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

Species	Area ha (ac)	Total Cover (%)
Smooth brome	13.01 (32.16)	0.33
Cheatgrass	2.41 (5.95)	0.06
Yellow sweetclover	1.85 (4.98)	0.05
Prickly Russian thistle	0.87 (2.14)	0.02
Saltcedar	0.29 (0.72)	0.01
Bull thistle	0.18 (0.44)	< 0.01
Common salsify	0.13 (0.33)	< 0.01
Common mullein	0.11 (0.26)	< 0.01
Field bindweed	0.10 (0.25)	< 0.01
Orchard grass	0.05 (0.13)	< 0.01
Timothy grass	0.05 (0.12)	< 0.01
Canada thistle	< 0.01 (0.01)	< 0.01
Clasping pepperwort	< 0.01 (0.01)	< 0.01
Common mallow	< 0.01 (0.01)	< 0.01
Common reed	< 0.01 (0.01)	< 0.01
Halogeton	< 0.01 (0.01)	< 0.01
Horehound	< 0.01 (0.10)	< 0.01
Musk thistle	< 0.01 (0.01)	< 0.01
Prickly lettuce	< 0.01 (0.01)	< 0.01
Russian knapweed	< 0.01 (0.01)	< 0.01
Russian olive	< 0.01 (0.01)	< 0.01
Storksbill	< 0.01 (0.01)	< 0.01
Tumble mustard	< 0.01 (0.01)	< 0.01
Total	19.21 (47.26)	0.50

Source: Dewey and Anderson (2005a,b).

conditions, these data indicate good condition since total cover in the target area was less than 1%, but the species with the highest cover were ranked high by NatureServe. Despite the low overall cover, smooth brome was spread over 13 ha (32 ac), which is a large area that may be difficult to manage. However, the targeted areas were chosen specifically because non-native plants were expected and yet, total cover was only 0.5% (Dewey and Anderson 2005a). Therefore, the condition is good. Confidence is medium because the surveys are more than a decade old and not all species were mapped. Trend could not be determined based on this single survey.

NPS Vegetation Classification and Mapping Project
The 15 species detected in the NPS vegetation classification and mapping project plots during 2005 and 2006 exhibited a low average cover of 1.03%, with Kentucky bluegrass representing most of that cover at 0.80% (Table 4.9.4-5). Based on reference conditions, these results warrant moderate concern, but average cover was only slightly over 1%. Confidence medium since the data is more than 10 years old. Trend could not be determined based on this single survey.

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

Species	Cover (%)
Kentucky bluegrass	0.80
Smooth brome	0.18
Dandelion	0.02
Common salsify	< 0.01
Cheatgrass	< 0.01
Prickly lettuce	< 0.01
White clover	< 0.01
Crested wheatgrass	< 0.01
Redtop	< 0.01
Prickly Russian thistle	< 0.01
Cutleaf waterparsnip	< 0.01
Japanese chess	< 0.01
Russian olive	< 0.01
Knotweed	< 0.01
Curly dock	< 0.01
Total	1.03

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

NCPN Uplands Plant Monitoring
In NCPN upland mixed coniferous forest plots, total cover ranged from 0.04% in 2010 and 2014 to 0.46% in 2015 (Table 4.9.4-6). Total average cover was 0.17%. As stated previously, there were no non-native species detected in pinyon-juniper plots. Since total average cover was <1%, these data indicate good condition in upland monitoring plots.

Summary
All three surveys indicate good condition for non-native plant cover, but the species exhibiting the most cover are highly invasive (i.e., smooth brome, cheatgrass) or moderately invasive (i.e., Kentucky bluegrass). These species tend to be most common in meadows, which may have been under sampled. Therefore, the condition for this measure is split between good and moderate concern. Confidence is medium and trend is unknown.

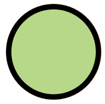
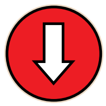
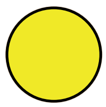
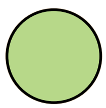
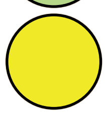
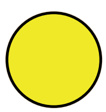
Overall Condition, Trend, Confidence Level, and Key Uncertainties
Overall, the condition of non-native and invasive plants warrants moderate concern in Bryce Canyon NP. This condition rating was based on three indicators

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

Species	2010 Cover	2011 Cover	2012 Cover	2013 Cover	2014 Cover	2015 Cover	Mean
Common dandelion	0.00	0.00	0.08	0.00	0.00	0.25	0.06
Kentucky bluegrass	0.00	0.00	0.00	0.00	0.00	0.21	0.04
Smooth brome	0.00	0.00	0.00	0.13	0.00	0.00	0.02
Orchard grass	0.00	0.08	0.00	0.00	0.00	0.00	0.01
Bull thistle	0.00	0.00	0.00	0.00	0.04	0.00	0.01
Cheatgrass	0.00	0.00	0.00	0.04	0.00	0.00	0.01
Lambsquarter	0.00	0.00	0.00	0.04	0.00	0.00	0.01
Prickly lettuce	0.00	0.00	0.08	0.04	0.00	0.00	0.02
Common salsify	0.04	0.00	0.00	0.00	0.00	0.00	0.01
Total	0.04	0.08	0.16	0.25	0.04	0.46	0.17

Source: NCPN unpublished data.

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		Species with the highest rank included smooth brome, cheatgrass, spotted knapweed, and Canada thistle, among others. Since the majority of higher ranked species are not problematic at Bryce Canyon NP, and the control of the ones that are have been a high management priority, this measure is good. Confidence in this condition is high since multiple studies have and continue to document non-native plants in the park. Trend does not apply to this measure.
Rate of Invasion	% of New Non-native Species of Total Species Detected Over Time		Although the total species added to the park plant list has slowed in recent years, the proportion of non-native plants has remained stable at about 10% since 1990. Since the rate of invasion is high and has increased over time, the condition for this measure warrants significant concern. Confidence is medium since the date of documentation does not necessarily reflect the date of introduction. Trend is deteriorating.
Prevalence	Frequency (%)		Eighteen of the 66 known non-native species were observed. Together, these data indicate that the majority of non-native plants known to occur in the park are rare, at least across the plots sampled. Of the 18 species observed, smooth brome, cheatgrass, and Russian olive were all ranked high by NatureServe. By species, frequency data indicate good condition, but overall frequency warrants moderate concern for NPS vegetation classification data and significant concern for NCPN upland data. For these reasons, the condition for this measure warrants moderate concern. Confidence is medium. Trend is unknown.
	Cover (%)	 	Total average cover was <1% in NCPN upland plots and in NCPN target areas. Average cover was 1.03% for the NPS vegetation classification and mapping project. All three surveys indicate good condition, but the species exhibiting the most cover are highly invasive (i.e., smooth brome, cheatgrass) or moderately invasive (i.e, Kentucky bluegrass). These species tend to be most common in meadows, which may have been under sampled. Therefore, the condition for this measure is split between good and moderate concern. Confidence is medium and trend is unknown.
Overall Condition, Trend, and Confidence Level			Thirty-three of the 66 non-native species were documented, but most of them were rare. Smooth brome, common salsify, Kentucky bluegrass, cheatgrass, and dandelion were the most common species. Although several are of particular concern (e.g., smooth brome and cheatgrass), most are not problematic at the park. In addition, the total infested area was low with most infestations located in upland meadows. Nearly all measures were assigned medium confidence. This is because, with the exception of NCPN upland data, the datasets used in this assessment are more than five years old. Trend could not be determined.

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 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 park. Based on these factors, nearly all measures were assigned medium confidence. This is because, with the exception of NCPN upland data, the datasets used in this assessment are more than five years old. Among the three studies included in this assessment, 33 of the 66 non-native species were documented. Although half of all known non-native species were observed, most of them were rare. Smooth brome, common salsify, Kentucky bluegrass, cheatgrass, and dandelion were the most common species encountered, but the total infested area of the park is low with most infestations located in upland meadows.

Non-native Plant Control and Revegetation Efforts

NPS staff treat at least 10 non-native species and revegetate treated areas with native plants. The five most commonly treated species are smooth brome, cheatgrass, bull thistle, musk thistle, and common mullein (*Verbascum thapsus*). Other species are treated when they are encountered. Smooth brome is the species of greatest concern in the park. NPS staff have chemically treated smooth brome since 2010 (NPS 2016e). Infestations usually require several treatments to be effective (NPS 2016e). In some areas, these treatments have been successful, especially when coupled with reseeding of native vegetation (NPS 2016e). 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 (0.33%), smooth brome infested 13 ha (32 ac). This is a considerable area to control. Controlling smooth brome and cheatgrass is particularly important for the federally threatened Utah prairie dog (*Cynomys parvidens*), which inhabits meadows. Although smooth brome and cheatgrass have infested prairies dog meadows, chemical treatment is not permitted in these areas (NPS 2016e).

Threats, Issues, and Data Gaps

How infestations change over time with treatment is not clear but critical for determining the success of these efforts. Measuring success is difficult because of the multiple treatments required for some species, restrictions placed on treating prairie dog meadows, and the constant threat of re-dispersal via roads, foot traffic, horses and mules, and other disturbances. For example, cheatgrass is not subject to weed-free hay restrictions and is therefore, regularly transported into the park (NPS 2016e). NCPN staff working on upland and water quality protocols have often observed stray cattle and downed fencing and reported these instances to park staff. At this time, it is unknown whether the *Phragmites* population at the park is of native lineage.

Like most NPS units, visitation has increased dramatically in recent years. In 2017, an estimated 2.5 million visitors toured the park (NPS Public Use Statistics Office 2018). People visit the park from all over the world and may inadvertently contribute to the introduction and spread of non-native species (NPS 2014a). Increasing visitation contributes to the establishment of social trails, which leads to soil compaction, increased runoff, and trampling of native vegetation (NPS 2016e). Although livestock grazing is no longer permitted in the park, there is limited access for cattle drives to summer range (NPS 2014a). The park has several incidents of cattle incursion on a yearly basis, frequently occurring in wet meadows, near perennial streams and springs, and areas recovering from wildfire. In many areas, there is no barrier preventing cattle from entering and grazing in the park, and it's likely that cattle are a constant presence in these areas over the course of a growing season. Although general data on grazing impacts seem to be abundant, it is lacking for specific impacts on Bryce Canyon NP's vegetation communities (Eric Vasquez, Vegetation Crew Leader, Bryce Canyon NP, pers. comm.). Landscapes of the northern Colorado Plateau evolved under low or sporadic grazing pressure (Mack and Thompson 1982), and large ungulates such as bison were absent from the region (van Vuren and Dietz 1993). Local soils tend to be highly vulnerable to erosion when trampled, and research conducted 321.9 km (200 mi) to the east near Canyonlands National Park found that livestock grazing can lead to declines in soil nutrients (Neff et al. 2005). While little or no research has specifically examined impacts of livestock on native versus invasive plants at Bryce Canyon, studies elsewhere on the northern Colorado Plateau have found that livestock grazing leads to a decline in more palatable grass and forb species and an increase in native shrubs such as broom snakeweed (*Gutierrezia sarothrae*) and rubber rabbitbrush (*Ericameria nauseous*), as well as the non-native invasives, Russian thistle (*Salsola tragus*) and cheatgrass (Cole et al. 1997). Recovery of native Colorado Plateau grasslands from grazing impacts is typically slow and incomplete (Schwinning et al. 2008).

The breaks contain most of the rare and sensitive plant species in the park (NPS 2014f). If invasive species continue to spread into these areas, native vegetation could be outcompeted (NPS 2016e). Mixed coniferous forests 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 community's vulnerability. All non-native species encountered in NCPN uplands were found within mixed coniferous plots as opposed to pinyon-juniper plots. Long-term fire suppression has transformed historically dominated ponderosa pine

(*Pinus ponderosa*) forests to white fir (*Abies concolor*) dominated forests with cascading effects on understory vegetation and fire return interval and severity (Stein 1988a,b; NPS 2010e). Some areas of the park have also been affected by bark beetles (NPS 2014a), which may also influence the spread of non-native species. A key uncertainty is how climate change will interact with these plant community changes to influence the spread of non-native plants (Hellmann et al. 2008).

The western U.S., especially the Southwest, has experienced increasing temperatures and decreasing rainfall (Prein et al. 2016). Since 1974 there has been a 25% decrease in precipitation, a trend that is partially counteracted by increasing precipitation intensity (Prein et al. 2016). 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 Bryce Canyon NP 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 of which the park exceeded some variables. These results indicate a trend toward warmer but not necessarily drier conditions within the park (Monahan and Fischelli 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 200 days of frost per year (Monahan and Fischelli 2014) limits the growing season for non-native species, but climate change 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). 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 is Lisa Baril, science writer, Utah State University. Subject matter review experts are listed in Appendix B.

4.10. Birds

4.10.1. Background and Importance

Protecting and managing some of our nation's most significant natural resources requires basic knowledge of the condition of ecosystems and species that occur in national parks. Birds are 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) (Figure 4.10.1-1), and relative to other vertebrates, they are also highly detectable and can be efficiently surveyed with the use of numerous standardized methods (Bibby et al. 2000, Buckland et al. 2001).

Another compelling reason to monitor birds is that birds themselves are inherently valuable. The high aesthetic and spiritual values that humans place on native wildlife are acknowledged in the National Park Service's (NPS) Organic Act: "to conserve . . . the wildlife therein . . . unimpaired for the enjoyment of future generations." Bird watching, in particular, is a popular, longstanding recreational pastime in the United States and forms the basis of a large and sustainable industry (Sekercioglu 2002).

Changes in bird population and community parameters have been identified as an important element of a comprehensive, long-term monitoring program administered by the NPS Northern Colorado Plateau Inventory and Monitoring Network (NCPN), at Bryce Canyon National Park (NP) (McLaren and White 2016). The program's level of inference is for selected survey habitats throughout *all* NCPN parks. For example, the data inform population density and trend for sage thrasher (*Oreoscoptes montanus)* in sage shrublands throughout NCPN parks with that habitat type but is not designed to say how sage thrasher is doing specifically in Bryce Canyon NP's sage shrubland.

In addition to the NCPN survey effort, Bryce Canyon NP staff have been monitoring the peregrine falcon (*Falco peregrinus*) as a species of management concern (Flower 2011). The current breeding range of the falcon is substantially smaller than its original (USFWS 2017b), and it is found most widely in Alaska and parts of the western U.S., including Utah, Arizona, western Colorado, and northern California. Areas within Bryce Canyon NP provide high quality nesting and foraging habitat for the peregrine (Burman 2016).

4.10.2. Data and Methods

Species Occurrence

To assess the three measures of species occurrence at the national park, including a temporal comparison of presence/absence, absence of non-native species, and

Figure 4.10.1-1. Mountain bluebird is a common species of conservation concern at Bryce Canyon NP. Photo Credit: © Robert Shantz.

presence of conservation concern species, we used the bird surveys of Gerstenberg (1972), Hallows (1982, 1983), and NCPN (McLaren and White 2016), and the park's certified NPSpecies birds list (NPS 2017a).

Gerstenberg (1972) conducted a study of nesting birds in ponderosa pine (*Pinus ponderosa*; referred to as yellow pine by Gerstenberg) habitat in the breeding seasons of 1971 and 1972. Even though detailed methods were not provided in the 1972 report, the author did report that six nets were used in 1971. In 1972, two nets were erected at a natural watering area, which was a different location than what was surveyed in 1971. What is unclear from the Gerstenberg (1972) report is the total number of discrete locations sampled during both years. Gerstenberg collected data on nesting birds, including whether a nest or young were observed and the type of nest used (cavity or cup).

Hallows (1982) studied birds within the national park and its vicinity in the summer of 1982 (1 June to 31 August). He looked for and recorded birds in every habitat type in the park, and throughout most areas of the park (Hallows 1982). He also recorded species outside of the park (Tropic Reservoir, East Fork Sevier River, southern edge of Johns Valley, Tropic, and Paria River), but we did not include those observations in this assessment. Hallows (1982) spent more than 300 hours collecting data during three parts of the day--early morning, mid-day, and evening. He provided a checklist based on his observations, and included information on habitat type, species abundance, and resident/migrant status.

Hallows (1983) made similar observations from September of 1982 to August of 1983 using 7 x 10 power binoculars. Over 300 hours were spent in the field during early morning, mid-day, and evening. It appears that the methods used were not plot-based but more of a strategic survey, although this is not explicitly included in the reports.

The most recent bird surveys at the park, beginning in 2005, have been conducted by NCPN as part of their long-term monitoring program (McLaren and White 2016). Surveys by the Bird Conservancy of the Rockies have been conducted every year since then except for 2016. A total of three transects, two within the sage shrubland habitat and one within the pinyon-juniper habitat, are surveyed following a protocol modified by Hanni et al. (2012 as cited by McLaren and White 2016) (refer to figure 4.10.2-1 for a map of NCPN's bird monitoring site locations).

In 2005-2013, transects were surveyed twice per year, but in 2014 and 2015, transects were surveyed only once per year. Brief descriptions of the two habitat types surveyed at Bryce Canyon NP have been excerpted from McLaren and White (2016):

> Pinyon-juniper (PJ) habitat typically occurs at elevations just above 1,500 m (4,921 ft) in the study area. PJ is present on most of the ridges and mesas, and is the most abundant habitat in the NCPN. Pinyon pine (*Pinus edulis*) and juniper species (*Juniperus* spp.) are dominant in this habitat. The relative abundance and composition of these species can vary significantly, and PJ habitat sometimes contains a significant sage component.
>
> The sagebrush shrubland (SA) community is also common on the Colorado Plateau. The stands of sage surveyed in the NCPN are generally narrow "fingers" of pure sage, and point-count stations are often near forests. The most common sagebrush species in the NCPN are big sagebrush (*Artemisia tridentata)* and mountain sagebrush (*Artemisia frigida*).

Along each transect, up to 15 5-minute point counts were conducted at 250-m (820-ft) intervals. At each point, all birds detected visually or aurally during the 5-minute point count were recorded. For each bird, field observers recorded the species, gender (if known), type of detection, horizontal distance to the bird (measured using a laser rangefinder), and whether or not the bird was believed to be a migrant. Sampling was conducted between a half-hour before sunrise and five hours after sunrise.

The NPSpecies certified list of birds for Bryce Canyon NP was obtained in March 2017 from the NPS Integrated Resource Management Applications web portal (NPS 2017). We used the list as supporting information and for the inclusion of additional species not recorded during the Gerstenberg (1972), Hallows (1982, 1983), and NCPN / McLaren and White (2016) bird surveys.

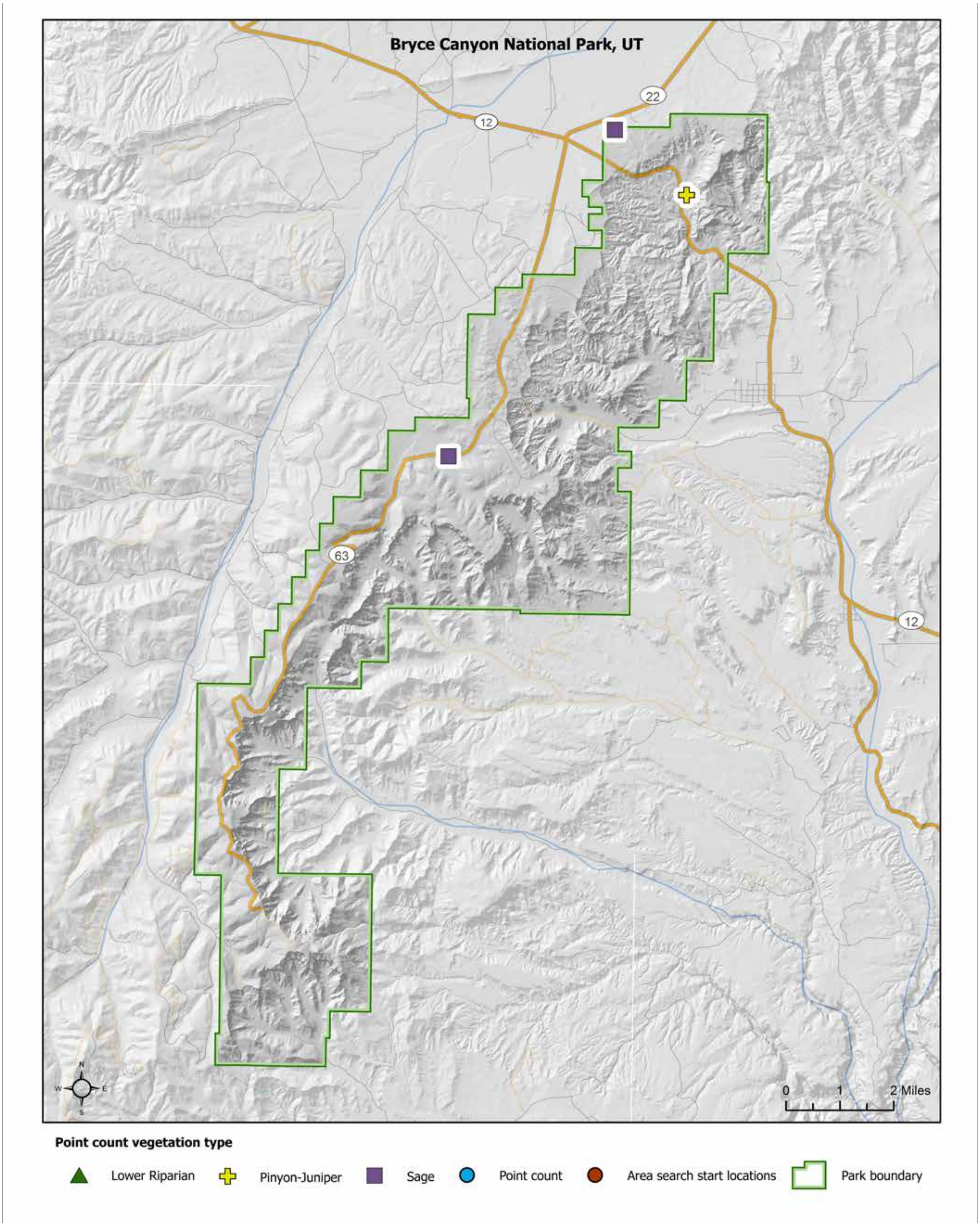


Figure 4.10.2-1. NCPN bird monitoring sites at Bryce Canyon NP (pinyon-juniper site is yellow, and sage shrubland sites are purple). Figure Credit: © Adapted from McLaren and White (2016) by NPS NCPN.

Temporal Comparison of Species Presence/Absence
Before we could temporally compare species presence/absence, we needed to develop a comprehensive list of species that made the temporal comparison relevant between the different survey efforts. To that end we began with an entire list, which included 215 species (Appendix H). We further refined the list to only include species with the NPSpecies 'present' status of occurrence designation and omitted species that were designated as 'unconfirmed' (14; two of these 'unconfirmed' species were recorded by Hallows - one in 1982 and one in 1983), 'not in park' (1; recorded by Hallows, during both the 1982 and 1983 surveys), or 'probably present' (38; none of these species were recorded during any of the bird surveys used for this condition assessment).

After omitting these three NPSpecies occurrence categories, 162 species remained. One hundred sixteen of these species were observed during one or more of the different survey efforts. The remaining 46 species were not documented during any of the survey efforts. These 46 species were further researched using NPSpecies notes to determine more detailed occurrence status. Species listed as summer/permanent or resident/migrant were retained (21 species), whereas species designated as seasonal or rare migrant (22 species) or winter resident/migrant (3 species) were omitted resulting in a final comprehensive list of 137 species (shaded in gray in Appendix H) from which the comparison of temporal presence/absence between the four bird surveys was made.

Absence of Non-native Species
The 137 bird species were evaluated to determine nativity using NPSpecies 'nativeness' designation (NPS 2017a) and were evaluated for degree of impact on native species.

Presence of Species of Conservation Concern
The 137 bird species were compared to five organizations' conservation concern lists, which are briefly summarized below. Please note that additional details for these conservation lists and organizations are presented in Appendix I.

Lists generated by the U.S. Fish and Wildlife Service (USFWS) included species designated as federally threatened, endangered, or candidates for listing (USFWS 2017a) and species within USFWS Regions and Bird Conservation Regions (BCR) (USFWS 2008). The USFWS Region and BCR listings included 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 Endangered Species Act (ESA) candidates, proposed endangered or threatened, and recently delisted species. The USFWS also maintains 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). Although we did not compare the list of birds that have been recorded at Bryce Canyon NP to the MBTA list, some of the lists we reviewed included birds protected under the MBTA (refer to Appendix I for additional MBTA details).

The North American Bird Conservation Initiative (NABCI) publishes a Watch List every few years, with the most recent report, "The State of North America's Birds," published in 2016 (NABCI 2016). 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). Most of the species on the Watch List are protected by the MBTA, and some are protected by the ESA. NABCI is responsible for delineating the North American Bird Conservation Regions (BCRs) (NABCI 2016; Figure 4.10.2-2). which are ecologically distinct areas containing similar bird communities, habitats, and resource management issues. Bryce Canyon NP is located within the Southern Rockies-Colorado Plateau BCR (BCR-16; shown in violet in Figure 4.10.2-2). The delineation of BCRs facilitates a regional approach to bird conservation (NABCI 2016).

The Utah Division of Wildlife Resources (UDWR) maintains the Utah Sensitive Species List for vertebrate and invertebrate species. The list includes species of concern, species that are federally listed or candidates for federal listing, or species for which a State conservation agreement exists (UDWR 2015). Wildlife species of concern are species that have

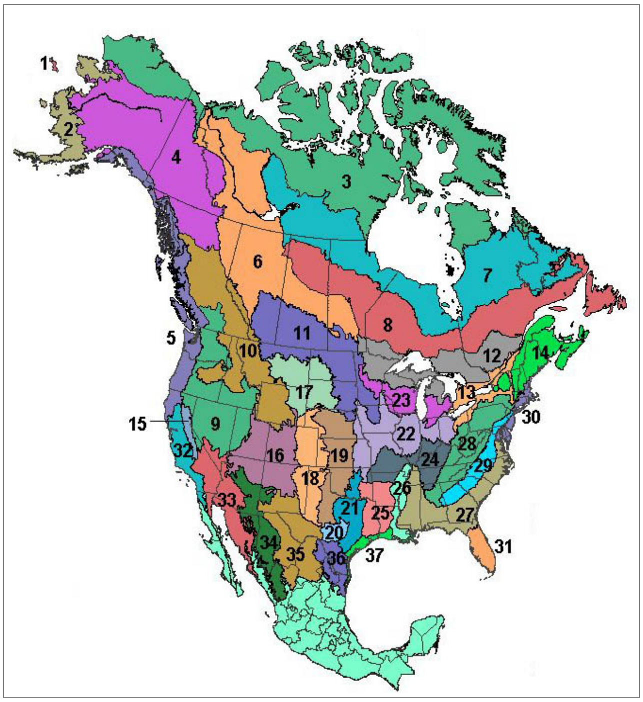


Figure 4.10.2-2. Bird Conservation Regions in North America. Figure Credit: © USFWS (2008).

scientific evidence substantiating a threat to their continued population viability (UDWR 2015).

Partners in Flight (PIF) 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. Species lists are based on Continental Importance (Continental Concern [CC] and Continental Stewardship [CS]) and Regional Importance (Regional Concern [RC] and Regional Stewardship [RS]). We compared Bryce Canyon NP's 137 species to only PIF's CC and RC species lists (PIF Science Committee 2012).

<u>Status of Peregrine Falcon Within Bryce Canyon NP</u>
Under provisions of the ESA, species that are delisted must be monitored for at least five years after being removed from the list (USFWS 2014). The peregrine falcon was delisted as an endangered species in 1999 and formal monitoring, following an established protocol, was conducted in 96 territories throughout the Rocky Mountain Peregrine Falcon Recovery Region; this included one territory (Farview) at Bryce Canyon NP (Daw et al. 2004). However, as described below, NPS staff have monitored peregrine falcons at more locations than just the Farview territory. Text was excerpted from NPS (2011a).

> Peregrine falcon monitoring at BRCA has occurred at three historic territories (Paria, Rainbow, and Farview) at varying degrees, from 1982-1997, 1999-2005, and again from 2009-2010. An intensive survey was first completed in the park in 1982. From 1983-1988, survey effort diminished, and limited data on territory occupancy and productivity was collected. Not until 1989 was another thorough survey undertaken. In 1991, a fourth territory at Sheep Creek was located. From 1989–1997, surveys in the park were complete and focused on establishing the location of breeding pairs and determining the productivity of each. No surveys were completed in 1998. From 1999-2005 survey effort again diminished and incomplete data were collected. Prior to this report [i.e., NPS 2011a], the last year in which all four sites were monitored during the breeding season was in 2002. Surveys outside of the known historic territories have not been performed since the early 1990s.

In the season of spring and summer in 2009 and 2010, Bryce Canyon NP conducted a soundscape study, including monitoring for peregrine falcon territory occupancy, nest success, and productivity, following a protocol developed for the NCPN parks (Daw et al. 2004). Park staff also observed the behavior of nesting peregrine falcons to study whether low-flying aircraft (i.e., helicopters and propeller planes) elicited behavioral responses. Four historical territories were monitored, as well as a fifth territory that was identified in 2009; all five territories were monitored in 2010 as well (Figure 4.10.2-3).

Biologists monitored each known and potential nest territory for a minimum of four hours, unless falcons were present and territory status was determined sooner (NPS 2011a). As described by NPS (2011), "if one or more peregrines were not detected during the first monitoring session (occurring between March 15th and April 15th), a second monitoring session was required at least 2 weeks after, but not more than 4 weeks following the first session. If peregrines were detected at the first monitoring session, a second protocol monitoring session was not conducted until fledglings could be detected (July–August) to determine successful productivity." The number of

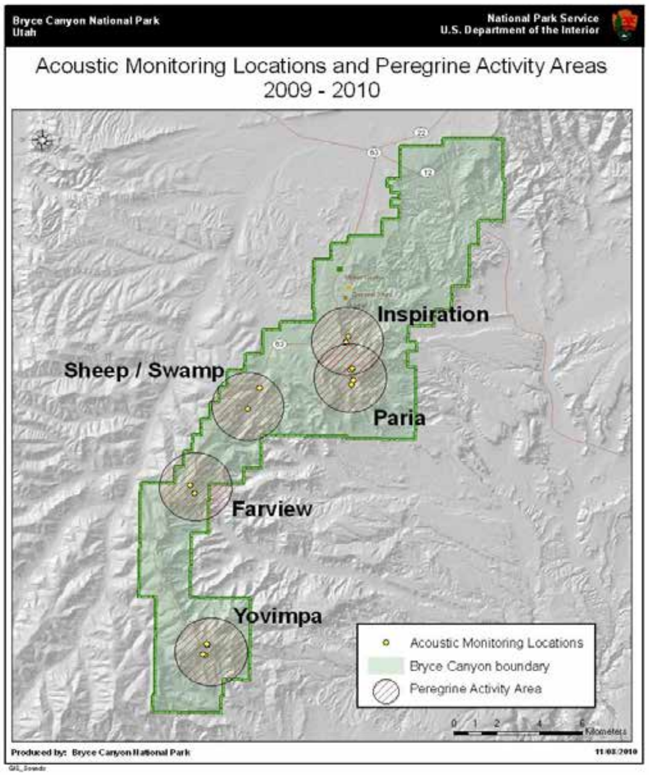


Figure 4.10.2-3. Location of historical territories and acoustic monitoring locations in 2009-2010. Figure Credit: NPS (2011).

protocol monitoring sessions per site in these years ranged from 2 to 4 per year.

The behavioral observations were made from June to August (the peak of the tourist season) of both years, with individual sessions lasting about four hours. When aircraft were within about 3,000 m (1.9 mi) from active nesting areas or perch sites, biologists recorded the behavioral response of the birds, distance from the aircraft to the known/suspected eyrie location, and the time the overflight was audible. More than 50 hours of behavioral monitoring was conducted each year (NPS 2011a).

Monitoring was also conducted from 2011-2014, using similar methods employed in 2009 and 2010 (Flower 2011, Chiu and Haas 2012, NPS 2013c, 2014i). In 2011, all of the territories were monitored, and in 2012, each of the five historical sites was monitored at least twice during the breeding season, but the visits were not full monitoring sessions per the formal protocol (Chiu and Haas 2012). Only one of the territories, Farview/Willis Creek, was monitored following the formal protocol. Annual monitoring reports were not available for 2013 and 2014 from the park, but overall monitoring results have been described elsewhere (e.g., in the FY Wildlife Reports for Bryce Canyon NP; NPS 2013c, 2014i). The wildlife reports are submitted in memorandum form to Bryce Canyon's Chief of Resource Management and Visitor Protection. We used reports from fiscal years 2010-2014 as supporting information (NPS 2010f, 2011d, 2012d, 2013c, 2014i)

Annual monitoring in 2015 (Salganek and Anderson 2015) and 2016 (Burman 2016) varied somewhat from the previous years. In 2015, the objectives of the effort were to provide a park-wide coverage of possible falcon locations and to continue monitoring territory occupancy, nest success, and productivity of the falcon within the park (Salganek and Anderson 2015). In 2015, field personnel surveyed 44 points, spaced one mile apart, along the western rim of Bryce Canyon. Points were surveyed twice during the breeding season for 30-minute intervals. Observations of other raptors were recorded as well. From each point, surveyors scanned the surrounding area without optics for perched or flying adults.; they then used binoculars and spotting scopes to search the surrounding cliffs for perched raptors and signs of nests and roost locations. Although evidence of breeding behavior was of interest, it was of lower priority than park-wide territory occupancy. In 2015, one historic territory (Farview/Willis Creek) was monitored using the formal monitoring protocol.

The 2015 monitoring approach was used in 2016, with a few differences. In 2016, the surveyors used a fewer number of observation points (23; Burman 2016). Burman (2016) reported, however, that this still allowed coverage of nearly all areas associated with past falcon sightings as well as other areas of suitable habitat. The length of observations was longer in 2016, with 60-minute observation sessions rather than 30-minute sessions.

Occupancy of Territories

To assess the status of the peregrine falcon, we examined the occupancy of their territories over the last eight years (2009-2016) using NPS (2011d) for 2009-2010; and the following for 2011-2016, respectively: Flower (2011), Chiu and Haas (2012), park Fiscal Year Wildlife Reports for 2013 and 2014 (NPS 2013c, 2014i), Salganek and Anderson (2015), and Burman (2016).

Peregrine falcons usually nest near water and most often in habitats containing cliffs. As summarized by Luensmann (2010), peregrine falcons are known to show a high degree of nest-site fidelity, returning to the same territory (although not necessarily the same eyrie) to breed in consecutive years. An occupied territory is defined as an area where either a pair of peregrines is present, or there is evidence of reproduction (e.g., adult on a nest, eggs or young are observed, or food is delivered to eyrie/nest site; USFWS 2003).

Number of Young Fledged per Year
The second measure used to assess the status of peregrine falcon was the number of young fledged per year. This measure was assessed using the same sources of data as we used to determine the condition of the occupancy of territories measure. The only difference is that data are presented from the sources for a longer period of time, with information dating back to 1982. It is very important to note, however, that the survey effort used to collect these data varied significantly over the years. Regardless, we believe it was worthwhile to include the information that was available.

4.10.3. Reference Conditions
Reference conditions for the five measures are shown in Table 4.10.3-1. Reference conditions are described for resources in good, moderate concern, and significant concern conditions for four of the indicators' measures. No reference conditions were developed for the other measure, as described in the table. The reference conditions are relatively general in nature due to the qualitative approach of the assessment.

4.10.4. Condition and Trend
Gerstenberg (1972), Hallows (1982), and the NCPN surveys (McLaren and White 2016) were conducted during bird breeding seasons, although the periods sampled differed somewhat. Hallows (1983) included the breeding season but also included additional months during the calendar year except for February and November. Additionally, Hallows (1982, 1983) surveyed all habitat types within the park (Hallows 1982), whereas Gerstenberg (1972) sampled in ponderosa pine habitat only, and the NCPN sampled in pinyon-juniper and sage shrubland habitats only (McLaren and White 2016). And finally, there were differences among the survey methods, with the NCPN using standardized sampling methods (McLaren and White 2016), and those from Hallows (1982, 1983) being more observational/opportunistic in nature.

As a result of the differences between the bird survey efforts, we acknowledge that the temporal comparison of species presence/absence is qualitative and relatively simplistic, but believe it is useful for examining whether there were any *major* differences in species occurrence between the earlier and later surveys. We further refined our presence/absence comparison by researching the habitat types used by species that were detected by one effort but not another to determine whether absence could be attributed to the differences in habitat types surveyed.

<u>Temporal Comparison of Species Presence/ Absence</u>
Results for comparing presence/absence of 137 species, spanning 44 years, are as follows:

The distinctly-marked peregrine falcon. Photo Credit: © Robert Shantz.

Table 4.10.3-1. Reference conditions used to assess birds.

Indicator	Measure	Good	Moderate Concern	Significant Concern
Species Occurrence	Temporal Comparison of Species Presence/ Absence	We considered condition good if all or nearly all of the species recorded during early surveys/observations in the park (especially during the breeding season and in similar habitat types) were recorded in the 2005-2015 breeding season surveys by NCPN.	Condition is of moderate concern if several bird species recorded during early surveys in the park (especially during the breeding season and in similar habitat types) were not recorded during 2005-2015 NCPN surveys (particularly if the species had previously been considered common at the park).	Condition is of significant concern if a substantial number of species recorded during early surveys in the park (especially during the breeding season and in similar habitat types) were not recorded during 2005-2015 NCPN surveys (particularly if the species had previously been considered common at the park).
	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 park, meaning that the park provides important habitat for these species and contributes to their conservation.	A small number of species of conservation concern occur at the national park.	No species identified as species of conservation concern have been recorded in the national park.
Status of Peregrine Falcon within the Park	Occupancy of Territories	During the most recent years of monitoring, all or nearly all of the territories historically occupied were occupied by peregrine falcons.	During the most recent years of monitoring, about half of the territories historically occupied were occupied by peregrine falcons.	During the most recent years of monitoring, only a few of the territories historically occupied were occupied by peregrine falcons.
	No. of Young Fledged per Year	No reference conditions were developed for this measure.	No reference conditions were developed for this measure.	No reference conditions were developed for this measure.

- A total of 116 species were recorded during the four survey efforts.
- NCPN/McLaren and White (2016) recorded 96 species or 70.1%.
- Hallows (1982, 1983) recorded a total of 99 species (72.3%) between the two surveys, 79 of which were the same between both years.
- Gerstenberg (1972) recorded 32 species or 23.4% of the species.

Of the 32 species detected by Gerstenberg (1972), all but two species were recorded during the 2005-2015 NCPN surveys (but were recorded by Hallows during 1982 and 1983). These two species were European starling (*Sturnus vulgaris*) and great horned owl (*Bubo virginianus*). The first species is non-native, but also requires more open areas than those surveyed by NCPN. The second species (a nocturnal one) would not necessarily be expected to be vocalizing during the NCPN daytime surveys.

We then combined the lists of species recorded during the Hallows (1982) and Hallows (1983) surveys for our temporal presence/absence comparison, but note that the two lists were very similar to one another even though the latter included the non-breeding season. There were 19 species recorded by Hallows, including the European starling and great horned owl, that were not detected during the 2005-2015 NCPN surveys (Table 4.10.4-1). Of the 17 remaining species shown in the table, we considered only five species to be potentially detectable during NCPN surveys based on habitat alone, but when combined with the NPSpecies abundance category of ‘common,’ only

Table 4.10.4-1. Species reported by surveys predating NCPN long-term bird monitoring program that have not been detected during the 2005-2015 NCPN surveys at Bryce Canyon NP.

Common Name	Scientific Name	Abundance [1]	NPS Tags [1]	Expected During NCPN Survey?
Band-tailed Pigeon	*Patagioenas fasciata*	Rare	Migratory	No - migratory
Black-throated Sparrow	*Amphispiza bilineata*	Rare	Breeder	Yes
Common Nighthawk	*Chordeiles minor*	Uncommon	Breeder	No - different habitat
European Starling [2]	*Sturnus vulgaris*	Uncommon	Breeder	No - different habitat
Golden-crowned Kinglet	*Regulus satrapa*	Rare	Resident	Yes
Great Horned Owl	*Bubo virginianus*	Uncommon	Breeder	No - nocturnal
Green-winged Teal	*Anas crecca*	Uncommon	Breeder	No - different habitat
Killdeer	*Charadrius vociferus*	Uncommon	Breeder	No - different habitat
Lazuli Bunting	*Passerina amoena*	Rare	Breeder	Yes
Lincoln's Sparrow	*Melospiza lincolnii*	Rare	Resident	No - different habitat
MacGillivrays Warbler	*Oporornis tolmiei*	Occasional	Breeder	No - different habitat
Northern Pintail	*Anas acuta*	Uncommon	Migratory	No - migratory
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*	Uncommon	Breeder	No - different habitat
Red-winged Blackbird	*Agelaius phoeniceus*	Common	Breeder	No - different habitat
Rufous Hummingbird	*Selasphorus rufus*	Common	Breeder	Yes
Sharp-shinned Hawk	*Accipiter striatus*	Uncommon	Resident	Yes
Song Sparrow	*Melospiza melodia*	Uncommon	Breeder	No - different habitat
Townsend's Warbler	*Dendroica townsendi*	Occasional	Migratory	No - migratory
Wilson's Warbler	*Wilsonia pusilla*	Rare	Migratory	No - migratory

[1] Category / designation from NPSpecies (NPS 2017a).

[2] Non-native species.

Sources: Gerstenberg (1972), Hallows (1982), Hallows (1983).

one species, rufous hummingbird (*Selasphorus rufus*), was considered to be detectable. Because the NCPN surveys were conducted in the park's two main habitat types, it is not surprising that Hallows (1982 and 1983) recorded additional species (given his surveys were conducted in most habitat types throughout the park).

It's also important to note that the rufous hummingbird was not recorded in any of the 12 NCPN parks during the 2005-2015 annual surveys (McLaren and White 2016). Information provided by Hallows (1982) indicated the species was observed in multiple habitats, was occasional (i.e., a few noted every year), and was a summer resident. It may simply be that this species does not occur in high numbers in the areas sampled by NCPN within the park, and so has gone undetected. Cornell Lab of Ornithology (2017) indicates that this species breeds to the north of Utah and would occur within the national park vicinity during the migratory season (especially after July). Although, this is a species that has been listed as of conservation concern, which is discussed in more detail under the conservation of concern measure.

The NCPN surveys from 2005-2015 have recorded 17 native species that were not reported by the previous surveys of Gerstenberg (1972) and Hallows (1982, 1983) (Table 4.10.4-2). The breeding range maps for these species were examined to see if the park was near the northern edge of their ranges, potentially suggesting the influence of climate change. Bewick's wren (*Thryomanes bewickii)* was the only species showing Bryce Canyon NP at the northern edge of its range.

Some of the other possible reasons for new detections include Witmer et al. (2014) documentation of the increase and expansion of cedar waxwing (*Bombycilla cedrorum*) populations during the last 20 years over much of North America. They cited factors such as an "increase in edge habitats conducive to fruiting trees and shrubs, especially as farmlands regenerate to forests; the planting of fruiting trees and shrubs in rural and urban areas; and, perhaps, the reduction of hard pesticides in many forms of agriculture." Habitat openings have also favored the expansion of American crows (*Corvus brachyrhynchos*), although

Table 4.10.4-2. Seventeen species detected only during NCPN 2005-2015 surveys at Bryce Canyon NP.

Common Name	Scientific Name	Distribution Relative to Park
American crow	*Corvus brachyrhynchos*	Range not in park
American goldfinch	*Carduelis tristis*	Southern edge of year-round; non-breeding
Bewick's wren	*Thryomanes bewickii*	Northern edge of year-round
Bullock's oriole	*Icterus bullockii*	Breeding
Cedar waxwing	*Bombycilla cedrorum*	Non-breeding
Common yellowthroat	*Geothlypis trichas*	Breeding
Downy woodpecker	*Picoides pubescens*	Year-round
Gambel's quail	*Callipepla gambelii*	Year-round (limited)
Lark sparrow	*Chondestes grammacus*	Breeding
Northern harrier	*Circus cyaneus*	Year-round (southern edge)
Northern mockingbird	*Mimus polyglottos*	Breeding
Orange-crowned warbler	*Vermivora celata*	Breeding (limited)
Tree swallow	*Tachycineta bicolor*	Breeding (southern edge)
Turkey vulture	*Cathartes aura*	Breeding
Veery	*Catharus fuscescens*	Range not in park
Wild turkey	*Meleagris gallopavo*	Year-round
Yellow warbler	*Setophaga petechia*	Breeding

their distribution currently does not include the park. Another newly detected species, Gambel's quail (*Callipepla gambelii*), is known as a "boom-and-bust" species, with reproductive rates that fluctuate markedly from year to year (Gee et al. 2013).

Although not used to assess temporal presence/absence of species, in Table 4.10.4-3 we listed the species that represented the greatest proportion of detections (based on the average annual number of detections for each species) during the 2005-2015 NCPN annual breeding season surveys. The top 12 species recorded within pinyon-juniper habitat, sage shrubland habitat, or overall resulted in a total of 20 species.

Table 4.10.4-3. Proportion of the most commonly detected species during NCPN 2005-2015 surveys at Bryce Canyon NP.

Pinyon-Juniper	Sage Shrubland	Overall
Spotted towhee (8.7%)	Vesper Sparrow (20.5%)	Vesper Sparrow (13.7%)
Plumbeous vireo (6.8%)	Western Meadowlark (7.9%)	Western Meadowlark (5.3%)
Grace's warbler (6.2%)	Mountain Bluebird (6.7%)	Mountain Bluebird (4.7%)
Blue-gray gnatcatcher (5.0%)	Chipping Sparrow (4.7%)	Chipping Sparrow (4.5%)
Dusky flycatcher (4.7%)	Brewer's Sparrow (4.3%)	Grace's Warbler (3.7%)
Yellow-rumped warbler (4.6%)	Green-tailed Towhee (3.7%)	Western Tanager (3.6%)
Virginia's warbler (4.5%)	American Robin (3.6%)	Plumbeous Vireo (3.3%)
Chipping sparrow (4.1%)	Western Tanager (3.5%)	Yellow-rumped Warbler (3.2%)
White-breasted nuthatch (3.9%)	Yellow-rumped Warbler (2.5%)	Spotted Towhee (3.0%)
Black-throated gray warbler (3.9%)	Grace's Warbler (2.5%)	American Robin (3.0%)
Western tanager (3.9%)	Northern Flicker (2.3%)	Brewer's Sparrow (2.9%)
Pygmy nuthatch (3.5%)	Violet-green Swallow (2.3%)	Green-tailed Towhee (2.9%)

The pinyon-juniper and sage shrubland habitat types shared four of the same most commonly detected species (chipping sparrow [*Spizella passerina*], western tanager [*Piranga ludoviciana*], yellow-rumped warbler [*Setophaga coronata*], and Grace's warbler [*Setophaga graciae*]). Note that this table is not suggesting that the other top species (eight for each habitat type) were not recorded in the other habitat type during NCPN surveys. Each of the 20 most detected species during NCPN surveys were recorded during at least two of the previous survey efforts (e.g., Gerstenberg (1972), Hallows (1982, 1983).

Finally, 21 (or 15.3%) of the bird species considered to be present at the park have not been recorded during any of the bird surveys. Of these species, almost half (47.6%) utilize habitats other than the pinyon-juniper or sage shrublands and may also be very limited in range relative to the park. An additional three species are nocturnal so would not likely be detected by NCPN surveyors. Two species exhibit characteristics that make them difficult to detect, such as secretive and quiet behavior and nesting during the late winter months instead of during the typical breeding season. And finally, three of the species' distributions are not located within Bryce Canyon NP (Cornell Lab of Ornithology 2017). The three species that remain included the Red-naped sapsucker (*Sphyrapicus nuchalis)*, Scott's oriole (*Icterus parisorum)*, and white-crowned sparrow (*Zonotrichia leucophrys)*. None of these three are listed as species of conservation concern. In fact, the white-crowned sparrow has been extensively studied due to its wide distribution and abundance over much of its range (Chilton et al. 1995).

In conclusion, based on our temporal comparison between the 116 species recorded during at least one of the bird survey efforts and examining the habitat and behavioral characteristics of the remaining 21 species not detected during surveys, there are no obvious concerns for species presence/absence in the national park. We consider this measure to be in good condition, with medium confidence. Our confidence rating is primarily due to the differences between the survey efforts used for the comparison. However, confidence in the NCPN survey data itself is high.

Presence of Non-native Species

Only two (1.5%) of the 137 species considered to be present in the park are non-native. They are the European starling and house sparrow (*Passer domesticus*). The European starling population in North America is estimated to be more than 200 million, representing one of the most successful avian introduction to North America (Cabe 1993). It competes exceptionally well for nest cavities and negatively impacts many native cavity-nesting species (Cabe 1993). Similar to the European starling, the house sparrow is also widespread throughout North America. It is opportunistic and an aggressive competitor, and frequently displaces native songbirds and other endemic species such as bluebirds, woodpeckers, and robins.

The European starling was recorded at Bryce Canyon NP during the 1972, 1982, and 1983 surveys but not during NCPN's 2005-2015 surveys. This may be due to the fact that European starlings require relatively open and disturbed areas, which aren't abundant throughout the park relative to its total acreage. While the house sparrow is on the park's species list, it hasn't been recorded during any of the four survey efforts. While no native species is ideal, it is unrealistic. Instead, these two non-native species do not appear to be abundant based on the results from the survey efforts, and habitat for the starling is limited.

We consider the condition of the absence of non-native birds to be good, with medium confidence. The confidence level rating is based on the fact that the starling's habitat isn't the focus of the park's long-term bird monitoring program. Trend is unknown.

Presence of Species of Conservation Concern

Of the 137 species evaluated for current resource condition of birds at Bryce Canyon NP, 30 (21.9%) are listed as species of conservation concern on one or more conservation lists (Table 4.10.4-4). Ten species have not been recorded during the four survey efforts but are considered to be present in the park. Twenty-two of these species were detected during two or more of the four survey efforts, including 20 species recorded by NCPN. In fact, Bewick's wren and veery (*Catharus fuscescens)* were only recorded during NCPN surveys, although Bryce Canyon NP is located at the northern edge of the Bewick's wren range and the veery's distribution currently does not include the park (Cornell Lab of Ornithology 2017).

The reason we included the presence of species of conservation concern measure is because Bryce Canyon NP can potentially contribute to their protection. Of the 20 species detected during the NCPN surveys, 11 were detected in five or more of the years, with most of the 11 having been recorded in nine to eleven of the years. In fact, five of the conservation species of concern, black-throated gray warbler (*Dendroica nigrescens)*, Brewer's sparrow (*Spizella breweri)*, Grace's warbler (*Setophaga graciae)*, mountain bluebird (*Sialia currucoides)*, and Virginia's warbler (*Vermivora virginiae*) were five of the 20 most detected species recorded by NCPN (refer to Table 4.10.4-4). However, the rufous hummingbird, which is on NABCI's 2016 Watch List and on PIF (2017) Yellow Watch List, although not in BCR 16, which is why it's not indicated as such in Table 4.10.4-4, has not been detected during NCPN surveys.

In summary, none of the 30 species of conservation concern were listed on the USFWS' threatened,

Table 4.10.4-4. Breeding bird species of conservation concern at Bryce Canyon NP.

Common Name	Federal [1]	State [2]	U.S. Fish and Wildlife Service		NABCI [3]	Partners in Flight National Conservation Strategy [4]		Designation from NPS (2017a); and whether recorded in 2005-2015 (per McLaren and White 2016)
	USFWS	UDWR	Region 6	BCR 16	2016 Watch List	BCR 16 CC	BCR 16 RC	Occurrence
American three-toed woodpecker	–	WSC	–	–	–	–	–	Present
Band-tailed pigeon	–	–	–	–	Yellow	–	–	Present
Bewick's wren	–	–	X	–	–	–	–	Present; NCPN survey
Black-chinned sparrow	–	–	–	–	Yellow	X	–	Present
Black-throated gray warbler	–	–	–	–	–	–	X	Present; NCPN survey
Brewer's sparrow	–	–	–	X	–	–	X	Present; NCPN survey
Cassin's finch	–	–	X	X	Yellow	X	X	Present; NCPN survey
Clark's nutcracker	–	–	–	–	–	–	X	Present; NCPN survey
Common nighthawk	–	–	–	–	–	–	X	Present
Common poorwill	–	–	–	–	–	–	X	Present; NCPN survey
Evening grosbeak	–	–	–	–	Yellow	–	–	Present; NCPN survey
Golden eagle	–	–	X	X	–	–	X	Present; NCPN survey
Grace's warbler	–	–		X	–	–	–	Present; NCPN survey
Gray vireo	–	–	X	X	Yellow	X	X	Present; NCPN survey
Juniper titmouse	–	–	–	X	–	–	–	Present; NCPN survey
Lazuli bunting	–	–	–	–	–	–	X	Present
Loggerhead shrike	–	WSC	X	–	–	–	X	Present
Long-eared owl	–	–	–	–	Yellow	–	–	Present
Mountain bluebird	–	–	–	–	–	–	X	Present; NCPN survey
Northern goshawk	–	CAS	–	–	–	–	–	Present; NCPN survey
Olive-sided flycatcher	–	–	–	–	Yellow	X	X	Present; NCPN survey
Peregrine falcon	–	–	X	X	–	–	–	Present; NCPN survey
Pinyon jay	–	–	X	X	Yellow	X	X	Present; NCPN survey
Prairie falcon	–	–	X	X	–	–	X	Present; NCPN survey
Rufous hummingbird	–	–	–	–	Yellow	–	–	Present
Sage sparrow	–	–	X	–	–	–	X	Present
Sage thrasher	–	–	X	–	–	–	–	Present; NCPN survey
Veery	–	–	X	X	–	–	–	Present; NCPN survey
Virginia's warbler	–	–	–	–	Yellow	X	–	Present; NCPN survey
Willow flycatcher	–	–	X [5]	X [5]	–	–	–	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; FE = Federally Endangered

[3] NABCI- 2016 Watch List: Yellow = Yellow List

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

[5] Listing is for a non-ESA-listed subspecies or population of willow flycatcher.

Note: X = Present.

endangered, or candidate species lists. Three of the species were on the Utah Sensitive Species List (UDWR), with two listed as wildlife species of concern and one as a conservation agreement species. There were 15 species identified by USFWS as having the greatest conservation need at a USFWS Regional or BCR geographic scale (USFWS 2008); twelve were listed for the region, and 11 were listed for the BCR (seven were on both lists). Ten species were on NABCI's 2016 Watch List, including the aforementioned rufous hummingbird. And finally, 17 of the bird species of conservation concern were listed by PIF as either CC or RC (recall we did not include the stewardship categories). Six of the species were listed as CC species, and 15 species are listed as RC species (four were on both lists).

Bryce Canyon NP provides undisturbed habitat for many of the species of conservation concern and several are the most commonly detected species in the park. For these reasons, we consider the condition for this measure to be good, with high confidence. The trend in condition is unknown.

Peregrine Falcon: Occupancy of Territories

Over the last eight years from 2009-2016, monitoring of peregrine falcon occupied territories was conducted. The monitoring methods and objectives were similar, although there were some differences in 2015 and 2016. Most of the data sources used to assess the condition of this measure explicitly reported whether territories were occupied or not, but in a few cases, we had to make this determination based on the information available in the report. We attempted to distinguish between instances when monitoring indicated that territories were occupied according to the formal definition of "occupied territory," as compared to when peregrine falcons were observed at the territories without evidence of pairs or breeding activity. In some instances this was difficult because the reporting language in the annual reports differed. Thus, we reported whether one or more peregrines were observed in the territories, followed by confirmed occupancy shown in parentheses in Table 4.10.4-5.

Use of the historic territories within the national park has been fairly consistent over the recent years. Some territories have been occupied in nearly every year (e.g., Paria Point), and four of the five territories were occupied in the majority of the eight years. The Sheep/Swamp Creek territory was occupied in at least three of the years. In addition to use of the historic territories, monitoring efforts have reported on four newer territories, with three of them recently reported in 2015 and 2016 (Silent City, Tropic Canyon, and

Table 4.10.4-5. Detections and occupancy of peregrine falcons in territories from 2009-2016.

Territories	Territory Name	2009	2010	2011	2012	2013 [1]	2014 [1]	2015	2016 [2]
Historic	Paria Point	X-Yes	X-Yes	X-Yes	X-Yes	X-Yes	X-Yes	X-Yes	X
	Yovimpa Point	X-Yes	X-Yes	X-Yes	X-Probably [4]	X-Yes	Absent	X-Yes	–
	Farview / Willis Creek	X-Yes [3]	X-Yes	X-Yes	X-Yes	X-Yes	Absent	–	X
	Sheep / Swamp Creek	Absent	X-Yes	X-Yes	Absent	Not Surveyed	n/a [6]	X-Yes	X
	Inspiration Point	X-Yes	X-Yes	X-Yes	X [5]	Absent	X-Yes	X-Yes	–
Newer	Silent City	–	–	–	–	–	–	X-Yes [8]	X
	Tropic Canyon	–	–	–	–	–	–	X-Maybe	–
	Fairyland / Boat Mesa	–	–	Absent	–	X-Yes	X-Yes	–	–
	Water Canyon [7]	–	–	–	–	–	–	X-Yes	X

[1] Data source for this year was the corresponding FY Wildlife Report to the Chief of Resource Management and Visitor Protection of Bryce Canyon NP.

[2] The annual report from 2016 (Burman 2016) provided fewer details (compared to past years) as to whether territories were considered "occupied" by pairs; therefore, we just noted whether peregrines were detected in the territories.

[3] NPS (2011) reported that territory occupancy was confirmed in 2009, but they also reported "that a pair was never documented."

[4] Chiu and Haas (2012) reported territory was probably occupied.

[5] Peregrine falcons were observed in 2012 at Inspiration Point, but territory status was unknown.

[6] Although it was not stated in the report, "N/A" probably means that the location was not surveyed in 2014.

[7] Location was about 3 km south of where Highway 12 enters the northwest corner of the park in Water Canyon (Salganek and Anderson 2015).

[8] It was unclear from Salganek and Anderson (2015) whether this was the same report of birds that were in the Inspiration Point area.

Note: X = Present.

Part of the Paria Point peregrine falcon territory at Bryce Canyon NP. Credit: NPS.

Water Canyon; Salganek and Anderson 2015, Burman 2016).

The revised protocol used in 2015 and 2016 led to somewhat less information on peregrine falcon reproduction, but the greater areal coverage of the surveys led to the observation of falcons in these newly-identified territories. Additionally, the annual report from 2016 (Burman 2016) provided fewer details (compared to past years) as to whether territories were considered "occupied" by pairs; therefore, we just noted whether peregrines were detected in the surveyed territories. No monitoring for the peregrine falcon was conducted in 2017 (Dr. Mark Graham, Supervisory Biologist, Bryce Canyon NP). As a result, we relied more heavily on the most recently collected comprehensive information, which was recorded during 2015.

We consider occupancy to be in good condition based on the fairly consistent use of territories, especially during the most recent years of monitoring. Furthermore, we would not necessarily expect every territory to be occupied every year. For example, a study in Colorado found that 77% of females and 83% of males used the same breeding territory in successive years (Enderson and Craig 1988 as cited by Luensmann 2010). Also, recent monitoring efforts in the park in 2015 and 2016 led to the identification of "new" territories. We have high confidence in the measure, although we recognize that there have been some inconsistencies and variations in monitoring efforts over the period examined. The trend appears unchanging at this time.

Peregrine Falcon: No. of Young Fledged per Year

Figure 4.10.4-1 shows the known number of fledged peregrines observed from 1982 to 2016. We created this figure using numbers reported in NPS (2011d) and

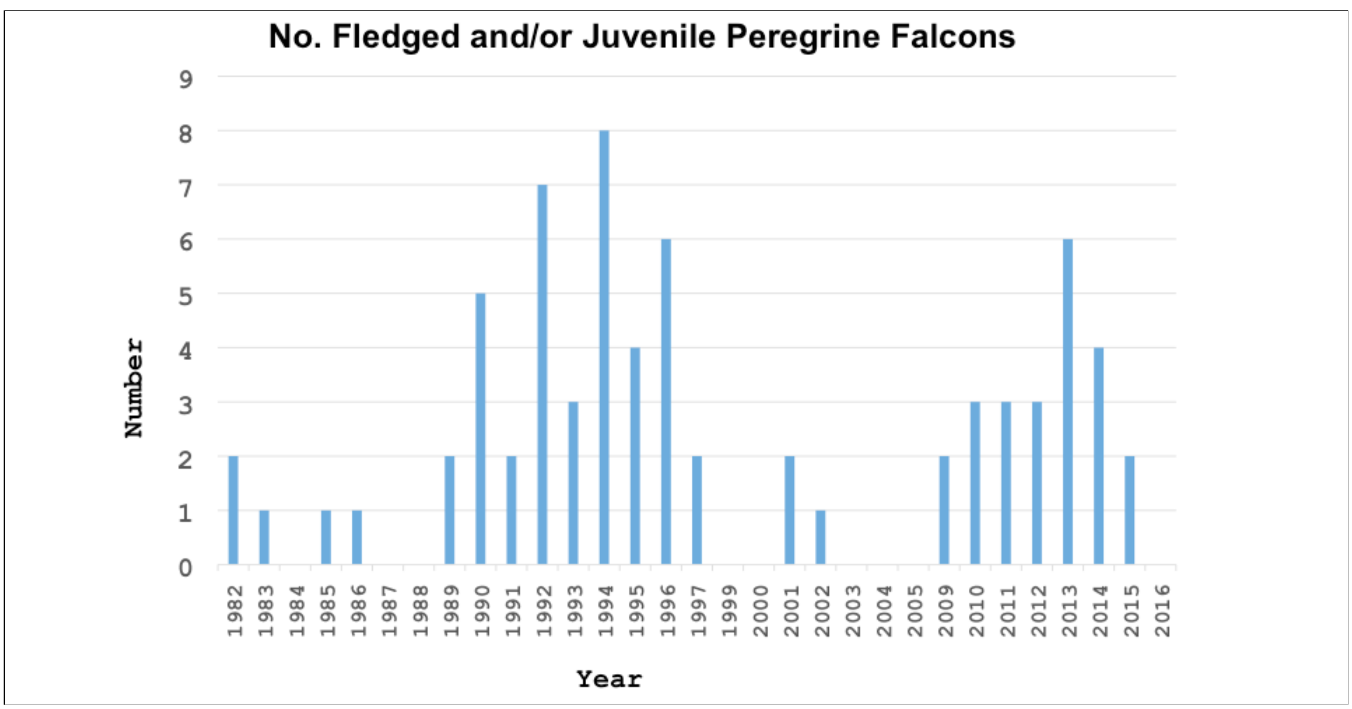


Figure 4.10.4-1. Number of fledged and/or juvenile peregrine falcons at Bryce Canyon NP, 1982-2016. Adapted from NPS (2011).

using information contained in the individual annual monitoring reports. We presented the figure as the number fledged and/or number of juveniles observed (rather than as just the number fledged) because it was unclear from some of the recent annual monitoring reports exactly what was being reported (e.g., the age/stage of the young peregrines).

The counts in the figure represent a minimum number of young observed during monitoring each year. Note that where years are missing, surveys were not conducted (i.e., 1998, 2006-2008), except for 2016. The reported number of fledged peregrine falcons observed from 1982 to 2016 varied from 0 to 8. The highest number of eight young and/or juveniles were recorded in 1994.

NPS (2011d) also presented the number of peregrines fledged per eyrie from 1982-2010, and these numbers varied from 0 to about 2.2. The 1984 Peregrine Falcon Recovery Plan (USFWS 1984) proposed a goal of 1.25 young/pair (Flower 2011). Further, Flower (2011) pointed out that rates of productivity averaging between 1.0 and 2.0 young per occupied territory are typical of expanding or stable populations (references in White et al. 2002 as cited by Flower 2011). However, it should be noted that the similar data issues discussed regarding the total number of young fledged and/or juveniles observed hold true for the number fledged per eyrie (because some nest sites or juveniles could have gone undetected in years with less thorough surveys).

The information used to assess the condition for this measure represents a minimum number of birds fledged or juveniles for a given year and because the survey efforts varied over the years, we assign a condition and trend status of unknown, with low confidence.

Overall Condition, Trend, Confidence Level, and Key Uncertainties

We used two indicators, with a total of five measures, (summarized in Table 4.10.4-6) to assess the condition for breeding birds in Bryce Canyon NP. The 137 species included in this evaluation were based on four survey efforts and on species accounts in the park's NPSpecies list.

The species occurrence indicator, with its three measures, was weighted more heavily to determine an overall condition of good, with medium confidence. This is due to the fact that the peregrine falcon is only one species and is no longer listed as endangered, therefore, not as high of a concern. Also, the confidence levels for measures ranged from low to high, but the temporal comparison of birds presence/absence measure was assigned a medium confidence level and assigned to the overall confidence level. While an overall trend cannot be determined at this time, the NCPN bird monitoring program was designed to provide data on population trend(s) for most of the diurnal, regularly-occurring, breeding landbird species that utilize low-elevation riparian, pinyon-juniper and/or sage shrubland habitats. 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, nine of which occur at Bryce Canyon NP. Six of these, Bewick's wren, black-throated gray warbler, canyon wren (*Catherpes mexicanus)*, dusky flycatcher (*Empidonax oberholseri)*, mountain bluebird, sage sparrow (*Amphispiza belli)*, and white-throated swift (*Aeronautes saxatalis*), with linear or log-linear trends, exhibited population declines. Four of these six species were listed as species of conservation concern in Table 4.10.4-4.

The juniper titmouse (*Baeolophus ridgwayi*) and dusky flycatcher initially showed an increase in population density followed by a decrease in later years. The gray vireo was the only species that exhibited a log-linear increase in population density (McLaren and White 2016), although Partners In Flight (2017) lists this species as vulnerable due to its small range or population and moderate threats.

According to McLaren and White (2012), "as additional years of data accumulate, trend analysis will become less sensitive to short-term fluctuations in population density and long-term trends underlying annual fluctuations will be revealed."

Some of the key uncertainties in this assessment are due to the differences in the various survey efforts used for the species occurrence indicator, especially due to potential differences in the habitat types sampled, the time of day sampled, and the season sampled. Similarly, for the status of peregrines indicator, there have been differences in the monitoring methods

Table 4.10.4-6. Summary of birds indicators, measures, and condition rationale.

Indicators of Condition	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Species Occurrence	Temporal Comparison of Species Presence / Absence		A comparison between the species observed during three surveys from the 1970s/1980s and the 2005-2015 surveys by the NCPN resulted in no obvious concerns for species occurrence. Some differences in species observed may have been due to differences in habitats surveyed, as well as time of day or year. We consider condition to be good. Trends are unknown, and confidence is medium.
	Absence of Non-native Species		Only two species are non-native and only one of these, European starling, has been recorded during any of the surveys. The European starling is widespread throughout North America but desired habitat of disturbed, open areas is limited throughout the park. We consider condition to be good, with medium confidence. Trend is unknown.
	Presence of Species of Conservation Concern		Of the 137 species of birds evaluated, 30 are listed on one or more government/ organization lists of conservation concern. Condition for this measure is good, as the national park provides important conservation of terrestrial habitat for a number of these species in particular need of conservation. Trends are unknown, and confidence in the assessment is high.
Status of Peregrine Falcon within the Park	Occupancy of Territories		Occupancy of the known, historic peregrine falcon territories within the park over the last eight years has been fairly consistent. Four of the five territories were occupied in the majority of the eight years. The other territory was occupied during at least three of the years. We consider condition to be good, with an unchanging trend over this short timeframe. We have high confidence in the measure, but there has been some variation in monitoring efforts among the years.
	No. of Young Fledged per Year		The reported number of young fledged from 1982 to 2016 varied from 0 to 8, with the number per eyrie varying from 0 to 2.2. However, because survey and monitoring effort varied significantly over the time period, no conclusions about trends in reproductive success can be made. Therefore, condition and trend are unknown, and confidence is low.
Overall Condition, Trend, and Confidence Level			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 park's bird comparison between the species observed during three surveys from the 1970s/1980s and the 2005-2015 surveys by the NCPN resulted in no obvious concerns for species occurrence, including non-native species. The occupancy of peregrine falcon territories has remained relatively consistent, although survey and monitoring efforts have varied over the years. Overall, we rated the condition of birds as good, with an unknown trend and medium confidence level.

between the different years. This was especially true for the peregrine falcon occupancy of territories measure in 2015 and 2016 compared to 2009-2014. For the number of young fledged/year measure, there was considerable variation in monitoring effort over the 1982-2016 period.

Threats, Issues, and Data Gaps

There are threats that are common to many bird species, including birds that occur within Bryce Canyon NP. 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). 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). Also, across the U.S., free-ranging domestic cats may be responsible for as many as one billion bird deaths each year (Wildlife Society 2011, Loss et al. 2013).

In Bryce Canyon NP, concerns have been expressed for disturbance to nesting peregrine falcons from noise (e.g., Flower 2011). Helicopters flying low over the park have been described as being of particular concern (Flower 2011). Additionally, the 2015 and 2016 annual monitoring reports mention potential human disturbance to nesting falcons from the construction of guest facilities, roadways, and parking lots within the park (Salganek and Anderson 2015, Burman 2016). While such disturbances are of concern to this species, these disturbances can affect other bird species as well. Another potential source of disturbance to peregrine falcons and other birds is unmanned aircraft flying over the park, but these overflights are prohibited from the park except as approved by the Superintendent (NPS 2017b).

Adverse impacts of human disturbance on raptor territory and resulting nest failures and territory abandonment have been documented in the scientific literature (e.g., Hickey 1942 and 1969, Bond 1946, Steenhof 1998 all as cited by Burman 2016). To protect peregrine falcon nesting and foraging grounds, a buffer area can be used. Resource managers at Bryce Canyon NP had been using a 1.6 km radius (1 mi radius) buffer area surrounding nests and occupied territories as a protection zone (Salganek and Anderson 2015, Burman 2016). However, the park recently adopted use of a 0.8 km-radius (0.5 mi-radius) protection zone, following recent guidelines from the Colorado Division of Wildlife (and adopted by the U.S. Forest Service; Salganek and Anderson 2015, Burman 2016). This buffer area is especially important to exclude human encroachment during the breeding season (from March 15 to July 31; Klute 2008 as cited by Salganek and Anderson 2015).

As mentioned previously, acoustic monitoring in historic peregrine falcon breeding territories, as well as behavioral observations of nesting peregrines, was conducted in 2009 and 2010 (NPS 2011a). Acoustic monitoring was also conducted at various locations within the park in 2011-2013, with some of the locations possibly near peregrine falcon territories. The behavioral observations made during more than 100 hours (2009-2010) included no records of peregrine falcons "reacting severely" to overflights (NPS 2011a). There was one report of a falcon potentially reacting to an overflight (propeller plane at an unknown distance) by vocalizing within the nest cavity for two minutes; this was considered a moderate reaction. However, there were two issues that may have affected the study results; the first was that there was difficulty in seeing birds during overflights, and the second was that aircraft activity was limited over the two study years (NPS 2011a). During both years, helicopter tours were not operating. However, commercial helicopter and fixed-wing tours have operated frequently over the canyon for decades, and park staff have observed helicopters below the rim and near peregrine territories. Furthermore, the number of air tours has increased over the last several years. In 2013 there were 385 air tours reported for the park, but in 2016 there were 455 reported air tours (NSNSD, E. Brown, acoustical resource specialist, e-mail communication, 27 March 2017). This still only represents 12-15% of the more than 3,100 allowable air tours in the park.

Since there are more than 50 air tours in the park per year, the Federal Aviation Administration (FAA) requires the NPS to develop an air tour management plan (FAA 2016). Some of the sites monitored in this study were established to develop this plan; however, it has not been completed to date and the park may instead develop a voluntary agreement with commercial air tour operators, which functions similarly to an air tour management plan but can be completed in a shorter amount of time (E. Brown, NSNSD acoustical resource specialist, e-mail message, 24 March 2017).

During the acoustic monitoring study, data were obtained for 16 sites, both frontcountry and backcountry (NPS 2011a). Across all of the sites, human-caused sounds increased the existing ambient sound levels more during the day than during the night (NPS 2011a). At all of the backcountry locations, the predominant extrinsic sound source was aircraft (especially jets). Aircraft were also the predominant source of extrinsic sounds in frontcountry monitoring sites, except for two (Farview and Sheep/Swamp), which were located next to the park road (and in which vehicle noise was dominant). Predominant natural sounds across the sites were wind and birds. We refer the reader to the soundscape assessment in this report for a detailed discussion of the park's soundscape, which also provides background information on responses of wildlife, including birds, to noise.

Additional data gaps include information pertaining to non-breeding birds, breeding birds in habitats other than pinyon-juniper or sage shrubland, or species that are nocturnal and would not likely be vocal during NCPN's annual surveys. For example, the bald eagle (*Haliaeetus leucocephalus*) and black rosy-finch (*Leucosticte atrata*) are considered to be winter residents at Bryce Canyon NP and on several conservation of concern lists. However, they have not been recorded during any of the previous survey efforts; therefore, condition status is unknown. Also, species like Bewick's wren, a species of conservation concern at Bryce Canyon NP, has all but disappeared east of the Mississippi River and has declined in western parts of its range (Kennedy et al. 2013). Its decline may be attributable to competition with the European starling and house sparrow, pesticides, and severe winters. However, without additional information about the European starling at the park, it's impossible to know its impact on Bewick's wren and other native birds.

4.10.5. Sources of Expertise

We consider the NCPN as a source of expertise, and their annual monitoring data provided the basis from which current condition of breeding birds was evaluated. Subject matter review experts are listed in Appendix B. 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.

4.11. Utah Prairie Dog (*Cynomys parvidens*)

4.11.1. Background and Importance

Prairie dogs, which are found only in North America, are burrowing rodents that belong to the squirrel family. They are diurnal and live in colonies, or towns that sometimes contain thousands of individuals and can extend for miles. There are five species of prairie dogs (four in the U.S.), with separate ranges (Hoogland 2006). The Utah prairie dog (UPD) (*Cynomys parvidens*; Figure 4.11.1-1) is the westernmost species and occurs only in southwestern and central Utah (U.S. Fish and Wildlife Service [USFWS] 2012). The UPD was federally listed in 1973 as endangered then was reclassified in 1984 as threatened (USFWS 2012). As of 2018, the UPD is still protected under the Endangered Species Act of 1973 (39 FR 1171) on all lands, regardless of ownership.

Prairie dogs are an important component of the ecosystems they inhabit and are considered a keystone species. Across their range, they show a preference for using swale-type habitat that provides access to moist herbaceous vegetation even during drought conditions (Collier 1975 as cited by USFWS 2012). Through their foraging and clipping of vegetation, as well as the mixing of subsoil and topsoil during burrow excavations, prairie dogs affect the redistribution of minerals and nutrients, encourage penetration and retention of moisture, and affect plant species composition (Kotliar et al. 2006). Although they reduce the biomass of vegetation, they may also increase the digestibility, protein content, and productivity of grasses and forbs at colony sites (especially relatively new colony sites; Kotliar et al. 2006).

UPDs remain underground in their burrows during the winter for about four to six months of the year (USFWS 2012). Within colonies, prairie dogs live in family groups called clans, and a clan generally consists of one adult male, several adult females, and offspring of each gender. Female prairie dogs have one litter of young per year, with litter sizes ranging from one to seven pups. The UPD breeding season is generally mid-March through early April, and gestation length is typically 28-30 days. Young emerge from the natal burrow at five to six weeks of age, usually by early to mid-June.

The historical distribution of the UPD included parts of Utah's Beaver, Garfield, Iron, Kane, Juab, Millard, Piute, Sanpete, Sevier, Washington, and Wayne Counties (Collier 1975 as cited by USFWS 2012). Populations began to decline in the 1920s with the onset of control programs, and by the early 1970s, the species was no longer found throughout large portions of its historical range (USFWS 2012), decreasing to an estimated 3,300 animals living in fewer than 40

Figure 4.11.1-1. Utah prairie dog at Bryce Canyon National Park. Photo Credit: © Kevin Doxstater.

colonies (Collier and Spillett 1972 as cited by USFWS 2012). The UPD is currently found in the following counties: Beaver, Garfield, Iron, Kane, Piute, Sevier, and Wayne but is believed to occupy less than 10% of its historic range (Utah Prairie Dog Oversight Group [UPDOG] 2016).

Within these counties, UPDs are distributed in three areas, which the USFWS has designated as recovery units (RUs): the Awapa Plateau RU, the Paunsaugunt RU, and the West Desert RU (USFWS 2012, 2015). Recovery units are special units of a listed species (e.g., Utah prairie dog) that is geographically or otherwise identifiable and is essential to the conservation and recovery of the species (USFWS 2012). Bryce Canyon National Park (NP) is located within the Paunsaugunt RU.

Bryce Canyon National Park is also part of a population focus area (PFA) for the Utah prairie dog. Population focus areas are landscape-level management areas located within each of the three RUs that are most suitable for supporting persistent Utah prairie dog populations (UPDRIT 2013). The Utah prairie dog Recovery Implementation Team focuses many conservation efforts for the species in the PFAs, ensuring consideration of metapopulation dynamics, habitat and population connectivity, habitat quality, and biogeographical variables (UPDRIT 2013).

UPDs flourished in Bryce Canyon NP during the first half of the 20th century but disappeared due to sylvatic plague (*Yersinia pestis*), loss of habitat due to drought and overgrazing, and extirpation efforts (Collier 1975 as cited by Salganek et al. 2015). After the species was federally listed, at least three early reintroductions were made to bring UPDs back to the national park— in 1974, 1975, and 1984-1988 (Salganek et al. 2015). Although most of the individuals from the first two efforts abandoned their transplant locations, individuals from the third effort remained within the park (Salganek et al. 2015). Since 1978, 12 UPD occupied areas (either colonies or clans) have been identified throughout Bryce Canyon NP but never have all 12 been active during the same year. Bryce Canyon NP's meadow habitat supports its UPD population and is identified by the park as an 'Other Important Resource and Value' (NPS 2014a), supporting a diverse assemblage of plants and animals.

4.11.2. Data and Methods

We used three indicators, population status, colony persistence, and quality of occupied meadows, with a combined total of six measures, to evaluate the current condition of Bryce Canyon NP's UPD. We begin our discussion with a summary of the UPD colonies (and clans) within Bryce Canyon NP. For annual reporting purposes, the Utah Division of Wildlife Resources (UDWR) assigns colony IDs (consisting of a number and letter) for areas individually counted (i.e., mapped habitat). We have identified 12 unique IDs for Bryce Canyon NP's colonies or clans, which are presented in Table 4.11.2-1 and shown in Figure 4.11.2-1. USFWS (2012) defines clans, colonies, and mapped habitat as follows:

> Clans – Clans are social groups consisting of an adult male, several adult females, and their offspring. These groups maintain geographic territorial boundaries, although they will use common feeding grounds.
>
> Colonies – Colonies are groups of animals with associated mounds, burrows, and food resources. These units are genetically similar and vulnerable to local catastrophes including

Table 4.11.2-1. Utah prairie dog colonies or clans at Bryce Canyon NP.

USFWS ID	Colony/Clan Name	Colony/Clan Spring Count Size and 2017 Status (last year active)
215a	Dave's Hollow West and Sewage Lagoon	Small & Inactive (2016)
215b	Dave's Hollow East and Historic Housing	Small & Active (2017)
215c	Mixing Circle Junction	Small & Active (2017)
215d	Mixing Circle	Medium & Active (2017)
215e	North Mixing Circle	Small & Inactive (2000)
215h	Sunset Point Road	Small & Active (2017)
218e	East Creek Meadow (Upper, Lower, & Well Site)	Medium & Active (2017); *size is based on NPS data only*
218b	Rainbow Gate	Small & Active (2017)
218f	Sheep Creek Trail	Small & Inactive (2005)
218c	Paria View West	Small & Inactive (2005)
218d	Paria View East	Small & Inactive (2005)
213a	Fairyland	Small & Inactive (2001)

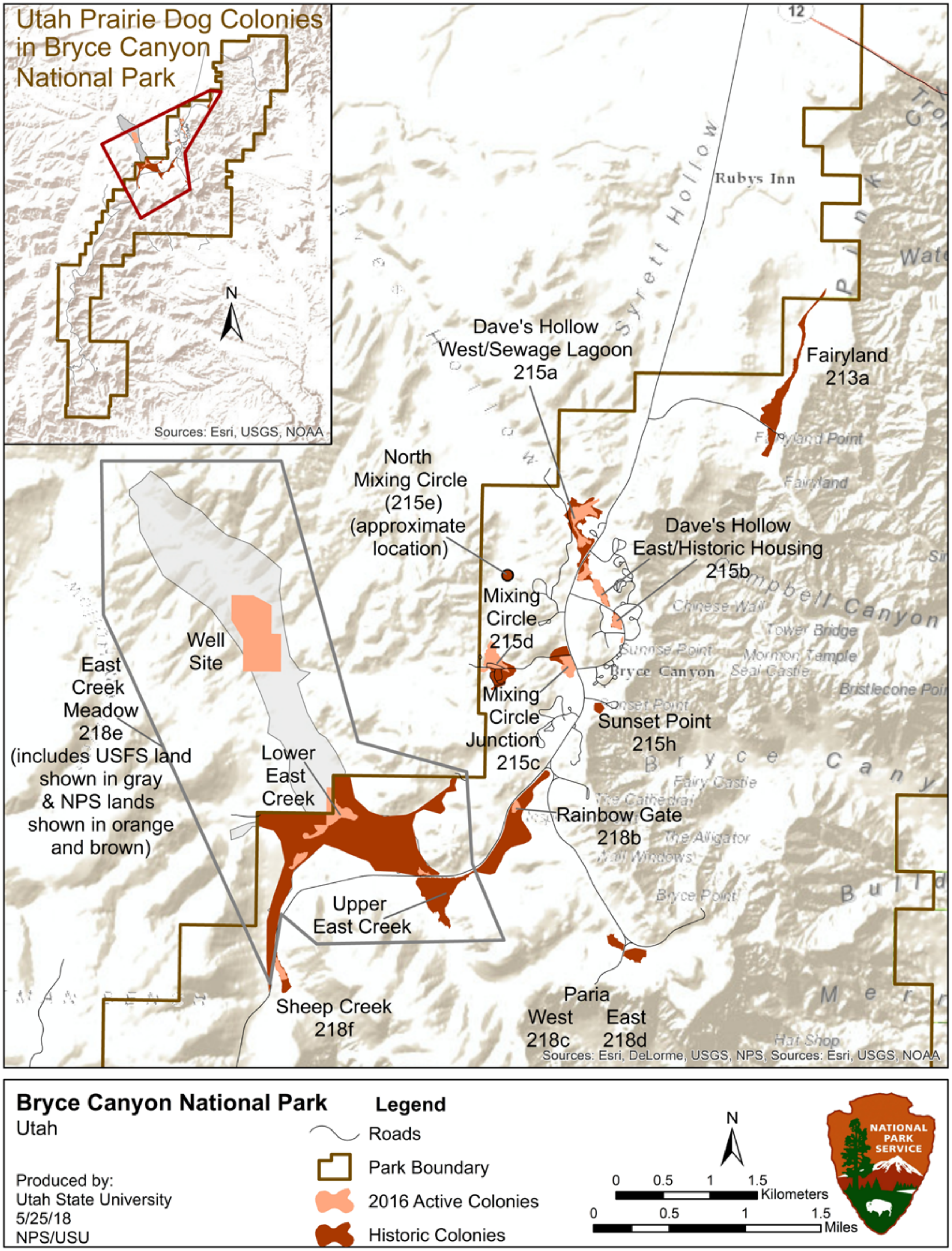


Figure 4.11.2-1. Locations of UPD colonies in Bryce Canyon NP, both historic and active in 2016. Note that colonies were not mapped in 2017 and an approximate location of the North Mixing Circle Colony is shown.

disease outbreaks. Colonies may contain one or several clans.

Mapped Habitat– any and all areas within the species' range that were mapped since 1972 as currently or historically occupied by Utah prairie dogs. Official maps of Utah prairie dog habitat are maintained by UDWR and updated annually

Three different size classes differentiate UPD colonies: large (an average annual spring count of more than 50 adult individuals over the previous 10 years), medium (an average annual spring count between 20 and 50 adult individuals during the previous 10 years) or small (an average annual spring count less than 20 individuals) (UPDRIT 2013). The USFWS (2012) and UPDRIT (2013) provide a discussion about UPD colony size and the importance of size to the persistence of the population:

> "....Large colonies, or colonies with an average annual spring count of more than 50 adult individuals, have a 95% probability of persisting for 200 years. Small colonies by themselves—or colonies with an average annual spring count less than 20 individuals—on the other hand, contribute less to the long term persistence of prairie dogs (see Appendix G in USFWS 2012). Therefore, we recommend focusing management efforts on achieving and sustaining large (>50 spring count) or medium (>20 spring count) colonies in each PFA (Appendix G in USFWS 2012).
>
> Though small colonies by themselves contribute less to the long term persistence of prairie dogs in demographic terms (Appendix G in USFWS 2012), it is recognized that they may play a pivotal role in the maintenance of prairie dog metapopulations across the landscape. Small colonies and small colony clusters can serve as "source" populations to adjacent large colonies following a population crash due to factors such as disease, drought, and predation. Small colonies and small colony clusters may serve as intermediate populations that occupy marginal habitat, but assist with dispersal between larger populations...."

In addition to the number of adults within each colony, the distance between colonies is also of significance to the persistence of the UPD population. According to UPDRIT (2013),

> "a population cluster is a set of at least two colonies that are connected by some level of migration but largely operate independently. The species persistence is dependent, in part, on the ability of Utah prairie dogs to move between colonies and colonization may be aided by proximity to larger colonies (Ritchie and Brown 2005). Therefore at least one of the colonies in each population cluster should be either a medium (or a small colony cluster) or a large colony.
>
> To delineate population clusters, we need to consider how far Utah prairie dogs will travel on a daily basis to forage as well as how far they travel to disperse. Foraging distance of prairie dogs within a colony averages 100-250 ft, with maximum 730 ft (222.5m) (Wright-Smith 1978). Most Utah prairie dog dispersal distances are between 528–3,960 ft (161–1,207 m) (Mackley et al. 1988). Thus, colonies should be located at least 730 ft (222.5 m) from each other, yet no more than 3,960 ft (1,207 m) apart to be considered separate colonies within the same population cluster.

For the purposes of our UPD condition assessment discussion, any UPD-occupied areas within Bryce Canyon NP that were closer than 222.5 m (730 ft) were considered to be within the same colony and referred to as clans instead of separate colonies. This is especially important when evaluating the condition of the colony size measure.

<u>Bryce Canyon UPD Colony/Clan Summary</u>
Colonies and clans have been GPSd by Bryce Canyon NP staff, with the most recent mapping effort occurring in 2016. Historic colonies, which USFWS (2012) defines as "any area known to have supported Utah prairie dogs for 5 or more years prior to the current date, but currently unoccupied" have also been mapped. Based on colony proximity and USFWS' definition of historic colony, in 2017 Bryce Canyon NP had five active colonies: Dave's Hollow East (215b), Mixing Circle (215d), Mixing Circle Junction (215c), East Creek Meadow (218e), which included Rainbow Gate

(218b) (for this assessment considered to be a clan), and Sunset Point Road (215h). Of the six remaining, three (i.e., North Mixing Circle (215e), Paria View East (218d), and Fairyland (231a)) were considered historic colonies in 2017 and two (i.e., Paria View West (218c), and Sheep Creek (218f)) were considered historic clans (within 222.5 m of Paria View East and East Creek Meadow, respectively so were evaluated as part of those colonies). Finally, Dave's Hollow West (215a), is located within 222.5 m (730 ft) of Dave's Hollow East so both are considered to be one colony, although in 2017, Dave's Hollow West was inactive during the spring count but later in the year, UPD activity was observed (Mark Graham, Supervisory Biologist, Bryce Canyon NP, pers. comm.). Hereafter, colonies or clans will be referenced by their names only.

Spring Count/Estimated Population

Annual prairie dog monitoring has been conducted within Bryce Canyon NP since 1977 to count the number of adults (only) within each colony, which is then used to estimate the annual population (Salganek et al. 2015, Burman et al. 2017). The exact timing of the spring count varies between years but should be completed before pups are up, and continues until numbers reach a plateau. The highest count within each colony is used as the annual spring count (USFWS 2012) and has most often occurred in May (NPS 1990-2017 UPD dataset). Multiple observers conduct surveys at each known colony using binoculars and spotting scopes. The following paragraph, taken from Salganek et al. (2015), describes the count process:

> According to USFWS protocol, surveys were conducted by scanning a colony or section of colony, depending on size, and counting prairie dogs, at least three times or more, until count reaches a consensus. Counts were conducted on sunny days with 0-20% cloud cover, and wind speeds less than three on the Beaufort Scale (<13 MPH). Colonies were approached slowly, and where possible counts were conducted from the tree line surrounding the occupied meadow in order to minimize stress on the prairie dogs and discourage retreat of prairie dogs underground. Counts occurred in mid-mornings (9am-11am) or in later afternoons (3pm-5pm). Population counts are done early in the season (optimal time varies slightly from year-to year) when it is still possible to distinguish between adult prairie dogs and juvenile prairie dogs, thus allowing a count of both age groups. USFWS protocol calls only for counts of animals determined to be adults; however, juveniles were recorded for park records.

Annual population estimates are calculated using a formula that accounts for the adult population estimate derived from spring counts and the estimated reproduction:

> Population Estimate = [(2 × Spring Adult Count) × 0.67 (proportion of adult females) × 0.97 (proportion of breeding females) × 4 (average number of young per breeding female) 4] + (2 × Spring Adult Count) (USFWS 2012).

The population size estimations include accounting for the proportion of breeding females in the population and the average number of young per breeding female, as well as the fact that only 40-60% of individual prairie dogs are above ground at a given point in time (USFWS 2012). According to USFWS (2012), "spring counts and population estimates do not provide an accurate population census but are indicative of long-term trends." We use Bryce Canyon NP's annual UPD count dataset (1978-2017) to evaluate the estimated population over time to determine an overall trend for Bryce Canyon's UPD population.

Roadkill Mortality Rate

The well-traveled main park road in Bryce Canyon NP bisects many of the UPD colonies (Salganek et al. 2015), and while park managers have implemented a number of actions to decrease potential UPD mortalities, roadkill remains a serious threat. Park staff record the number of UPD roadkills annually using a carcass report form following the park's protocol for UPD carcass disposition and reporting (NPS 2017c). Park law enforcement officers patrol the roads frequently and promptly remove any roadkilled UPDs then report the information to the park's Resource Management Division.

We evaluate Bryce Canyon NP's UPD roadkill mortality rate condition relative to the total estimated population within the park using two time periods: 1978-2017 and 1991-2017. The second time span, 1991-2017, was selected since roadkill counts were not reported for a total of seven years between 1978 and

1990, thus it represents a more consistent reporting record, although likely represents minimum counts.

Colony Counts

Both the USFWS (2012) and the Utah Prairie Dog Recovery Implementation Team (UPDRIT) (2013), which is now known as the UPDOG, recognize the importance of colonies whose spring counts exceed 20 adult UPDs and are within proximity for dispersion. We evaluate the colony counts measure using Bryce Canyon NP's annual count dataset by colony (1990-2017), and the GIS dataset of active and historic colonies to determine distances between colonies versus clans. For this condition assessment, if any portion of the historic colony boundaries intersected, they were considered to be within the required distance to be reported as one colony. We evaluate colony counts using a 5-year (2013-2017) and 10-year (2008-2017) average annual count in addition to the percentage of years (1990-2017) that colony sizes were small, medium, or large.

Plague Presence/Absence

While high annual variability in the UPD population exists, site-specific numbers can be significantly affected by disease outbreaks from plague (USFWS 2012). And while close proximity of larger colonies to smaller colonies may support the persistence of the species, it may also aid the spread of plague (USFWS 2012). Plague has been identified as one of the two primary threats to UPDs, and the routine management of plague is considered to be one of the most important management actions for the recovery of the species (USFWS 2012). While Bryce Canyon NP staff has compiled records from 1992-2017 of pesticide application to burrows to kill fleas that may carry the sylvatic plague, we only review records from the last three years (2015-2017) to evaluate the condition of this measure at each colony.

Quality of Occupied Meadows

Within Bryce Canyon NP, UPDs primarily inhabit meadow habitat in the northern portion of the park (NPS 2011e, NPS 2016f). The meadows range in elevation from 2,343 m to 2,430 m (7,687 to 7,972 ft; Ikeda and Ironside 2012) and are mainly surrounded by ponderosa pine (*Pinus ponderosa*) forests. Prairie dog colonies are found in shrub/grassland vegetation communities, with example shrubs being *Artemisia* sp. (sagebrush) and *Chrysothamnus* sp. (rabbitbrush), and example grasses being *Poa* sp. (bluegrass) and *Juncus* sp. (rush; Ikeda and Ironside 2012).

NPS personnel developed a UPD habitat restoration 5-year work plan in 2011 in consultation with the USFWS for mitigative purposes (NPS 2011e). The total area targeted for restoration, 70.4 ha (174 ac), occurred within three UPD colonies, Dave's Hollow West (8.9 ha [22 ac]), Mixing Circle Junction (2.4 ha [6 ac]), and East Creek Meadow (59 ha [146 ac]). These areas represent some of the most active and productive colonies within the park. Restoration and habitat improvements included removing non-native invasive species, reducing shrub abundance, and seeding with a native plant mixture to increase forage species.

NPS (2011f) and (2016e) present the results of the vegetation monitoring activities at the three colonies in 2011 and 2016, respectively. Each report briefly described the sampling methods as follows:

> Random location points were generated for each site using ArcMap Random Point Generator. Each point functioned as the origin of a 25 m transect along which percent cover of each functional plant category was sampled using line intercept. The number of points per site was dependent on the site's total area. Due to the large area of East Creek Meadow [ECM], it was divided into four quadrants, and random points were generated for each quadrant to ensure even distribution of sampling over the entire meadow. An average of eight points was surveyed per quadrant at ECM. A total of twelve points were surveyed at Dave's Hollow West and nine points at the Mixing Circle Junction.

Percent Vegetation Cover

Although we present the percent ground cover results for the 2011 and 2016 vegetation monitoring, we only use the data from the 2016 monitoring to evaluate current condition for four functional plant groups: warm season grasses, cool season grasses, forbs, and shrubs. Improvements to the monitoring protocol were made in 2016, thereby, making direct comparisons between the two datasets difficult. We also cross-referenced the park's NPSpecies (NPS 2017a) list to identify non-native plants that were recorded during the vegetation monitoring effort. It should be noted that other vegetation data exist for plots within the park's meadows from the park-wide vegetation mapping project (i.e., Tendick et al. 2011), but those data are from 2005-2007, with a different data collection methodology than the park's vegetation restoration efforts.

Plant Species Diversity

To assess the plant species diversity within Dave's Hollow West, Mixing Circle Junction, and East Creek Meadow, we use the park's 2011 and 2016 vegetation monitoring results (NPS 2011f, 2016e). USFWS guidelines specify a minimum number of native plant species for UPD habitat (i.e., 10), as well as a preferred number of plant species (i.e., >20).

4.11.3. Reference Conditions

The Utah Prairie Dog Final Revised Recovery Plan (USFWS 2012) identifies three primary recovery actions:

> 1) protecting or enhancing occupied or suitable habitats on federal or non-federal lands in a manner that protects and enhances existing prairie dog colonies, restores unoccupied prairie dog habitats, and protects corridors of connectivity between populations;
>
> 2) increasing translocation success; and
>
> 3) managing plague.

Reference conditions for all measures, except the roadkill mortality rate and plague presence/absence, are based on criteria listed in USFWS (2012) and in the *Population Structure for Utah Prairie Dog Recovery* report developed by the UPDRIT (2013). The references for each of the measures in good, moderate concern, and significant concern are presented in Table 4.11.3-1. The vegetation criteria shown in Table 4.11.3-1 for good condition of occupied meadows are based on the most current information available on ideal vegetation conditions for the species (USFWS 2012). These criteria are also recommended for UPD translocation sites, and Bryce Canyon NP personnel have adopted them as targets in their UPD habitat restoration efforts (NPS 2011e, NPS 2016f).

4.11.4. Condition and Trend

Spring Count / Estimated Population

Bryce Canyon NP's annual UPD spring count dataset spans 39 years, ranging from 1978-2017 except for 2003. The Bryce Canyon NP UPD files did not contain any spring colony counts for 2003, but the State of Utah Division of Wildlife Resources was able to provide counts for three colonies. Since the 2003 counts did not include all colonies, they were omitted from this measure. In addition, each management agency (e.g., NPS, USFS, BLM, etc.) is required to report colony counts to the UDWR for UPDs on their lands. One colony within Bryce Canyon NP, East Creek Meadow, is part of a much larger colony that is located on the USFS' Dixie National Forest adjacent to the park. Typically, both the NPS and USFS have conducted their own spring counts within the portions of land owned by each agency except for eight years (1992, 1994-1999, 2002), which included combined UPD counts for the East Creek Meadow Colony. In addition, variability in the counting effort is considered to be quite significant between the two agencies. As a result, those eight years of combined UPD counts represent a higher than actual population for Bryce Canyon NP that is shown in Figure 4.11.4-1, but there is no way to separate the combined counts; therefore, they're included but considered to be a source of uncertainty.

The USFWS (2012) states that "spring adult counts and population estimates provide population trend information, but are not accurate enough to determine actual population numbers." In addition, there is considerable annual fluctuations, and the park's estimated population has fluctuated over time with four cycles of highs and three cycles of lows (Figure 4.11.4-1), which is representative of the range-wide population cycle for UPDs (USFWS 2012).

The most prolific period spanned from approximately 1990-1995, which includes three of the eight years of combined NPS and USFS East Creek Meadow Colony counts, and more recently (2014-2017), UPD counts at the park have resulted in the highest numbers observed over a 12-year period from 2006-2017. Counts were highest in 2015 and 2017 (173 and 141, respectively). The 2016 count (79) was lower, however, the monitoring effort was reportedly less comprehensive compared to previous years so likely represents a lower number than actual (Mark Graham, Supervisory Biologist, NRCA workshop meeting, April 2017.) but is consistent with the lower 2016 total count within the Paunsaguant RU (UPDOG 2016). Overall, the UPD population trend at Bryce Canyon is stable to slightly increasing, which is good,

Table 4.11.3-1. Reference conditions used to assess the Utah prairie dog.

Indicator	Measure	Good	Moderate Concern	Significant Concern
Population Status	Spring Count / Estimated Population	Large annual variability in the UPD population is expected, but overall the population is stable to increasing over the period of record.	Large annual variability in the UPD population is expected, but overall the population is decreasing over the period of record.	Large annual variability in the UPD population is expected, but overall the population is significantly decreasing over the period of record.
	Roadkill Mortality Rate	Roadkill mortality rate is decreasing or stable for a stable or increasing UPD population.	Roadkill mortality rate is increasing for a stable UPD population.	Roadkill mortality rate is increasing for a decreasing UPD population.
Colony Persistence	Colony Counts	The number of colonies with spring counts of > 20 adult UPD remains stable or increases.	No specific reference was developed but conditions do not meet the USFWS (2012) good reference condition specifications.	No specific reference was developed but conditions do not meet the USFWS (2012) good reference condition specifications.
	Plague Presence/Absence	Pesticide is applied at least every other year at active colonies since 2015 and plague is not present.	Pesticide is applied at least every other year at active colonies since 2015 but there are some conflicting management mandates. Plague is not present.	Pesticide is not applied at least every other year since 2015 at active colonies and plague is present.
Quality of Occupied Meadows	Percent Vegetation Cover	Warm season grasses: 1 - 20% ground cover; Cool season grasses: 12 - 40% ground cover; Forbs: 1 - 10% ground cover (perennial, non-noxious); Shrubs: 0 - 8% ground cover and < 10% canopy cover.	Percent cover deviates somewhat from the ideal vegetation parameters shown in the "good" condition column, such as in the number of individual parameters meeting objectives, or in the magnitude of deviation from the "good" range.	Percent cover deviates substantially from the ideal vegetation parameters shown in the "good" condition column, such as in the number of individual parameters meeting objectives, or in the magnitude of deviation from the "good" range.
	Plant Species Diversity (USFWS 2012)	Minimum number of native plant species (i.e., 10) is met, and the number recorded may exceed 20 species (which is preferred).	Minimum number of native plant species (i.e., 10) is not met, but the number occurring is only a few below the minimum.	Minimum number of native plant species (i.e., 10) is not met, and the number occurring is well below 10.

but our confidence is low due to the combined USFS/NPS UPD counts at the East Creek Meadow Colony, reflecting a higher number than actual because of the eight years of combined NPS/USFS spring colony counts.

Another related metric is the 5-year moving average of the estimated population with productivity, which smooths out some of the annual fluctuations (green line shown in Figure 4.11.4-1). For a given year, this metric shows the population average for the year in question and the preceding four years. Over the period of record (1978-2017), the moving average varied between about 352 to 1,244, with a most recent 5-year average (2013-2017) of 793.4 UPDs. The highest moving averages occurred during the early to mid-90s when NPS and USFS counts were combined. The early 90s counts would likely be even higher for subsequent years, but in 1992, 114 UPDs were trapped from within Bryce Canyon NP and relocated to other colonies outside the park (NPS colony history dataset 1992-2017) Trapping and translocating within the park occurred during at least six additional years between 1990-2017, which would have an effect on the population number as well.

A recent USFWS (2015) "status of the species" update reported that the range-wide UPD spring counts fluctuated considerably year to year over the past 30 years, but that long-term trends appear stable to increasing (USFWS 2012), however, the population trend for all UPD recovery units is increasing at a much higher rate than at Bryce Canyon NP, although

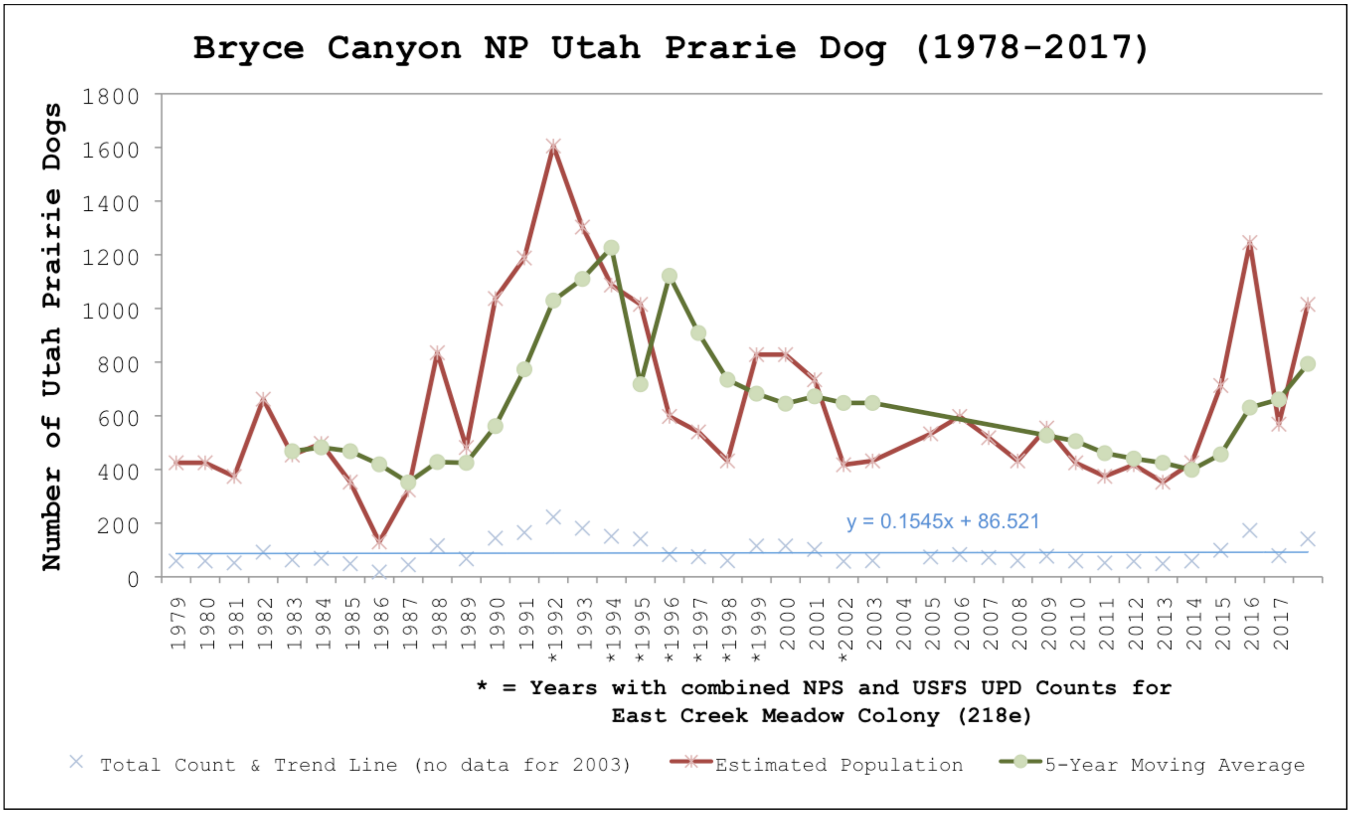


Figure 4.11.4-1. Annual UPD counts (blue) (1978-2017), along with the estimated annual population (with productivity; red line) and the 5-year moving average (green line). Blue line shows a stable to slightly increasing trend based on UPD spring counts. Surveys during 2003 are not included because they were incomplete. The eight years shown with an asterisk represent combined counts for UPDs on USFS and NPS lands in the East Creek Meadow Colony.

this is typical of most federal/protected lands in the UPD recovery area.

Roadkill Mortality Rate

The number of the road-killed UPDs in Bryce Canyon NP has been recorded since 1978, except for seven years (1982, 1984, 1986-1990), and the reporting has been very thorough during the last few years, but in general, roadkill numbers have been likely under-reported in previous years, representing minimum counts (Mark Graham, Supervisory Biologist at Bryce Canyon NP, pers. comm).

The number of UPDs killed by vehicles has varied over the period of record (1978-2017), ranging from a low of one in 2002 to a high of 73 in 1992. The roadkill mortality rate relative to the park's UPD population has ranged from 0.23-12.3%, (mean is 3.15, s = 2.70) with the highest mortality rates occurring during the initial five of the six years of UPD monitoring in the park. The higher mortality rates may reflect a more consistent recording effort during the earlier years when UPD reintroductions were actively occurring at Bryce Canyon NP.

If the roadkill mortality rate is reviewed over a more recent period of record (1991-2017), the UPD mortality rate due to roadkills is increasing (figures are presented in Appendix J). The roadkill number ranged from one in 2002 to a high of 73 in 1992. The roadkill mortality rate relative to the park's UPD population ranged from 0.23-5.6%, (mean is 2.1, s = 0.01).

The higher roadkill rate may be a result of the increased visitation to the park. The number of annual visitors has consistently increased since 1991, with the highest rate of increase of 35.5%, occurring between 2015 and 2016 (NPS Public Use Statistics Office 2018).

While the trends from 1978-2017 for the dataset with and without the combined NPS/USFS counts for East Creek Meadow Colony remained the same (i.e., improving trend), the trends with and without the combined NPS/USFS counts from 1991-2017 were different; one increased and the other decreased. While we know that UPD roadkill under-reporting has occurred consistently and/or randomly over time, the combined annual counts did affect the 1991-2017 trend analysis; therefore, we reported an unknown condition and trend for the roadkill mortality rate measure. However, we believed this analysis and discussion was worth including for future reference since this is an ongoing management issue at the park.

Park managers have taken efforts to minimize prairie dog mortality from vehicles by implementing various protective measures, such as adding stop signs, speed bumps, lowering speed limits, and adding ranger patrols (Salganek et al 2015). Park managers have also made efforts to reduce impacts from park concessions, such as more effectively containing trash and minimizing horse manure left on roads, which attract prairie dogs to roadways. Park staff remove dead prairie dogs from roads to the nearest colony to prevent scavengers, including prairie dogs, from getting struck by vehicles. The park areas with the highest level of prairie dog mortality have varied but include the Mixing Circle Colony in 2008 and 2010 and Dave's Hollow East in 2013-2015, specifically the historic housing area within the colony, (Salganek et al. 2015).

Colony Counts

UPDs have moved into or out of various park meadows since they were reintroduced into Bryce Canyon NP in the 1970s (Ikeda and Ironside 2012). Using UPDRIT's (2013) colony size criteria of small, medium, and large, based on spring annual counts and distances between colonies, we have identified four colonies in Bryce Canyon NP where we evaluate the 5-year (2013-2017) and 10-year (2008-2017) average annual counts and the percentage of years that spring counts were within one of the three size classes (Table 4.11.4-1 and Figure 4.11.4-2).

Of the four active colonies evaluated for this measure, the Mixing Circle Junction Colony has been small (<20 UPDs) 100% of the recording period (1990-2017). The remaining three colonies, Dave's Hollow East and West, Mixing Circle, and East Creek Meadow fluctuated between all three size classes. Both Dave's Hollow East and West and East Creek Meadow varied the most between colony sizes, and Mixing Circle was a medium-sized colony (20-50 UPDs) almost 68% of the time (1990-2017), representing the largest colony consistently over the period of record, which is evident in Figure 4.11.4-2.

The 5- and 10-year annual averages for Dave's Hollow East and West, Mixing Circle, and East Creek Meadow are all within the medium-sized colony spring count range. Of these three colonies, East Creek Meadow has had large spring counts almost 26% of the time over the period of record (1990-2002, 2004-2017, excluding 2003).

However, recall that eight of the years for East Creek Meadow Colony had combined USFS and NPS counts so represent a higher colony count for Bryce Canyon NP's portion of the colony than actual. It also implies that from a biological perspective, East Creek Meadow is a larger colony than just the Bryce Canyon NP portion that is presented in the table and shown in the figure. Evaluating the colony as a whole

Table 4.11.4-1. Utah prairie dog annual spring colony counts at Bryce Canyon NP.

Colony Name	5 year (2013-2017) Average Annual Count (current condition)	10 year (2008-2017) Average Annual Count (USFWS 2012)	Percentage of Years Adult UPDs Counted Were <20 (1990-2017, n=27*/28)	Percentage of Years Adult UPDs Counted Were 20-50 (1990-2017, n=27*/28)	Percentage of Years Adult UPDs Counted Were >50 (1990-2017, n=27*/28)
Dave's Hollow West & Dave's Hollow East	33.4	21.9	63%*	22.2%*	14.8%*
Mixing Circle Junction	9.4	8	100%	0%	0%
Mixing Circle	22.4	24.5	21.4%	67.9%	10.7%
East Creek Meadow: *Lower, Upper, Rainbow Gate, Sheep Creek, Well Site*	44.6	29.3	44.4%*	29.6%*	25.9%*

Sources: Bryce Canyon NP Historic UPD Colonies shapefile and UDWR UPD colony shapefile.

Note: If any or all portions of historic colony boundaries intersected, they were considered to be within the required distances to be reported as the same colony.

*Adult Utah prairie dogs were not counted in 2003 at Dave's Hollow East and West and at East Creek Meadow, therefore, n=27 years instead of n=28.

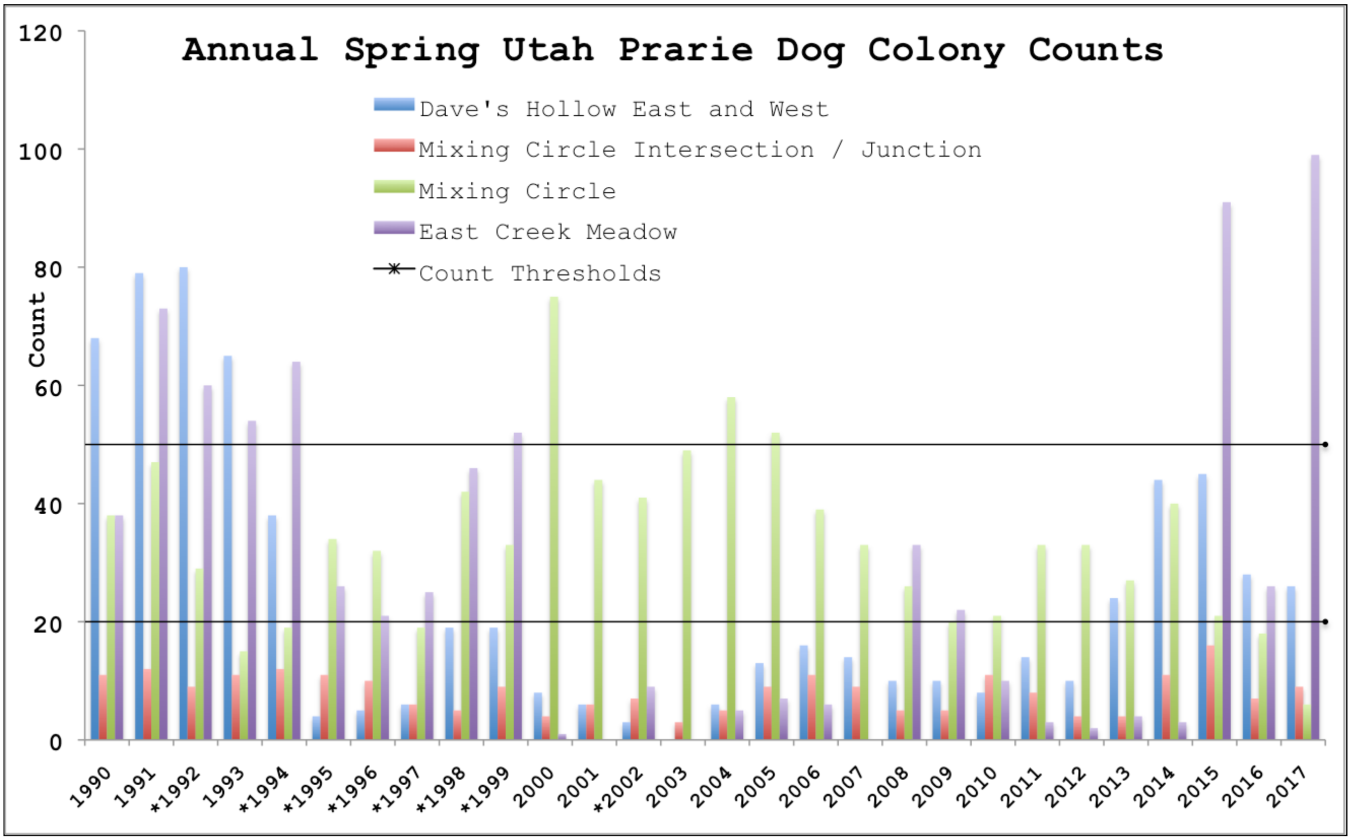


Figure 4.11.4-2. Annual UPD spring counts from 1978-2017 for four colonies, Dave's Hollow East and West, Mixing Circle, Mixing Circle Junction, and East Creek Meadow are shown. Colony size thresholds are shown as three categories on the graph ranging from 0-20 UPDs for small, 21-50 UPDs for medium, and greater than 50 UPDs for large colonies. All colonies are medium except Mixing Circle Junction, which is small.

by combining NPS and USFS UPD counts for all years will likely result in the colony increasing in size for most years.

When evaluating the persistence of a colony based on size, the 5- and 10-year annual averages for three of the four colonies at Bryce Canyon NP are greater than the good reference condition threshold of 20 UPDs. Additionally, the park's UPD meadow habitat is located within drainages, which are long and narrow, likely limiting colony size. Regardless of this potential limiting factor, between 1990-2017, each of these four colonies has been occupied except for one year (2007) when the East Creek Meadow Colony had a spring count of zero. Based on the persistence and spring colony counts, we consider this measure to be in good condition, with medium confidence and an unknown trend based on colony size fluctuations.

Plague Presence/Absence

A pesticide is applied to UPD burrows to kill fleas that may carry the sylvatic plague. Based on a review of park records from 1992-2017, dusting for plague began as early as 1995 at the Mixing Circle Colony. While pesticide application has become more consistent in recent years, it has been relatively sporadic, with Mixing Circle representing the most actively managed colony (i.e., 46% or 12 years since 1992). Beginning in 2015, park staff began dusting colonies every other year to help reduce the fleas from building a resistance to the continued use of the dust, and it is from the 2015-2017 dataset that we evaluate the current condition of plague at Bryce Canyon NP.

In 2015, park staff dusted East Creek Meadow, including the well site portion of the colony, Mixing Circle, and Mixing Circle Junction. In 2016, park staff dusted Dave's Hollow West and Dave's Hollow East. In 2017, the following colonies were dusted with Deltamethrin (Delta Dust): the gas station/historic housing portion of Dave's Hollow East, Mixing Circle Junction, Mixing Circle, Sunset Point Road, Rainbow Gate, Sheep Creek Trail, and the portion of the East Creek Meadow Colony that is within the main park boundary. The reason dusting was repeated in 2016 and 2017 for the historic housing and gas station portions of Dave's Hollow East Colony (versus every other year) is because of the close proximity to visitors and park residents (Mark Graham, Supervisory Biologist, email correspondence, March 2018).

In 2017, park staff dusted colonies that were due to be dusted and either had confirmed UPD presence or had active burrows but unconfirmed UPDs. The Sheep Creek Trail Colony had two active burrow systems but no confirmed UPD sightings, so park staff dusted the colony to ensure protection. All of the other colonies had confirmed UPD during the 2017 counts. Also note that park staff did not dust the well site portion of the East Creek Meadow Colony in 2017 because that site is located within the water capture zones 1 and 2 for the park's public water supply (Mark Graham, Supervisory Biologist, email correspondence, March 2018). The USFS plague management efforts also affect the park's portion of the East Creek Meadow colony.

While conflicting management mandates at the park's well site may become an issue for the East Creek Meadow Colony, one of the largest UPD colonies within the park, based on the fact that a pesticide has been applied at least every other year to active colonies since 2015 and plague is currently absent, we consider this measure to be good, with high confidence and an unknown trend.

Percent Vegetation Cover

The 2011 percent ground cover of the grasses, forbs, and shrubs functional groups in East Creek Meadow, Dave's Hollow West, and Mixing Circle Junction UPD colonies is presented in Table 4.11.4-2. NPS (2011f) did not report results for warm season grasses and cool season grasses separately. However, we summed the USFWS target coverages for the warm and cool season grasses (i.e., 1-20 and 12-40 equals 13-60) to provide a crude comparison. Using this overall target coverage, only East Creek Meadow and Mixing Circle Junction met the target coverage for grasses. In 2011, forbs were within the target coverage range, and the shrub cover exceeded the target range at two of the colonies (East Creek Meadow and Dave's Hollow West).

Based on 2016 vegetation monitoring in the three colonies, the plant functional groups met the target percent coverages in some cases but not in others. For warm season grasses, only the East Creek Meadow Colony met the target coverage (NPS 2016f; Table 4.11.4-3). Likewise, for both cool season grasses and shrubs, only Mixing Circle Junction Colony met the target coverages. The percent cover of forbs in all three colonies was within the target range. However, shrubs

Table 4.11.4-2. Target percent cover of plant functional groups and percent ground cover from 2011 in three UPD colony sites.

Plant Functional Group	Target Coverage (% ground cover)	East Creek Meadow (% Cover)	Dave's Hollow West (% Cover)	Mixing Circle Junction (% Cover)
Grasses	13-60*	15	10	23
Forbs	1-10	8	7	4
Shrubs	0-8	17	16	2
Exotics	n/a	1	1	<1

* USFWS (2012) provides a target coverage for warm season and cool season grasses individually, but NPS (2011) combined these grass types.

Table 4.11.4-3. Target percent cover of plant functional groups and percent ground cover from 2016 in three UPD colony sites.

Plant Functional Group	Target Coverage (% ground cover)	East Creek Meadow (% Cover)	Dave's Hollow West (% Cover)	Mixing Circle Junction (% Cover)
Warm Season Grasses	1-20	2	0	0
Cool Season Grasses	12-40	6	3	26*
Forbs	1-10	4	7	6
Shrubs	0-8	11	9	3

* NPS (2016f) indicates this figure is outside of the target range, but that is because the park report gives a range of 12-14%, which is not consistent with what USFWS (2012) presents.

were higher than targets at Dave's Hollow West and East Creek Meadow in both 2011 and 2016.

From a colony site standpoint, the vegetation at Mixing Circle Junction met three of the four targets (or 75% of the targets); East Creek Meadow met two of the four targets (or 50%); and Dave's Hollow West met one of the four targets (or 25%). NPS (2016f) did not discuss the results of the 2016 vegetation sampling in comparison to the 2011 data, and because different methods were used between the two years, we did not attempt to do so either. Based on our limited analysis using the 2016 data only, we consider the condition of percent vegetation cover to be of moderate concern, with an unknown trend and low confidence, with only one recent year of sampling.

NPS (2016f) noted that based on the 2016 sampling results, more management actions are needed at all three sites. NPS (2016f) also noted that increasing the coverage of warm season grasses in the park's meadows is a challenge due to the difficulty in locating enough seeds within the park to use for seeding the habitat; only two species of warm season grasses (blue grama [*Bouteloua gracilis*] and mountain muhly [*Muelhenbergia montana*]) occur naturally within the park's meadows (NPS 2016f). Also, because the meadow elevations are relatively high (~2,438 m [8,000 ft]) and the summer temperatures are mild, a lower coverage of warm season grasses compared to lower-elevation habitat might be expected (NPS 2011e).

A High Elevation Meadow Restoration Study will be undertaken in 2019 at Bryce Canyon NP to collect information on meadow components such as vegetation, wildlife, soil structure, hydrology, and wetlands, as well as to provide recommendations for mechanical and fire-based treatments of encroaching trees and shrubs, ensuring these disturbances don't provide pathways for invasive plants (NPS 2018). Historic meadow extent will be evaluated using surveys of soils, encroaching tree aging, wetland delineations, historic aerial photographs, aquifer data, and vegetation surveys.

<u>Plant Species Diversity</u>

The number of plant species recorded in each of the three sites in 2011 was above the recommended minimum number and above or close to the preferred number (NPS 2011f; Table 4.11.4-4). However, note that these numbers may include some non-native species. At least four species were reported as occurring in the project areas- smooth brome (*Bromus inermis*), cheatgrass (*Bromus tectorum*), crested wheatgrass (*Agropyrom cristatum*), and spotted knapweed (*Centaurea stoebe*; NPS 2011f). Given the high number of species reported, however, even with the presence of a few non-native species, the minimum target number would have been met. In 2016, the minimum number of species was exceeded for each of the three occupied meadow sites (see Table 4.11.4-5), but it's important to note that the species that were in the sampling plots were used for estimating cover of functional groups and that a complete inventory of the species in each colony location was not conducted. As a result, overall number of species at each colony location is expected to be much higher than the numbers reported.

Based on the 2016 monitoring results and our USFWS (2012) reference conditions, we consider the condition of plant diversity to be good, with an unknown trend. Confidence in the condition evaluation is low due to only having two years of data and different data collection methodologies between both years.

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

The indicators and measures used to assess the condition of the UPD are summarized in Table 4.11.4-6. Overall, we consider the condition of Bryce Canyon's UPD to be in good condition, with low confidence and an unknown trend.

The key uncertainties include a lack of monitoring or thorough monitoring of roadkill numbers in some

Table 4.11.4-4. Species diversity in three UPD occupied meadows.

Year	Minimum # Plant Species	East Creek Meadow	Dave's Hollow West	Mixing Circle Junction
2011	10 (>20 preferred)	54 [1]	45 [1]	20 [1]
2016	10 (>20 preferred)	28 (24 native) [2]	16 [2]	24 (20 or 21 native) [2]

[1] Numbers taken from NPS (2011), but the numbers may include a small number of non-native species.

[2] Numbers obtained from the data file provided by the park (i.e., Eric Vasquez, Bryce Canyon NP).

Table 4.11.4-5. Species recorded at East Creek Meadow, Dave's Hollow West, and Mixing Circle Junction in 2016.

Plant Group	Scientific Name	Common Name	East Creek Meadow	Dave's Hollow West	Mixing Circle Junction
Forbs [1]	*Achillea millefolium*	Western yarrow	–	X	X
	Antennaria rosulata	Breaks pussytoes	X	X	–
	Artemisia frigida	Fringed sagebrush	X	X	X
	Astragalus humistratus var. humivagans	Ground cover milkvetch	–	X	X
	Calyophus lavandulifolius	Lavender primrose	X	–	–
	Calochortus nuttallii	Sego lily	X	–	X
	Castilleja miniata	Scarlet paintbrush	X	–	–
	Chaenactis douglasii	Dusty maiden	X	–	–
	Erysimum capitatum	Pursh's wallflower	X	–	–
	Hymenoxys acaulis	Stemless woolybase	X	–	–
	Iris missouriensis	Rocky Mountain iris	–	X	X
	Linum kingii	Golden flax	X	–	–
	Linum lewisii	Blue flax	X	X	–
	Lupinus argenteus	Silvery lupine	X	–	–
	Oenothera howardii	Bronze evening primrose	–	X	X
	Penstemon caespitosus	Dwarf/mat penstemon	X	X	X
	Phlox pulvinata	Cushion phlox	–	X	–
	Potentilla concinna	Bicrenate cinquefoil	X	X	X
	Tragopogon dubious [2]	Yellow salsify [2]	X	–	X
Grasses [1]	*Achnatherum hymenoides*	Indian ricegrass	X	–	–
	Bouteloua gracillis	Blue grama	X	–	–
	Bromus anomalus	Nodding brome	X	–	–
	Bromus inermis [2]	Smooth brome [2]	X	–	X
	Bromus japonicus [2]	Japanese brome [2]	X	–	–
	Elymus trachycaulus	Slender wheatgrass	–	X	X
	Hesperostipa comata	Needle and thread	X	–	–
	Koeleria macrantha	June grass		X	X
	Poa compressa [2]	Canada bluegrass [2]	X	–	–
	Poa fendleriana	Muttongrass	–	X	X
Shrubs [1]	*Artemisia nova*	Black sagebrush	–	X	–
	Chrysothamnus depressus	Dwarf rabbitbrush	–	–	X
	Gutierrezia sarothae	Broom snakeweed	X	X	X
	Tetradimia canescens	Spineless horsebrush	X	X	–

Source: Eric Vasquez, Bryce Canyon NP.

[1] Growth habit information according to Ikeda and Ironside (2012) Appendix A.

[2] Non-native species.

Note: X = Present.

years, and the uncertainty associated with estimates of the UPD population based on the combined NPS and USFS East Creek Meadow Colony Counts. At this time, we do not have the USFS spring UPD counts to evaluate the East Creek Meadow colony in its entirety.

In addition, there is uncertainty related to having only one year of vegetation data to evaluate the condition of occupied habitat. Also, it is unknown whether vegetation monitoring results for the three colonies are applicable to the remaining active colonies.

Table 4.11.4-6. Summary of Utah prairie dog indicators, measures, and condition rationale.

Indicators of Condition	Measures	Condition/ Trend/ Confidence	Rationale for Condition
Population Status	Spring Count/ Estimated UPD Population		Based on the 1978-2017 annual spring count dataset and population estimates, the UPD population at Bryce Canyon NP appears to be in good condition. The trend is stable, although it fluctuates over time. Even though there is a relatively long period of record, the amount of effort between years and combined USFS/NPS colony counts confound condition interpretation, and as a result, confidence in the rating for this measure is low.
	Roadkill Mortality Rate		The UPD roadkill mortality rate is unknown, with low confidence, due to under-reporting and uncertainties associated with combined NPS and USFS spring counts for the East Creek Meadow Colony. Inconsistent trends resulted from the analysis that is presented in Appendix J.
Colony Persistence	Colony Counts		Based on UPD spring counts, the 5- and 10-year annual average colony counts for three of the four colonies at Bryce Canyon NP are greater than the good reference condition threshold of 20 UPDs. This measure is rated as good, with medium confidence and an unknown trend.
	Plague Presence/ Absence		Each active colony is routinely managed for plague and as of 2017, plague is absent from all UPD locations throughout Bryce Canyon NP. As a result, condition is good, with high confidence and an unknown trend.
Condition of Occupied Meadows	Percent Vegetation Cover		Based on 2016 data, plant functional groups met the target percent coverages in some cases but not in others. For warm season grasses, only one of the three sites met the target coverage; for both cool season grasses and shrubs, only one of the three sites met the target coverages; for forbs, all three sites had percent coverages within the target range. Overall, the sites met the targets 50% of the time. Condition is of moderate concern, with an unknown trend and low confidence.
	Plant Species Diversity		Based on 2016 monitoring, the minimum number of plant species recommended by USFWS (2012) was exceeded for each of the three meadow colony sites. The preferred number was met and exceeded for one site, East Creek Meadow; however, when excluding four non-native species from the list, the number was just below that preferred. Condition for this measure is good with an unknown trend and low confidence.
Overall Condition, Trend, and Confidence Level			When combining all measures, we consider the overall condition of UPDs within the park to be in good condition, with a low confidence level. The overall trend is unknown at this time given the uncertainties highlighted throughout the assessment.

Threats, Issues, and Data Gaps

USFWS (2012) reports a number of existing threats across the UPD's range– habitat loss and fragmentation, plague, unauthorized take, a changing climate, and disturbance from recreation and other land uses. Within Bryce Canyon NP, prominent threats appear to be from vehicle traffic on roads, sylvatic plague, and lack of habitat connectivity.

As visitation increases, associated traffic increases (and therefore the potential for increased UPD mortalities). For example, visitation in 2017 was 8.7% higher than in 2016. In 2016 visitation was 35.5% higher than in 2015, and in 2015 visitation was 21.6% higher than in 2014 (NPS Public Statistics Office 2018). According to park personnel, GPS locations and associated roadkill data within problem areas would be beneficial to the park's management efforts to minimize this threat.

Sylvatic plague also remains a threat to UPDs within the park, as well as across their range and is identified as one of the primary threats to the species (USFWS 2012). The disease may also affect many different mammal species, including people. UPDs have little or no immunity to the disease and may experience high mortality rates during outbreaks— even as high as 90% or greater. The bacterium can also lead to chronic issues that can limit UPD population growth rates (USFWS 2012). A primary method used to control the sylvatic plague in prairie dog colonies has been the dusting of burrows within colonies to kill fleas. According to USFWS (2012), dusting treatments are generally used within colonies that experience plague outbreaks and with large colonies that are at risk for outbreaks. The control method is labor intensive (USGS 2012), and some flea species may be developing resistance to the insecticide(s). Scientists have been researching the use of a vaccine for the plague that can be administered through oral bait (USGS 2012, USFWS 2012). Results of a 2013-2015 study of the vaccine bait in all four prairie dog species found that survival rates were higher on plots treated with the vaccine than on plots receiving a placebo during plague outbreaks (Rocke et al. 2017). This may prove to be a more effective and efficient way of managing plague.

The focus of the UPD recovery efforts is on creating and maintaining medium and large-sized colonies because of their contribution to the persistence of the species (UPDRIT 2013). While small colonies contribute to the overall population structure, they are more vulnerable than the larger colonies. The reality is that Bryce Canyon NP has habitat and size limitations that will likely prevent them from having standalone large colonies. According to UPDRIT (2013), population clusters should contain at least one medium (20-50 count) or large (>50 count) colony.

According to Mark Graham, Supervisory Biologist at Bryce Canyon NP, a possible explanation emerges as to why the Fairyland, Paria View West, Paria View East, and possibly Sheep Creek colonies did not persist; they were too far away from the other colonies given their small size (<20). The park's draft UPD Stewardship Environmental Assessment (NPS 2015c) lists connectivity distances as follows: Fairyland 1.9 km (1.2 mi), Paria West 2.2 km (1.4 mi), Paria East 2.5 km (1.6 mi), and Sheep Creek 1.3 km (0.81 mi). The other colonies' connectivity distances are much less than 1.2 km (0.75 mi) (0.2 - 0.4 km / 0.1-0.25 mi). If park staff manages the UPD colonies as a population cluster, they will need to create habitat connectivity between the smaller colonies for their persistence or with colonies on adjacent lands. It also points to a strategy that if they want Fairyland, Paria View (East and West), and Sheep Creek Trail colonies to persist, habitat connectivity needs to be established, linking colonies between them and the rest of the population cluster or to adjacent colonies outside the park's boundary.

Long-distance dispersals of up to 6 km (3.73 mi) (Brown et al. 2011 as cited in UPDRIT 2013) have been documented for Utah prairie dogs. Thus, population clusters should be managed within 6 km (3.73 mi) of at least one other population cluster, lowering the probability of population crashes because of an increased capability for individual animals to disperse and occupy vacated habitats or "rescue" crashing colonies (UPDRIT 2013). A list of these colonies adjacent to Bryce Canyon NP was provided to park staff in an Excel file.

Another threat to UPDs is the quality of vegetation within colonies. UPDs will avoid areas where shrub species dominate, and will eventually decline or disappear in areas invaded by brush (Collier 1975, Player and Urness 1982). Open habitats are important for foraging, visual surveillance to escape predators, and intraspecific interactions (Player and Urness 1982). Grasses and forbs appear to be the preferred food items for prairie dogs, and they appear to select particular forage species rather than choosing foods based on availability (Crocker-Bedford and Spillett 1981). Vegetation quality and quantity are important in helping UPDs survive hibernation, lactation, and other high nutrient demand times (Environmental Defense 2007). Plant species richness is correlated with increased weight gain, higher juvenile to adult ratios, and higher animal densities (Crocker-Bedford and Spillett 1981, Ritchie and Cheng 2001).

While efforts by park staff have been made to restore UPD habitat within three occupied colonies by increasing warm season grasses and decreasing the cover of shrubs, as well as treating non-native invasive plants (e.g., Salganek et al. 2015, NPS 2016e), Ikeda and Ironside (2012) noted that black sagebrush differed significantly in height in occupied and unoccupied meadows. The researchers suggested that the UPDs were either browsing the black sagebrush to maintain a low height, or selecting habitat with a low shrub height. It has been suggested that this shrub may have been one of the drivers of the UPD decline (Collier and Spillett 1975 as cited by Ikeda and Ironside 2012). Ikeda and Ironside (2012) recommended that efforts to improve the quality of meadow habitat for UPDs within the park should include decreasing the height and cover of black sagebrush in active UPD colonies. However, within the three colonies that are monitored for vegetation cover and diversity, only Dave's Hollow West contains black sagebrush.

Finally, a draft UPD stewardship plan and environmental assessment (NPS 2015c) has been developed to help guide future management activities at Bryce Canyon NP. The location of some of the UPD colonies within the park (or perhaps conversely, the location of services and operations) is such that it presents management conflicts and increases park staff workload due to USFWS Section 7 consultations. Consultations are required by federal agencies before management actions can be implemented that have the potential to affect the federally listed species. If it's determined that an action may affect the species, then a lengthier formal consultation process is required, which includes drafting a biological assessment or other review. The length of the formal consultation review period can sometimes preclude implementing the needed action, which may create secondary management issues.

4.11.5. Sources of Expertise

The assessment was based on UPD and habitat restoration monitoring efforts conducted by park personnel. Bryce Canyon NP Supervisory Biologist, Mark Graham, provided an extensive review of the park's Utah prairie dog spring count datasheets. This information was used to update the charts with the most accurate data. Bryce Canyon NP Vegetation Crew Lead, Eric Vasquez, provided all vegetation monitoring data. Patty Valentine-Darby, biologist and writer authored the first assessment draft, focusing on the vegetation measures, and Kim Struthers, NRCA team coordinator and biologist, authored the second draft, focusing on the UPD population measures. Both are from Utah State University. Subject matter review experts are listed in Appendix B.

NRCA meeting participants at Bryce Canyon NP. Photo Credit: USU.

Chapter 5. Discussion

Of the 11 natural resources evaluated for Bryce Canyon NP's NRCA, both viewshed and geology are cited in the park's purpose statement. Several of the remaining resources evaluated are listed as significant and/or fundamental resource statements, emphasizing the importance of maintaining or improving resources conditions and the underlying processes that are most important to the park. The overall condition ratings for the 11 topics and their relationship to the park's core components (i.e., purpose, significance, and fundamental), as identified in its Foundation Document (NPS 2014a), 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 per effort. 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.

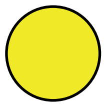
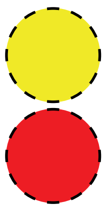
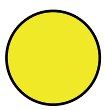
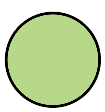
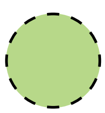
In preparation of Bryce Canyon NP's NRCA report, it became very evident the wealth of natural resource information that has been gathered over the years at the park. Unfortunately, much of the data has not been synthesized or analyzed and remains in hard copy and digital formats, without integration. In addition, as new staff arrive, there's no summary of previous efforts (either standard operating procedures or summaries) that can be referenced to assist managers with orientation. Furthermore, the limited resource management staff and myriad of competing management issues for a park the size and popularity as Bryce Canyon, creates a major burden on staff and resources. The unprocessed data represents a major data gap and a systematic file review (both paper and digital) and synthesis would serve all resources at the park, including natural, operational, and personnel.

Table 5-1. Natural resource condition summary for Bryce Canyon NP.

Core Component: Purpose	Core Component: Significance	Core Component: Fundamental	Resource	Overall Condition	Overall Condition Discussion
X	X	X	Viewshed		Viewsheds are an important part of the visitor experience at national parks, and features on the visible landscape influence a visitor's enjoyment, appreciation, and understanding of a particular region. At Bryce Canyon NP, few non-contributing features are visible within its viewsheds. The composite viewshed shows that views to the west and north are blocked, which is a result of natural features (i.e., vegetation). The housing and road density analyses show that the region surrounding the park is mostly rural, but is susceptible to possible future extractive uses that could alter the viewshed quality. Currently, the viewshed condition at Bryce Canyon NP is good with an unknown trend. Confidence is medium.
–	X	X	Night Sky		Overall, we consider the night sky at Bryce Canyon NP to be good with an unknown trend and medium overall confidence level since the most recent data were collected 10 years ago. The all-sky light pollution ratio, zenith sky brightness, and the Bortle Dark Sky measures are in good condition. The conditions of the remaining two measures are unknown since thresholds have not been established by the NPS Night Skies Program.
–	X	X	Soundscape		We consider the soundscape at the national park to warrant moderate to significant concern. Noise levels are greater during the day than at night, and noise is high, especially from vehicles in the frontcountry and jets in the backcountry. Although anthropogenic noise dominates the park's soundscape, the proportion of time decibels above reference conditions is relatively low, especially for sounds greater than 45 dBA. Lastly, the geospatial model indicates moderate concern across the park. Trend in sound levels has deteriorated and confidence in the condition rating is high.
–	X	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 park's air quality is influenced largely by activities occurring outside its boundary. Haze, ozone levels for human health, and wet deposition of nitrogen and mercury are of moderate concern. Wet deposition of sulfur is good and improving; however, the condition for vegetation ozone level is of significant concern.
X	X	X	Geology		The erosive forces of water and wind are responsible for the park'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 moderate to significant concern. Anthropogenic damage to paleontological resources is low, largely due to the inaccessibility of the canyon. Rockfalls and slope failures, however, have been an issue along the rim. Confidence is medium since data are limited, and trend could not be determined.
–	–	–	Water Quality		Overall, water quality at Bryce Canyon NP is in good condition with an unknown trend. Confidence in the condition rating is high. Virtually all attributes and analytes are within the range that is considered good. *E. coli* and pH occasionally exceed the standards. Only two wastewater contaminants exceeded limits, but occurred during only one site visit. These chemicals have not been detected on subsequent site visits.

Notes: Purpose, significance, and fundamental resources and values statements are listed in NPS (2014a) and if applicable are denoted by 'X.'

Table 5.1 continued. ***Natural resource condition summary for Bryce Canyon NP.***

Core Component: Purpose	Core Component: Significance	Core Component: Fundamental	Resource	Overall Condition	Overall Condition Discussion
–	–	X	Upland Vegetation		Ponderosa pine savannas and pinyon-juniper woodlands are considered in good condition with improving trends for the former forest type; however, there aren't sufficient data to assess the condition of ponderosa pine-Douglas-fir forest. Mixed coniferous forests warrant moderate concern, with a deteriorating trend. The reintroduction of fire has had beneficial effects on vegetation in the park, especially ponderosa pine savannas. However, three of five trends are deteriorating. Thus, we did not assign an overall trend. Overall condition is of moderate concern, and confidence in the condition rating is medium.
–	–	X	Unique Vegetation		The condition of unique and distinctive vegetation in Bryce Canyon NP warrants moderate to significant concern based on two of the three measures, but confidence in all three measures is low due to insufficient data. NPS vegetation mapping data were collected >10 years ago, and rare plant survey plots exhibited several issues regarding sampling design and loss of plots over time. Trend could not be determined.
–	–	–	Non-native Invasive Plants		Although several non-native plants at Bryce Canyon NP are of particular concern (e.g., smooth brome and cheatgrass), most are not problematic at the park. In addition, the total infested area is low with most infestations located in upland meadows. Nearly all measures were assigned medium confidence. This is because, with the exception of NCPN upland data, the datasets used in this assessment are more than five years old. Trend could not be determined.
–	–	X	Birds		The park's bird comparison between the species observed during three surveys from the 1970s/1980s and the 2005-2015 surveys by the NCPN resulted in no obvious concerns for species occurrence, including non-native species. The occupancy of peregrine falcon territories has remained relatively consistent, although survey and monitoring efforts have varied over the years. Overall, we rated the condition of birds as good, with an unknown trend and medium confidence level.
–	–	X	Utah Prairie Dog		While the Utah prairie dog population at Bryce Canyon NP appears stable, roadkill mortality continues to present a threat, especially to those individuals within colonies along busy park roads. The dog's meadow habitat plant species diversity is good, although the percent cover of vegetation is of moderate concern. Overall, we consider the Utah prairie dog to be in good condition with low confidence and an unknown trend.

Notes: Purpose, significance, and fundamental resources and values statements are listed in NPS (2014a) and if applicable are denoted by 'X.'

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

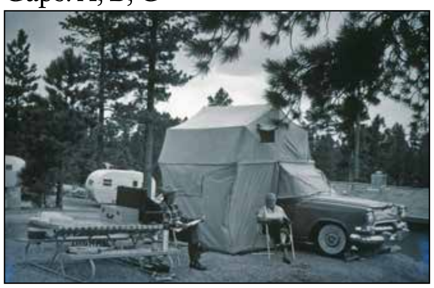
Knowledge or data gaps:

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

B) Acoustic Resources
Increased transportation noise from overflights and vehicles disturbs the natural quiet and can mask other natural sounds. Knowing the most quiet areas and mitigating adverse impacts is necessary for preserving resource conditions.

C) Scenic Resources
Poor visibility impacts a visitor's ability to see, both day and night scenery, and is of moderate concern at the park. The viewshed and night sky are listed in the park's purpose and significance and fundamental resource statements.

Gaps: A, B, C



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

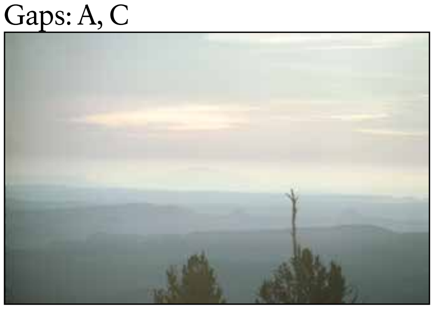
Addresses Resources
- Viewshed
- Night Sky
- Soundscape
- Air Quality
- All remaining resources

Gaps: A, B, C

Partnership Inventory
Inventorying existing partnership activities within an ecologically-relevant area would provide information from which park 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
- All remaining resources

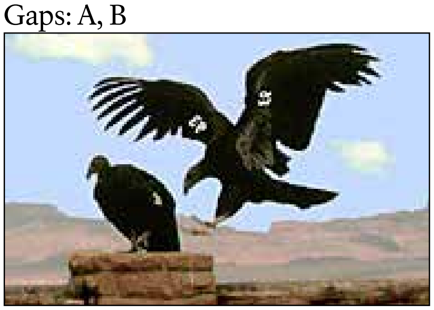
Gaps: A, C



Visibility Data Analysis
Linking the park's robust qualitative scenic vista datasets, including night sky images, with quantitative haze index data would provide a framework that managers could use for educational and potential air pollution advocacy efforts, especially with the coal development near the park and the increasing motorized traffic.

Addresses Resources
- Viewshed
- Night Sky
- Air Quality

Gaps: A, B



Soundscape Preservation
Managing back- and frontcountry operations to foster natural soundscape conservation is imperative given the rapid increase in visitation. In addition to noise pollution, overflights have the potential to adversely impact the park's geologic features.

Addresses Resources
- Soundscape
- Geology
- Birds
- Mammals

From top: Campers, NPS and USU partners, layered haze, California condors. Photo Credits: NPS

GEOLOGIC and WATER RESOURCES— geology and water quality

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 and increasing visitor use activities.

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) Riparian Impacts
Cattle trespass has been observed in the park along the riparian corridors of Sheep and Yellow creeks. Potential physical and biological damage to the riparian corridor and degradation of water quality may occur.

Gaps: A, B, C

<u>Comprehensive Erosion Study</u>
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.

<u>Addresses Resources</u>
- Geology
- Water Quality
- Vegetation and Soils

Gaps: A, B

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

<u>Addresses Resources</u>
- Geology
- Vegetation & Soils
- Unique & Distinctive Vegetation

Gap: C

<u>Boundary Fence Maintenance</u>
Routine maintenance of the park's boundary fence will help protect its water and vegetation resources. It will also help manage new introductions of invasive non-native plants.

<u>Addresses Resources</u>
- Water Quality
- Vegetation & Soils

From top: Erosion, rock slide along trail, monitoring along Sheep Creek. Photo Credits: NPS.

VEGETATION RESOURCES— uplands, unique and distinctive, and non-native invasive plants

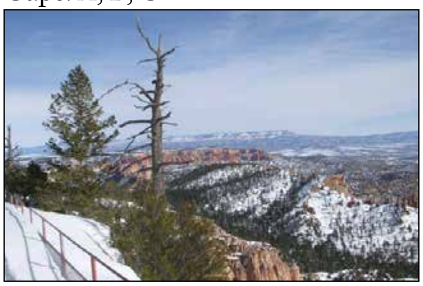
Knowledge or data gaps:

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) Lack of Fire
Unnatural fire regimes with associated extreme fuel loadings exist at the park.

C) Unique & Distinctive Vegetation Data
Lacking current data

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.

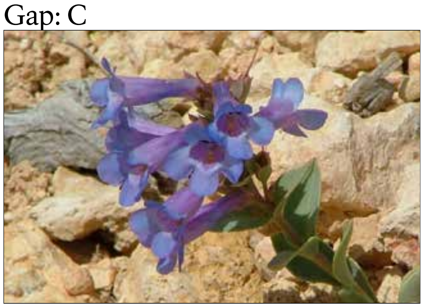
Addresses Resources
- Upland Vegetation
- Unique & Distinctive Vegetation
- Non-native Invasive Plants

Gaps: B, C

Restore Fire
Allow natural wildland fires to burn when and where appropriate and prioritize prescribed fire management in certain areas to restore vegetation communities in the park, especially in areas to improve habitat conditions for selected species.

Addresses Resources
- Upland Vegetation
- Unique & Distinctive Vegetation
- Non-native Invasive Plants
- Wildlife

Gap: C



Unique & Distinctive Veg Monitoring
Monitor the unique and distinctive vegetation throughout the park, focusing efforts on “hotspots” and areas of high endemism. This will protect the greatest variety of unique and distinctive vegetation and help identify management action(s) and potential research studies.

Addresses Resources
- Unique & Distinctive Vegetation

From top: Piracy Point, sunset over Thor’s Hammer, red canyon penstemon. Photo Credits: NPS.

WILDLIFE RESOURCES— birds and mammals, including Utah prairie dog

Knowledge or data gaps:

A) Utah Prairie Dog Colony Sizes
Many of the park's Utah prairie dog colonies are small, which doesn't meet the species recovery goal of maintaining medium to large-sized colonies.

B) Protect Sensitive Nesting Birds
Concerns have been expressed for disturbance to nesting peregrine falcons from noise, especially with increased visitation and overflights.

C) Utah Prairie Dog Habitat Quality and Connectivity
Invasive species are untreated near colonies and functional connectivity is lacking between several colonies.

Gaps: A, C

Focus Utah Prairie Dog Efforts on Larger Colonies
The persistence of the Utah prairie dog is dependent on maintaining medium and large-sized colonies. Currently, the park primarily has small and medium-sized colonies. Focusing management on larger colonies may increase the population.

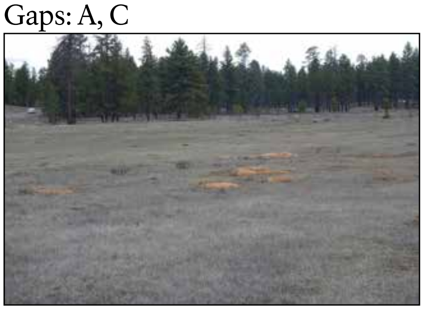
Addresses Resources
- Mammals
- Landscape-scale Partnerships

Gap: B

Integrate Landscape-scale Baseline Inventory with Nesting Bird Protection
Focus management efforts where both natural quiet and sensitive species, such as the peregrine falcon are conserved and proactively manage overflights.

Addresses Resources
- Birds
- Soundscape

Gaps: A, C



From top: Utah prairie dog, peregrine falcon, Utah prairie dog colony. Photo Credits: Top and bottom: NPS. Middle @ R. Shantz.

Meadow Habitat Management
Improving meadow habitat quality would increase the potential for prairie dog populations to be successful at the park and also support the species range-wide recovery goals by creating functional connectivity, including to non-NPS colonies. In addition, actions would reduce the presence of non-native species in the meadows.

Addresses Resources
- Mammals
- Vegetation
- Non-native Invasive plants

Due to time and budget constraints, only a summary of bats was included in Appendix A, however, they are a high priority management focus at the park. Bats routinely roost in the attic spaces of the historic Bryce Lodge and Bryce Inn (General Store). This creates potential human health threats that park staff have attempted to address by bat-proofing potential entrances while maintaining the historic integrity of the buildings. This is an on-going management process and gathering data to understand when bats arrive and depart will inform future management efforts. This is especially critical given the longer warm season due to climate change, which will likely cause changes in species behaviors.

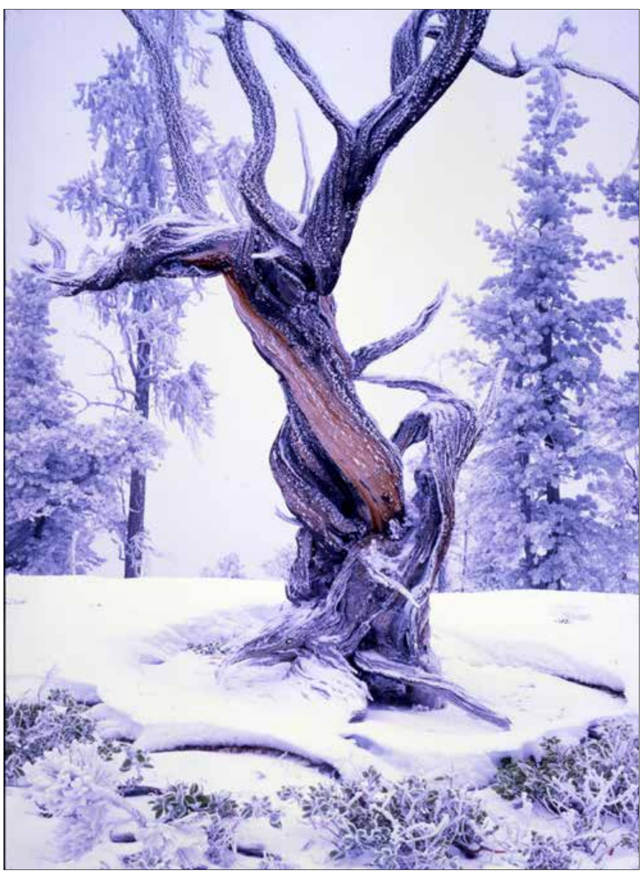
Climate Change

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. With temperatures already increasing and the amount of precipitation decreasing, a warmer and drier landscape will mean a decrease in water resources, both surface and groundwater. Species on the edge of their range or confined to specialized habitats (i.e., breaks habitat, bristlecone pine) will likely be most vulnerable to these types of climate changes. What is unclear, and represents a significant data gap and uncertainty, is how intensely resources will respond.



Snow covered bristlecone pine tree at Bryce Canyon NP. Photo Credit: NPS.

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 5-1 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 to help inform actions will be extremely beneficial. As shown in Figure 5-1, trees are the most vulnerable group to changing temperature and precipitation patterns due to their inability to move (disperse) quickly.

The NCPN has developed a landscape-scale model linking vegetation response to climate variables using satellite imagery and weather data to complete a Normalized Difference Vegetation Index (NDVI) assessment for Bryce Canyon NP (Thoma et al. 2017). The information derived from the model provides park managers with climate change science that may inform future adaptive management strategies.

Much of the NDVI results are presented in the Upland Vegetation condition assessment in this report, but additional information pertaining to vegetation productivity within the six forest types assessed is presented here to emphasize the connection between climate, specifically temperature and precipitation, and resource response.

Since 1980, all forest types at Bryce Canyon NP responded positively to actual evapotranspiration, which integrates the effects of temperature, precipitation, slope, aspect and soil properties. Annual precipitation was variable, but no significant trend was observed since 1980 in any of the forest types (Figure 5-1, left). However, temperature increased significantly ($p<0.10$) in each of the forest types (Figure 5-1, right). The trend in actual evapotranspiration was upward and statistically significant ($p<0.1$), which was consistent with the upward trend in production for all unburned forest types.

Trends in four phenology metrics, start of season (SOS), length of season (LOS), end of season (EOS), and period of peak (POP), using the derivative method of Forkel et al. (2015) after implementing a spline smooth on the NDVI time series, were also evaluated. Metrics were summarized by area and percentage of area that changed within each of the six vegetation types (Table 5-2). The most prominent changes in phenology were an earlier start of growing season in pinyon pine-juniper spp. (*Pinus edulis-Juniperus*

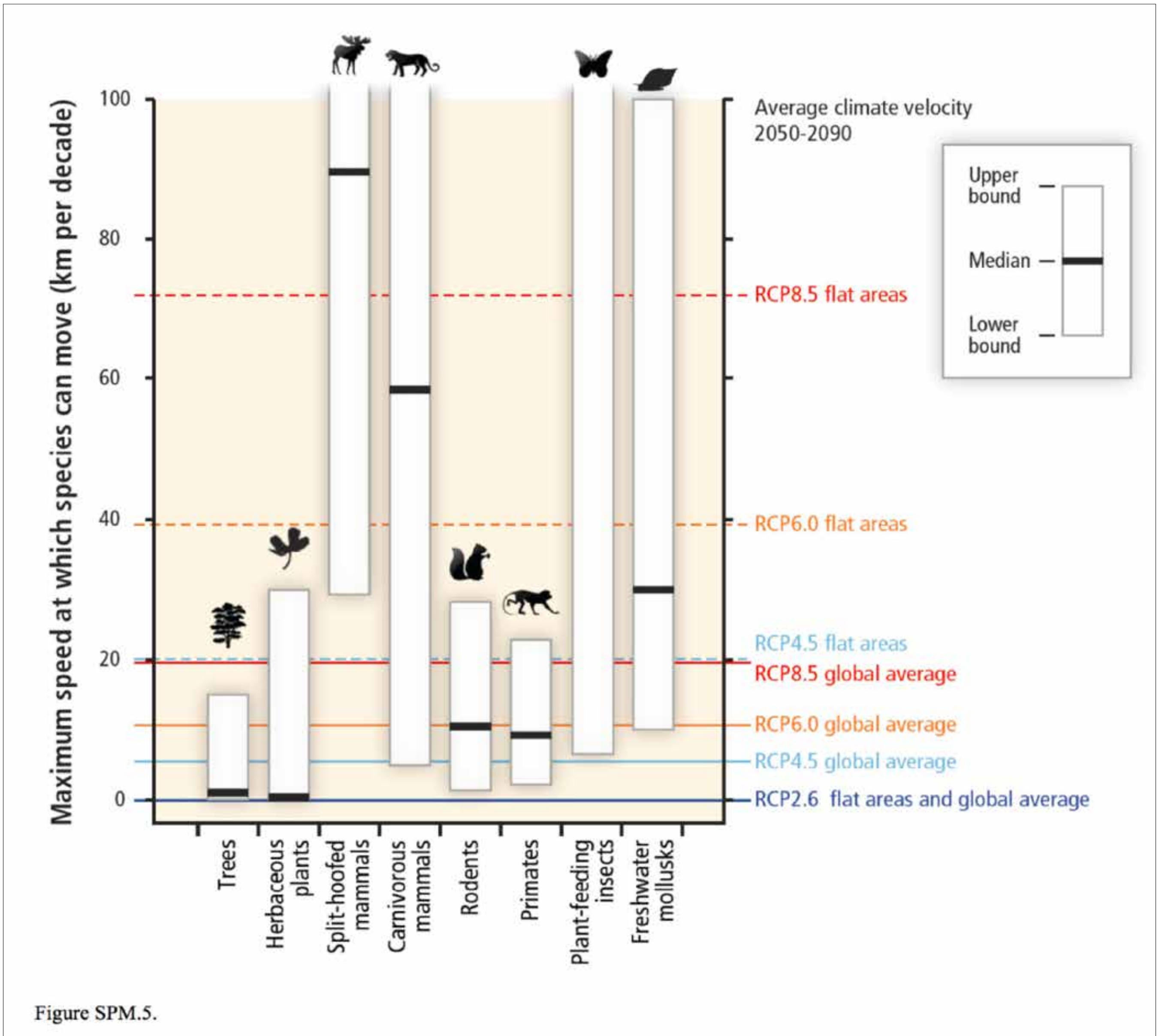


Figure 5-1. Graph of climate change impacts, adaptation, and vulnerability for eight groups of organisms based on the maximum speed at which the organism can move. Figure Credit: IPCC (2014).

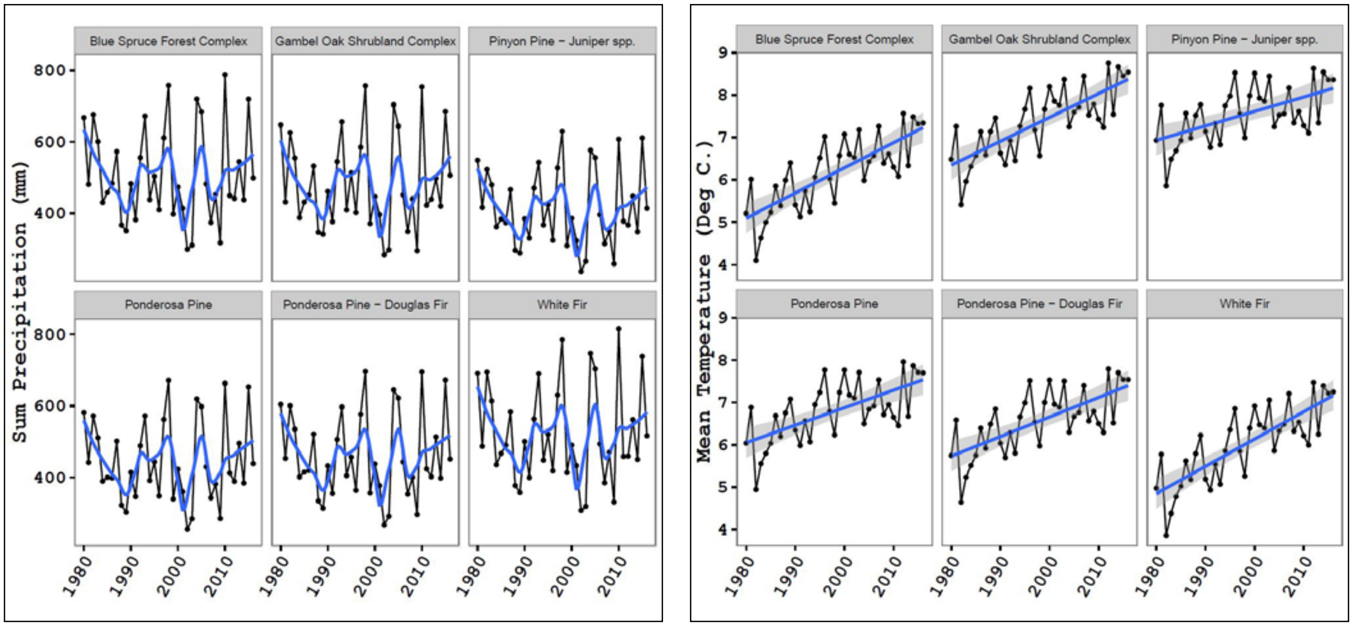


Figure 5-2. Precipitation variability for wetter and drier years was consistent across forest types There were no statistically significant trends in precipitation (left). All forest types experienced warm and cool years consistently. Temperature trends were statistically significant (p<0.1) in all forest types (right). 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.

Table 5-2. Phenology trend direction and extent by forest type for the period 2000-2016.

Vegetation Type	Area Analyzed (ha)	Polygon Count	SOS later	SOS earlier	LOS longer	LOS shorter	EOS later	EOS earlier	POP later	POP earlier
Blue Spruce Forest Complex	103	10	0 (0%)	9 (8%)	9 (8%)	0 (0%)	0 (0%)	0 (0%)	17 (17%)	0 (0%)
Gambel Oak Shrubland Complex	55	6	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Pinyon Pine-Juniper spp.	4,379	185	45 (1%)	1026 (23%)	685 (16%)	38 (1%)	7 (0%)	31 (1%)	419 (10%)	23 (1%)
Ponderosa Pine	2,626	174	0 (0%)	336 (13%)	1074 (41%)	0 (0%)	46 (2%)	25 (1%)	254 (10%)	0 (0%)
Ponderosa Pine-Douglas Fir	4,391	160	0 (0%)	303 (7%)	1017 (23%)	0 (0%)	47 (1%)	0 (0%)	394 (9%)	119 (3%)
White Fir	2,459	123	0 (0%)	0 (0%)	86 (4%)	0 (0%)	9 (0%)	0 (0%)	100 (4%)	0 (0%)
Total Park Area	14,014	658	45 (0%)	1674 (12%)	2872 (20%)	38 (0%)	109 (1%)	56 (0%)	1184 (8%)	142 (1%)

Note: Confidence in phenology trends is low due to high degree of interannual variability and small sample size (n=17 per polygon).

SOS = start of season; LOS = length of season; EOS = end of season; POP = period of peak productivity.

Source: Thoma et al. (2017).

osteosperma), Ponderosa Pine (*Pinus ponderosa*) and Ponderosa Pine-Douglas Fir (*Pseudostuga menziesii*), which translated to a longer growing season in these same forest types. However, confidence in phenology trends is low due to high inter-annual variability in NDVI and the relatively short 17 year record (Forkel et al., 2013). These changes were consistent with rising temperatures that extend the growing season when water is available for growth. The forest types that exhibited longer growing seasons were more sensitive to actual evapotranspiration, which is an estimate of water use during the growing season. This sensitivity combined with a longer growing season and increased production since 2000 also corresponded with an increase in actual evapotranspiration over the same period. Collectively, these findings suggest greater water availability and use by these forest types since 2000.

As temperatures continue to rise as they have at Bryce Canyon NP, with the last decade representing the warmest on record for years 1901-2012 (Monahan and Fisichelli 2014), changes are inevitable, especially for vegetation and species that depend on particular habitat structures and compositions. Evidence-based information, such as presented here, can help communicate complex climate change effects and impacts to the public and park staff, especially since all aspects of Bryce Canyon NP's resources, operations, and visitor experiences will likely be affected as a result (Monahan and Fisichelli 2014).

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Appendix A. Bryce Canyon NP Mammal and Herpetofauna Species Lists

Listed below are the mammal species that have been recorded at Bryce Canyon National Park (NP). The list is based on the Certified NPSpecies list for the national park (NPS 2017a, dated 23 March 2017). Species in the list below are separated by mammal group (i.e., order). A total of 55 species have been documented in the park, with non-native species shown in bold font. An additional 20 species are either probably present or are unconfirmed. The list of species was compared with lists of federally threatened and endangered species (U.S. Fish and Wildlife Service [USFWS] 2017a) and those listed as sensitive by the state of Utah (Utah Division of Wildlife Resources 2015).

Table A-1. Mammals species (except bats) list for Bryce Canyon NP.

Mammal Group	Common Name	Scientific Name	NPSpecies Occurrence
Ungulates	Bighorn sheep	Ovis canadensis	Present
	Elk	Cervus canadensis (or elaphus) [2]	Present
	Mountain goat[1]	Oreamnos americanus	Present
	Mule deer	*Odocoileus hemionus*	Present
	Pronghorn	*Antilocapra americana americana*	Present
Carnivores	American badger	*Taxidea taxus*	Present
	American black bear	*Ursus americanus*	Present
	Bobcat	*Lynx rufus*	Present
	Canada lynx[2]	*Lynx canadensis*	Probably Present
	Coyote	*Canis latrans*	Present
	Ermine	*Mustela erminea*	Unconfirmed
	Gray fox	*Urocyon cinereoargenteus*	Present
	Kit fox	*Vulpes macrotis*	Unconfirmed
	Long-tailed weasel	*Mustela frenata*	Present
	Mountain lion	*Puma concolor*	Present
	Northern raccoon	*Procyon lotor*	Unconfirmed
	Red fox	*Vulpes vulpes*	Present
	Ringtail	*Bassariscus astutus*	Present
	Striped skunk	*Mephitis mephitis*	Present
	Western spotted skunk	*Spilogale gracilis*	Present
Lagomorphs	Black-tailed jackrabbit	*Lepus californicus*	Present
	Desert cottontail	*Sylvilagus audubonii*	Probably Present
	Mountain cottontail	*Sylvilagus nuttallii*	Present
	Snowshoe hare	*Lepus americanus*	Unconfirmed
	White-tailed jackrabbit	*Lepus townsendii*	Present
Rodents	American beaver	*Castor canadensis*	Unconfirmed
	Brush mouse	*Peromyscus boylii*	Present
	Bushy-tailed woodrat	*Neotoma cinerea*	Present
	Canyon mouse	*Peromyscus crinitus*	Present
	Cliff chipmunk	*Tamias dorsalis*	Present
	Common muskrat	*Ondatra zibethicus*	Unconfirmed

[1] Nativity unknown.

[2] Federally threatened species.

[3] Utah Division of Wildlife Species of Concern.

[4] Non-natve species.

Table A-1 continued. Mammals species (except bats) list for Bryce Canyon NP.

Mammal Group	Common Name	Scientific Name	NPSpecies Occurrence
Rodents *continued*	Deer mouse	*Peromyscus maniculatus*	Present
	Desert woodrat	*Neotoma lepida*	Present
	Golden-mantled ground squirrel	*Spermophilus lateralis*	Present
	Great Basin pocket mouse	*Perognathus parvus*	Present
	House mouse[4]	*Mus musculus*	Unconfirmed
	Least chipmunk	*Neotamias minimus*	Present
	Long-tailed vole	*Microtus longicaudus*	Present
	Montane vole	*Microtus montanus*	Present
	North American porcupine	*Erethizon dorsatum*	Probably Present
	Northern flying squirrel	*Glaucomys sabrinus*	Present
	Northern grasshopper mouse	*Onychomys leucogaster*	Unconfirmed
	Northern pocket gopher	*Thomomys talpoides*	Present
	Ord's kangaroo rat	*Dipodomys ordii*	Present
	Pinyon mouse	*Peromyscus truei*	Present
	Red squirrel	*Tamiasciurus hudsonicus*	Present
	Rock squirrel	*Spermophilus variegatus*	Present
	Sagebrush vole	*Lemmiscus curtatus*	Present
	Uinta chipmunk	*Neotamias umbrinus*	Present
	Utah prairie dog[2]	*Cynomys parvidens*	Present
	Western harvest mouse	*Reithrodontomys megalotis*	Present
	White-tailed antelope squirrel	*Ammospermophilus leucurus*	Unconfirmed
	Yellow-bellied marmot	*Marmota flaviventris*	Present
Insectivores	American water shrew	*Sorex palustris*	Unconfirmed
	Crawford's desert shrew	*Notiosorex crawfordi*	Unconfirmed
	Dwarf shrew	*Sorex nanus*	Present
	Masked shrew	*Sorex cinereus*	Unconfirmed
	Merriam’s shrew	*Sorex merriami*	Present
	Montane shrew	*Sorex monticolus*	Present

[1] Nativity unknown.

[2] Federally threatened species.

[3] Utah Division of Wildlife Species of Concern.

[4] Non-natve species.

World-wide, about one-fourth of all mammal species are bats (Tuttle 1988), and nearly 50 bat species inhabit the United States and Canada (USFWS 2015). Nineteen bat species have been recorded in Utah (Table A-2) (Oliver 2000, Hasenyager 1980), with the nineteenth species, the Arizona myotis (*Myotis occultus*), representing a subspecies of little brown myotis (*Myotis lucifugus*). Fifteen of Utah's bats (or 79%) have been observed in Bryce Canyon NP, accounting for almost one quarter (22.4%) of the mammals in the park (NPS 2017a). Several bat species checklists for Bryce Canyon NP and vicinity have been developed (Wilhelm 1967, Hasenyager 1980, Bogan 1992a, NPS 2017a) and are summarized by species in Table A-2.

Table A.2. Bat species checklists for Bryce Canyon NP and vicinity.

Common Name	Scientific Name	Wilhelm (1967)	Hasenyager (1980)[2] # in Garfield County	Bogan (1992a) Tentative List	NPSpecies Occurrence (NPS 2017a)	NPS (2017a) Abundance
Allen's Big-eared bat[1]	*Idionycteris phyllotis*	–	0	X	–	Probably Present
Big brown bat	*Eptesicus fuscus*	Common, Breeder	18	X	Breeder	Uncommon
Big Free-tailed bat[1]	*Nyctinomops macrotis*	–	0	X	–	Unconfirmed
Brazilian free-tailed bat	*Tadarida brasiliensis*	–	0	X	–	Unconfirmed
California myotis	*Myotis californicus*	Uncommon, Breeder	4	X	Present	Uncommon
Canyon bat (formerly Western pipistrelle)	*Parastrellus hesperus*	–	3	X	–	Unconfirmed
Fringed myotis[1]	*Myotis thysanodes*	–	2[3]	X	Breeder	Uncommon
Hoary bat	*Lasiurus cinereus*	Casual, Breeder	1	X	Present	Unknown
Little brown myotis	*Myotis lucifugus*	Casual, Breeder	1	X	Breeder	Uncommon
Long-eared myotis	*Myotis evotis*	Uncommon, Breeder	3[3]	X	Breeder	Uncommon
Long-legged myotis	*Myotis volans*	Common, Breeder	10	X	Breeder	Uncommon
Pallid bat	*Antrozous pallidus*	Uncommon, Breeder	1	X	Breeder	Uncommon
Silver-haired bat	*Lasionycteris noctivagans*	Uncommon, Breeder	3	X	Present	Uncommon
Spotted bat[1]	*Euderma maculatum*	Uncommon, Breeder	5	X	Breeder	Uncommon
Townsend's big-eared bat[1]	*Corynorhinus townsendii*	–	0	X	–	Probably Present
Western red bat	*Lasiurus blossevillii*[4]	–	0	X	–	–
Western small-footed myotis	*Myotis ciliolabrum*[5]	Common, Breeder	4[3]	X	Present	Uncommon
Yuma myotis	*Myotis yumanensis*	–	2	X	Present	Unknown

Note: X denotes the possible presence of the species at Bryce Canyon NP.

[1] NPSpecies (2017a) lists these five species as management priorities.

[2] Oliver (2000) summarizes information concerning the bat fauna of Utah providing an update to Hasenyager (1980). Some of Hasenyager's (1980) confirmations are disputed.

[3] Some of these species were recorded at Bryce Canyon NP.

[4] Hasenyager (1980) listed this species as *Lasiurus borealis,* which is now *L. blossevilli* (Oliver 2000).

[5] Hasenyager (1980) and Bogan (1990) listed this species as *Myotis leibii*, which is no longer used for the western species (Oliver 2000).

Note: X = Present.

Several bat surveys have occurred at Bryce Canyon NP since 1964 and are summarized in Tables A-3 and A-4. Fifteen of the 18 bat species listed as possible for Bryce Canyon NP have been recorded during at least one survey. Three of the park's undocumented species or species where their acoustic spectograms cannot be differentiated, Allen's big-eared (*Idionycteris phyllotis*), big free-tailed (*Nyctinomops macrotis*), and western red (*Lasiurus blossevillii*) bats, have also not been documented as occurring in Garfield County. However, both Allen's and big-free-tailed bats have been documented in counties adjacent to Garfield, although recordings are quite rare (Hasenyager 1980).

Threats, Issues, and Data Gaps

Data are lacking at Bryce Canyon NP for big-eared bats, which are also considered rare in Utah. These include the spotted (*Euderma maculatum*), Townsend's big-eared (*Corynorhinus townsendii*), big free-tailed, and Allen's big-eared bats. These bats use low frequency echlocation so can avoid mist nets (Toone 1993a), which has been the most common survey method used at the park. Furthermore, locations where mist nets are placed, usually over water holes, do not represent the types of habitat used by all bat species. According to Toone (1993b), "many large bats need long open pools (i.e., swoop zone) to drink due to their wing structure, which makes them less maneuverable in small confined situations." Additional characteristics of the spotted bat that would preclude its detection include its non-colonial behavior and ability to fly high, avoiding mist nets (UTHP and UDWR no date). In addition, during the Taylor et al. (2013) bat survey, certain species (i.e., western bonneted bat (*Eumops perotis*), spotted bat, and western red bat were reported as flying higher than their mist net sampling design. The low numbers detected may reflect a need for a different sampling technique versus low population numbers (Taylor et al. 2013). Taylor et al. (2013) also mentioned that echo-location monitoring for western small-footed (*Myotis cilioabrum*) and California myotis (*M. californicus*) is a better survey technique since these species are difficult to tell apart.

Toone (1993b) submitted a proposal to Bryce Canyon NP Resource Manager, Richard Bryant, to conduct an inventory in the park using echlocation methods to detect the four big-eared bat species. While it appears that the inventory never occurred at the park, Toone did conduct a general inventory for spotted bats on the Wasatch Plateau, Manti-La Sal National Forest and the Old Woman Plateau and Thousand Lakes Mountain, Fishlake National Forest (Toone 1993c).

Other types of bat species, particularly little brown myotis (*M. lucifugus*), select roosts that are located in old structures. Bogan and Geluso (1999) studied bat roosts in historic structures at several national parks throughout the Rocky Mountain Region. Their generalized findings were that buildings with small spaces and warm nighttime temperatures were most likely to contain bat colonies. Roosts provide protection for the life cycle needs, such as avoiding predation and bearing and raising young, but also present management conflicts for park and concessions staffs, which is true at Bryce Canyon NP. Bogan and Geluso (1999) suggested modifying nighttime temperatures or roosting sites within buildings to deter roosting. They also suggested that providing alternative structures with similar characteristics may alter their roost site selection as well (Bogan and Geluso 1999).

While not documented at the park, white-nose syndrome (WNS), a disease that affects hibernating bats, has resulted in the mortality of more than six million of these species in eastern and mid-western North America (USFWS 2018). WNS is named for the white fungus, originally known as *Geomyces destructans*, but now called *Pseudogymnoascus destructans* (USFWS 2018), that grows on the muzzle and other parts of bats' bodies (USFWS 2018). The disease is thought to spread primarily through direct contact between bats, but it is also believed possible to spread the fungus to new hibernacula on shoes, clothing, or gear (USFWS 2018).

In the U.S., the occurrence of WNS has been confirmed in nine species of bats, and the fungus has been observed on an additional seven but no diagnostic sign of WNS has been documented (USFWS 2018a). Of these species that have been afflicted with WNS, two are known to occur at Bryce Canyon NP, big brown bat (*Eptesicus fuscus*) and little brown myotis. Three of the seven species with the fungus but no diagnostic sign of WNS are on the park's species list, silver-haired bat (*Lasionycteris noctivagans)*, and Townsend's big-eared bat, and Brazilian free-tailed bat (*Tadarida brasiliensis*). Currently, the closest state to Utah with confirmed cases of WNS is Wyoming (White-nose Syndrome.org 2018).

Table A.3. Number of bat species recorded during Bryce Canyon NP surveys.

Common Name	Scientific Name	Easterla (1964)	Hallows (1982)	Bogan (report dates below)			Foster (1995)	Taylor et al. (2013)	National Park Service Bryce Canyon NP (2010-2012, 2014)[4]				Southeastern Bat Diversity Network (2014)
		Park / Vicinity[1]	Park / Vicinity[1]	1990	1991[1]	1992b	Park	Netted / Acoustic[2]	2010f[5]	2011d[5]	2012d[5]	2014i[5]	Park
Allen's big-eared Bat	*Idionycteris phyllotis*	–	–	–	–	–	–	–	–	–	–	–	–
Big brown bat	*Eptesicus fuscus*	Many	–	1	0/8	1	28	2 / 590	X	X	47	X	–
Big free-tailed Bat	*Nyctinomops macrotis*	–	–	–	–	–	–	–	–	–	3[6]	X[6]	–
Brazilian (or Mexican) free-tailed bat	*Tadarida brasiliensis*	–	–	–	–	–	–	0/3578	X	–	528	X	–
California myotis	*Myotis californicus*	5	–	–	0/6	–	–	0/6	–	–	1	X	–
Canyon bat (formerly Western pipistrelle)	*Parastrellus hesperus*	–	–	–	–	–	–	– [3]	–	–	9	–	–
Fringed myotis	*Myotis thysanodes*	7	1 / 2	–	2/5	–	4	2 / 392	X	–	–	–	1
Hoary bat	*Lasiurus cinereus*	1	–	–	–	–	1	0/1538	–	–	941	X	–
Little brown myotis	*Myotis lucifugus*	1	–	–	1 VC Roost	–	1	0/6376	X	X	50	X	–
Long-eared myotis	*Myotis evotis*	4	0 / 2	1	6/4	–	11	3 / 53	–	–	2	X	14
Long-legged myotis	*Myotis volans*	Many	1 / 1	1	3/4	3	29	13 / 26	X	–	67	X	4
Pallid bat	*Antrozous pallidus*	–	–	1	–	–	–	0/7	–	–	1	X	–
Silver-haired bat	*Lasionycteris noctivagans*	4	–	–	–	5	47	0/1132	X	–	97	X	–
Spotted bat	*Euderma maculatum*	0 / 4	–	–	–	–	–	0/13	–	–	1	X	–
Townsend's big-eared bat	*Corynorhinus townsendii*	–	–	–	–	–	–	0/0	–	–	2	–	–
Western red bat	*Lasiurus blossevillii*	–	–	–	–	–	–	0/0	–	–	–	X	–
Western small-footed myotis	*Myotis ciliolabrum*	Many	3 / 1	–	–	–	21	0/138	–	–	4	X	–
Yuma myotis	*Myotis yumanensis*	–	–	–	–	–	3	0/38	–	1	2	–	–

Note: X denotes species captured but numbers were not provided.

[1] First number represents the number caught at Bryce Canyon NP. The second number represents the number caught outside of the park. Bogan's numbers were taken from actual datasheets.

[2] Second reported value is the corrected counts for species calls (summarized from Taylor et al. (2013) Appendix C acoustic results for Bryce Canyon NP).

[3] Taylor et al. (2013) noted that one call for PAHE was recorded. It was not included since it did not meet the corrected count threshold.

[4] NPS (2013) reports results from Taylor et al. (2013) effort so was only included in the Taylor et al. column. In 2016, Mark Graham, Bryce Canyon NP, and Keith Day, UDWR, captured `two *Myotis volans*, one *M. evotis*, one *M. lucifigus*, and two *Lasionycteris noctivagans* at East Creek (BC1B) site (393257E, 4163536N). This information was not included in the table summary.

[5] Results from acoustic analysis.

[6] Cannot differentiate spectograms between *Nyctinomops macrotis* and *Eumops perotis* but *E. perotis* has not been confirmed in Utah (Oliver 2000) even though Jackson and Herder (1997) reported acoustic detection in Utah.

Table A.4. Bat survey location summary at Bryce Canyon NP.

Survey Location	UTM Coordinates (12S)	Easterla (1964)[1]	Hallows (1982)	Bogan (1990)[2]	Bogan (1991)[2]	Bogan (1992b)[2]	Foster (1995)	Taylor et al. (2013)	NPS (2010f)	NPS (2011d)	NPS (2012d)	NPS (2014i)	Southeastern Bat Diversity Network (2014)
Rigg's Spring	0390272E 4145544N	–	–	–	–	–	–	–	–	–	–	–	X
Rigg's Spring (0.5 mi ESE)	–	–	–	–	X	–	–	–	–	–	–	–	–
Rigg's Spring	–	–	–	–	X	–	–	–	–	–	–	–	–
East Creek Wells	–	–	–	X	–	–	–	–	–	–	–	–	–
East Creek Area	0393316E 4163551N	–	–	–	–	–	X	–	–	–	–	–	–
East Creek Meadow	0393045E 4165769N	–	–	–	–	–	–	X	–	–	–	–	–
Podunk Creek	0388554E 4147660N	–	–	–	–	–	–	X	–	–	–	–	–
Sheep Creek	0394021E 4159120N	–	–	–	–	–	–	X	–	–	–	–	–
Bryce Lodge	0396929E 4165118N	–	–	–	–	–	–	X	–	X	X	X	–
Sunrise Camper Store	0397190E 4165664N	–	–	–	–	–	–	–	–	–	X	–	–
Sewer Lagoon	0396370E 4167015N	–	–	–	–	–	–	–	X	–	–	–	–
Mossy Cave	0402071E 4169355N	–	–	–	–	–	–	X	–	–	–	–	–
Mossy Cave	–	–	–	–	–	–	–	–	X	–	–	–	–
Mossy Cave Bridge	0402149E 4169143N	–	–	–	–	–	X	–	–	–	–	–	–
Swamp Canyon	0394303E 4157633N	–	–	–	–	–	X	–	–	–	–	–	–
Bryce Creek	0400310E 4163352N	–	–	–	–	–	X	–	–	–	–	–	–

Notes: X denotes survey location. Locations were listed individually if no coordinates were reported. Not all sites listed in the table were within Bryce Canyon National Park and not all survey sites outside of park boundaries were included.

In 2016, Mark Graham, Bryce Canyon NP, and Keith Day, UDWR, captured `two *Myotis volans*, one *M. evotis*, one *M. lucifigus*, and two *Lasionycteris noctivagans* at East Creek (BC1B) site (393257E, 4163536N). This information was not included in the table summary.

[1] Not all survey locations were reported for Easterla (1964) in Hallows (1982).

[2] Bogan's survey locations were taken from the actual datasheets.

Table A-4 continued. ***Bat survey location summary at Bryce Canyon NP.***

Survey Location	UTM Coordinates (12S)	Easterla (1964)[1]	Hallows (1982)	Bogan (1990)[2]	Bogan (1991)[2]	Bogan (1992b)[2]	Foster (1995)	Taylor et al. (2013)	NPS (2010f)	NPS (2011d)	NPS (2012d)	NPS (2014i)	Southeastern Bat Diversity Network (2014)
Yovimpa Pass Area	0388626E 4147320N	–	–	–	–	–	X	–	–	–	–	–	–
Yovimpa Pass	–	–	–	–	X	–	–	–	–	–	–	–	–
Bryce Canyon Airport	0400495E 4173320N	–	–	–	–	–	X	–	–	–	–	–	–
Livestock Pond just North of Bryce Canyon NP	–	–	X	–	–	–	–	–	–	–	–	–	–
Livestock Pond <1 mile North of Bryce Canyon NP Boundary	–	X	–	–	–	–	–	–	–	–	–	–	–
Livestock Pond 1.5 mile Northeast of Bryce Village	–	–	X	–	–	–	–	–	–	–	–	–	–
Water Canyon - between bridge and Mossy Cave	–	–	X	–	–	–	–	–	–	–	–	–	–
Water Canyon	–	–	X	–	–	–	–	–	–	–	–	–	–
Nature Center	–	–	–	–	X	–	–	–	–	–	–	–	–
Visitor Center	–	–	X	–	–	–	–	–	–	–	–	–	–
Pink Cliffs Motel (1.5 mi NE)	–	–	–	–	X	X	–	–	–	–	–	–	–
Ruby's Inn	–	X	–	–	–	–	–	–	–	–	–	–	–
Tropic Ditch at Highway 12	–	–	–	X	–	X	–	–	–	–	–	–	–
Near Highway 12 and Highway 54 Intersection	–	–	X	–	–	–	–	–	–	–	–	–	–

Notes: X denotes survey location. Locations were listed individually if no coordinates were reported. Not all sites listed in the table were within Bryce Canyon National Park and not all survey sites outside of park boundaries were included.

In 2016, Mark Graham, Bryce Canyon NP, and Keith Day, UDWR, captured `two *Myotis volans*, one *M. evotis*, one *M. lucifigus*, and two *Lasionycteris noctivagans* at East Creek (BC1B) site (393257E, 4163536N). This information was not included in the table summary.

[1] Not all survey locations were reported for Easterla (1964) in Hallows (1982).

[2] Bogan's survey locations were taken from the actual datasheets.

Additional bat survey data for Bryce Canyon NP are included in Utah Bat Conservation Cooperative's (UBCC, no date) on-line database, BatBase. These data include surveys by Lengas (1997) (unpublished data), Foster et al. (1995 but listed as 1997 in BatBase), and several years of surveys conducted by Utah Division of Wildlife Resources (UDWR). No new species for the park were recorded during these surveys. These data were not included in Tables A-3 and A-4 summaries since no associated report was provided. It was difficult to determine whether some of the UDWR entries were duplicates of what was already included in the summaries, although we know this was true for the Foster et al. (1995) survey effort. Bryce Canyon NP staff have the original BatBase shapefile, which also includes results of bat survey efforts that occurred outside of the park.

Listed below in Table A-5 are the reptile and amphibian species that have been listed for Bryce Canyon NP. Sources used for the list were the Certified NPSpecies list for the national park (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 20 species are listed for the park, 12 of which are confirmed as occurring within the park. None of the species listed are considered non-native. The list of species was compared with lists of federally threatened and endangered species (U.S. Fish and Wildlife Service 2017a) and those listed as sensitive by the state of Utah (Utah Division of Wildlife Resources 2015).

Table A-5. Herpetofauna species list for Bryce Canyon NP.

Herpetofauna Group	Common Name	Scientific Name	NPSpecies Occurrence
Reptiles	Common sagebrush lizard[1,2]	*Sceloporus graciosus*	Present
	Eastern fence lizard[2]	*Sceloporus undulatus*	Present
	Gopher snake[1,2]	*Pituophis catenifer*	Present
	Nightsnake[1]	*Hypsiglena torquata*	Unconfirmed
	Mountain (Greater) short-horned lizard[1,2]	*Phrynosoma hernandesi*	Present
	Plateau lizard[1]	*Sceloporus tristichus*	Present
	Prairie rattlesnake[1]	*Crotalus viridis*	Present
	Ring-necked snake[2]	*Diadophis punctatus*	May Occur
	Striped whipsnake[1,2]	*Masticophis taeniatus*	Unconfirmed
	Terrestrial gartersnake[1,2]	*Thamnophis elegans*	Present
	Tree lizard[1,2]	*Urosaurus ornatus*	Present
	Western rattlesnake[1]	*Crotalus oreganus*	Present
	Western skink[1,2]	*Eumeces skiltonianus*	Unconfirmed
	Western whiptail[1,2]	*Cnemidophorus tigris*	Unconfirmed
Amphibians	Great Basin spadefoot[1]	*Spea intermontana*	Present
	Northern leopard frog[1,2]	*Rana pipiens*	Present
	Tiger salamander[1,2]	*Ambystoma tigrinum*	Present
	Western chorus frog[1]	*Pseudacris triseriata*	Probably Present
	Western toad[2,3]	*Bufo boreas*	Encroaching
	Woodhouse's toad[2]	*Bufo woodhousii*	May Occur

Note: Occurrence is based on the most current information available.

[1] Occurrence from NPSpecies (2017a).

[2] Occurrence from Platenberg and Graham (2003).

[3] Utah Division of Wildlife Species of Concern.

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
Dr. Mark Brunson	Utah State University, Professor and Principal Investigator
Dr. Mark Graham	National Park Service Bryce Canyon National Park, Supervisory Biologist
Cynthia Morris	National Park Service Bryce Canyon National Park, Chief, Resource Management and Visitor Protection
James (Doug) Sprouse	National Park Service Bryce Canyon National Park, Fire Management Officer
Kim Struthers	Utah State University, NRCA Project Coordinator and Writer/Editor
Eric Vasquez	National Park Service Bryce Canyon National Park, Vegetation Crew Leader
Rebecca Weissinger	National Park Service Northern Colorado Plateau Inventory and Monitoring Network, Aquatic Ecologist

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	Birds, Utah Prairie Dog, Night Sky, Non-native Invasive Plants, and Geology, Assessments
Mark Graham	National Park Service Bryce Canyon National Park, Supervisory Biologist	Park Resource Expert Reviewer
Eric Vasquez	National Park Service Bryce Canyon National Park, Vegetation Crew Leader	Park Resource Expert Reviewer
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	Water Quality Assessment
Dana Witwicki	National Park Service Northern Colorado Plateau Inventory and Monitoring Network, Ecologist	Unique & Distinctive Vegetation, Upland Vegetation Assessments
Amy Tendick	National Park Service Planning and Compliance	Unique & Distinctive Vegetation
Li-Wei Hung	National Park Service Natural Sounds and Night Skies Division, Night Sky Research Scientist	Night Sky Assessment and Data
Randy Stanley	National Park Service Intermountain Region Office, Natural Sounds & Night Skies Coordinator	Soundscape Assessment
Ksienya Taylor	National Park Service Air Resources Division, Natural Resource Specialist	Air Quality Assessment
Tim Connors	National Park Service Geologic Resources Division, Geologist	Geology Assessment

Table B.2 continued. Report reviewers.

Name	Affiliation and Position Title	Section(s) Reviewed or Other Role
Walter Fertig, Ph.D.	Washington Natural Heritage Program, State Botanist	Unique and Distinctive Vegetation Assessment
Jeff Conn	National Park Service Intermountain Region Southwest Exotic Plant Management Team, Liaison	Non-native Invasive Plants Assessment
Kristen Philbrook	National Park Service Intermountain Region Office, Wildlife Biologist	Utah Prairie Dog Assessment
Laura Romin	United States Fish and Wildlife Service Utah Ecological Services Field Office, Deputy Field Supervisor	Utah Prairie Dog Assessment

Appendix C. Viewshed Analysis Steps

The process used to complete Bryce Canyon National Park'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 2016) 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 (2016b) 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 area of analysis (AOA) for the NPS NPScape's housing, road, and conservation status tools as described in NPS 2014b,c,d. A text attribute field was added to the AOA for the area of analysis identifier.

Housing (CONUS, Density, SERGoM, 1970 - 2100, Metric Data (ESRI (2016a) 9.3 File Geodatabase) (Theobald 2005), U.S. Census Bureau 2016b TIGER/Line Shapefiles: Roads) (U.S. Census Bureau 2016b), and conservation status (NPS 2014c, USGS GAP 2016) GIS datasets were downloaded from NPScape (NPS 2016b,c) and the USGS GAP (USGS GAP 2016) websites. Standard Operating Procedures for all three tools were followed based on NPScape instructions (NPS 2014b,c,d).

The housing and road density maps are shown in Figures C-1 and C-2. The GAP status lands and management agency maps are shown in Figures C-3 and C-4.

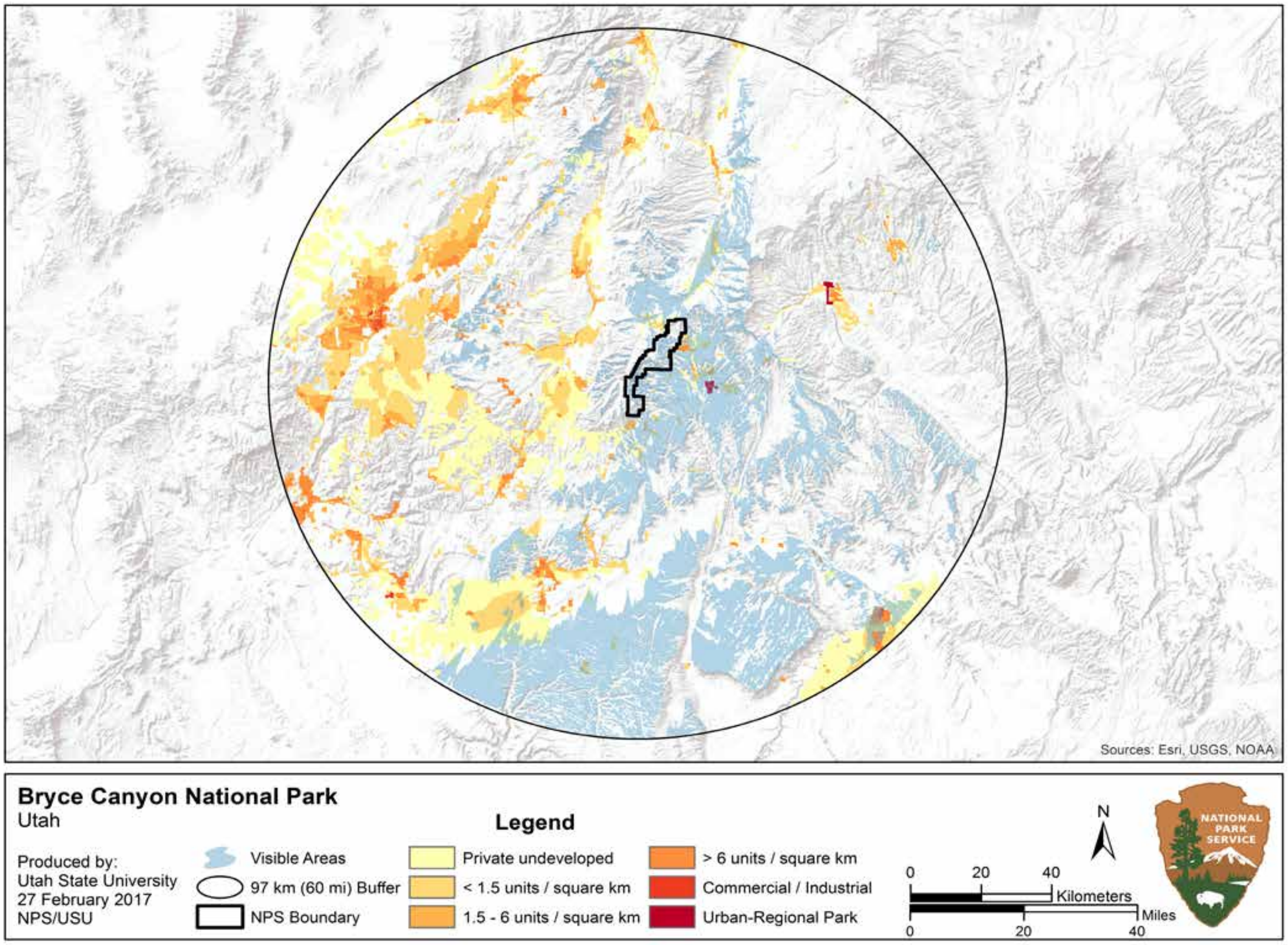

Figure C-1. **Housing density and visible areas in and around Bryce Canyon NP.**

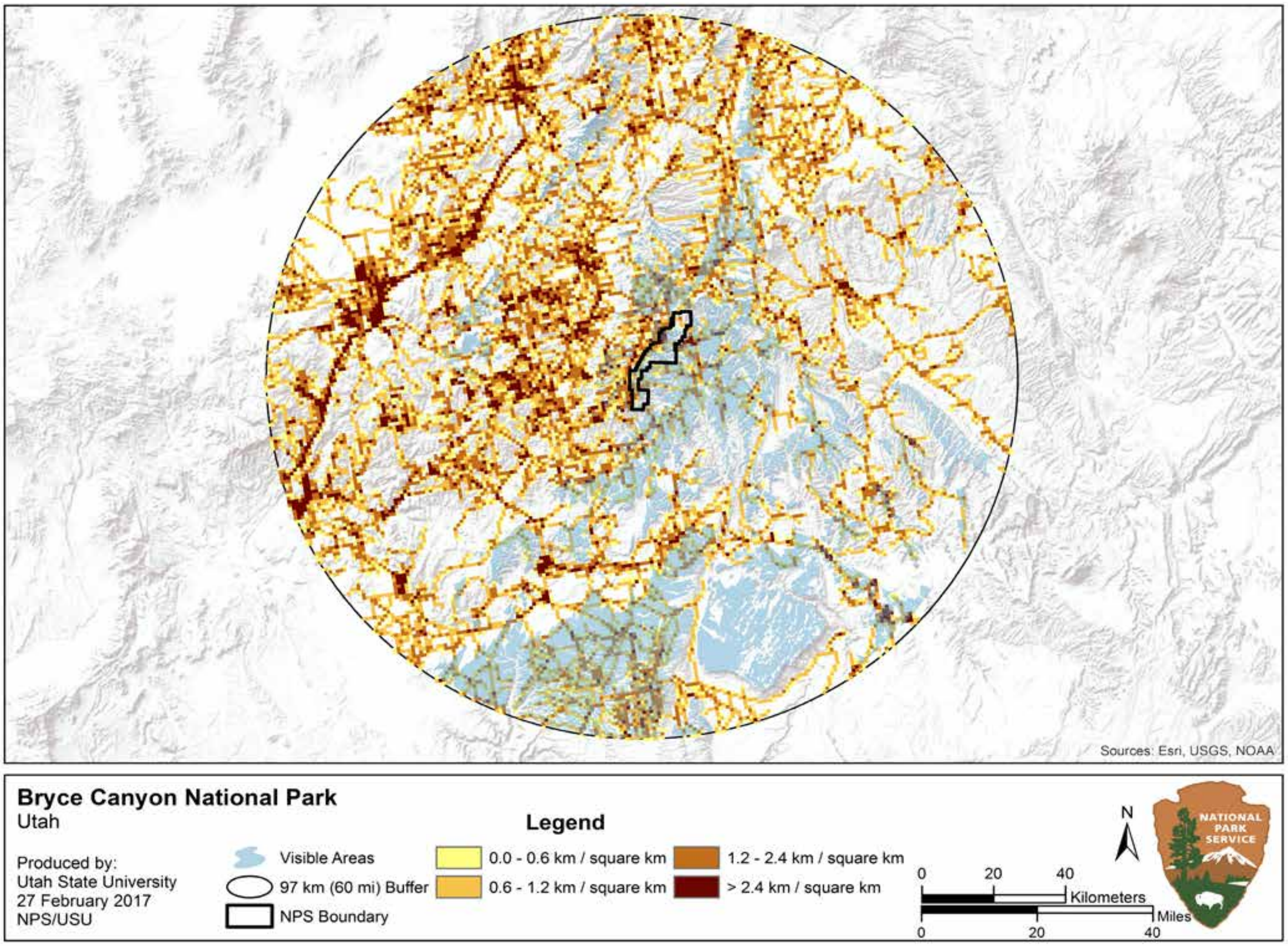

Figure C-2. **Road density and visible areas in and around Bryce Canyon NP.**

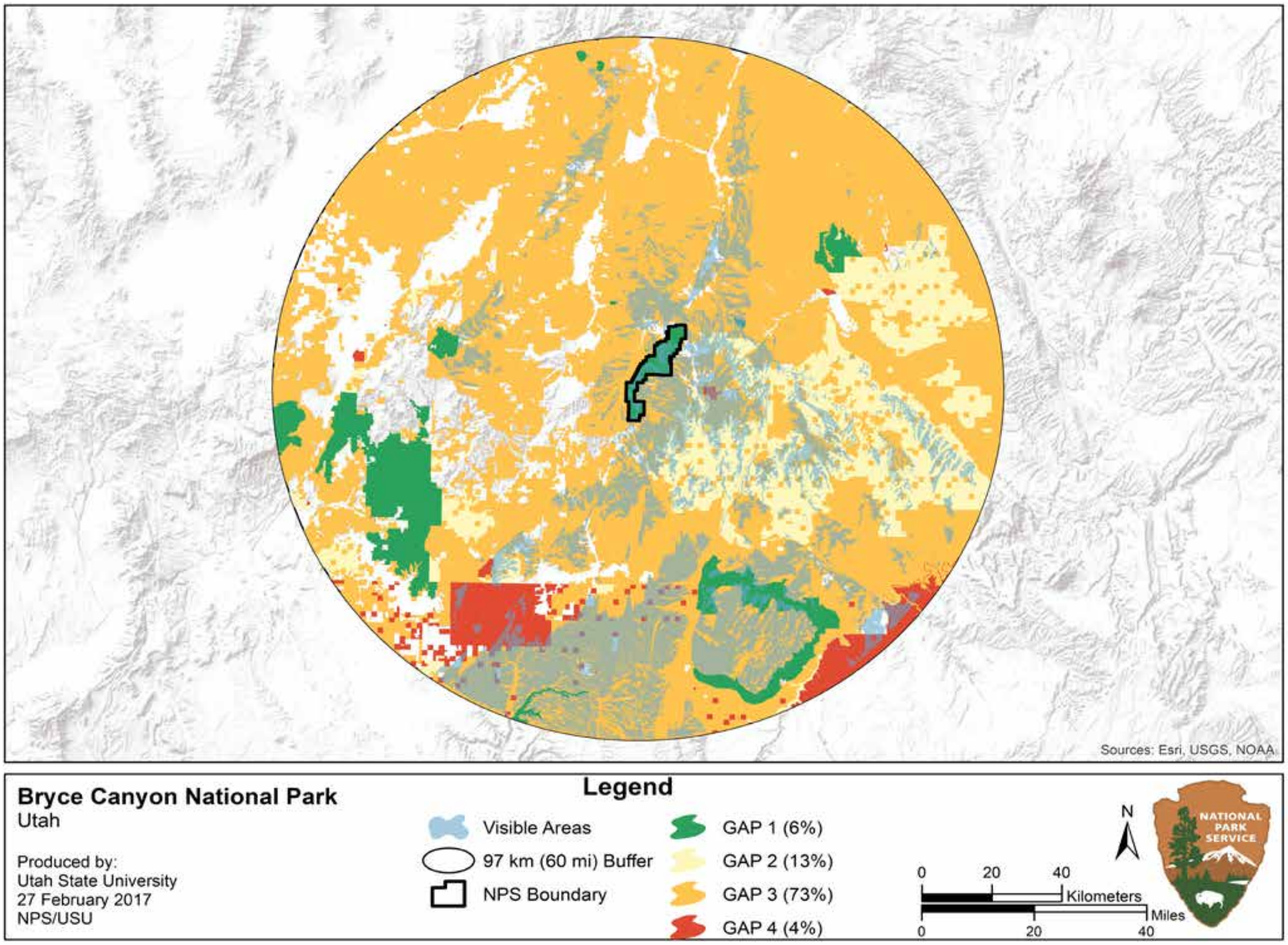

Figure C-3. **Map of GAP Status lands in and around Bryce Canyon NP.**

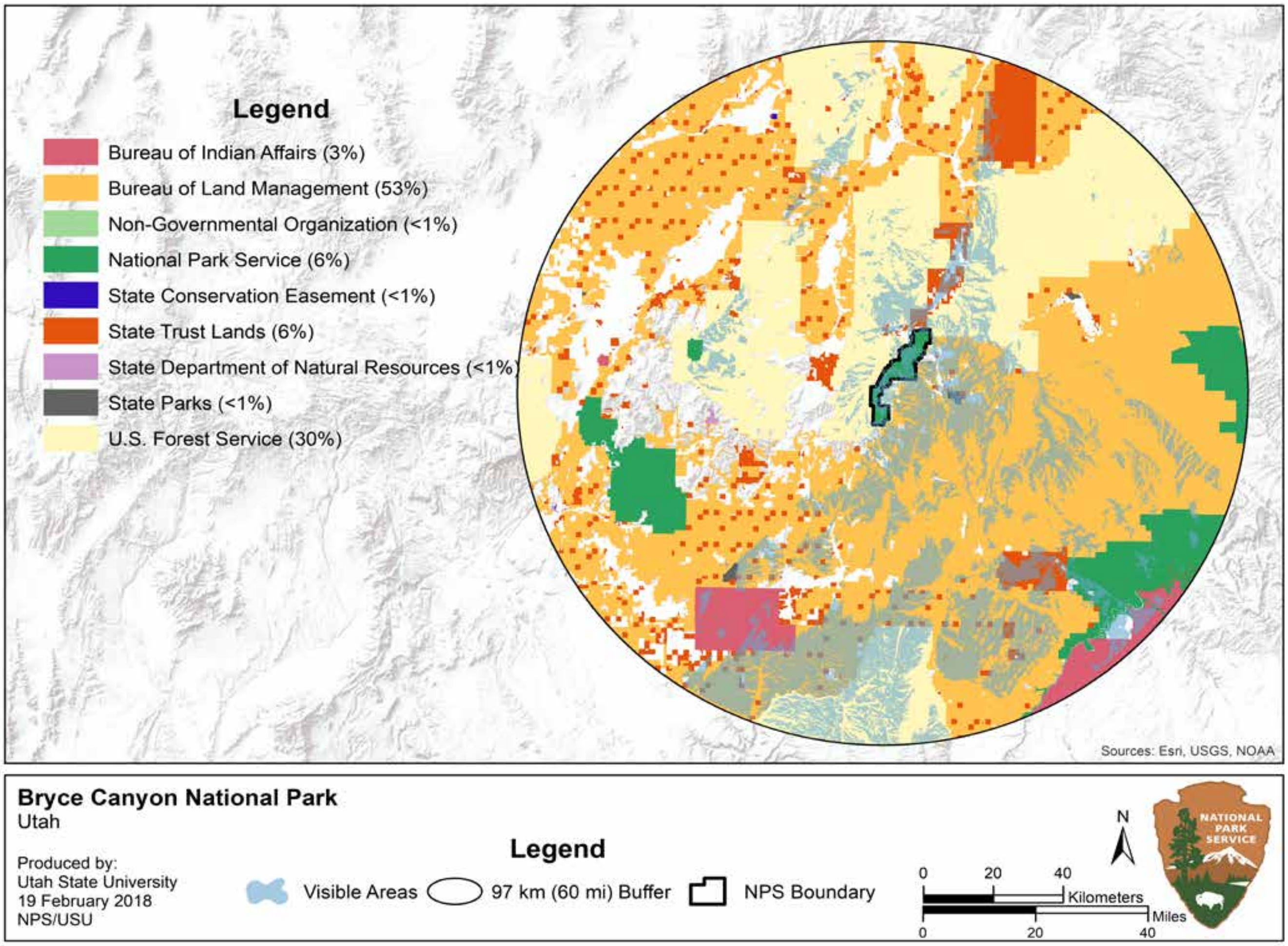

Figure C-4. **Types of and management agencies around Bryce Canyon NP.**

Appendix D. Night Sky Panoramas

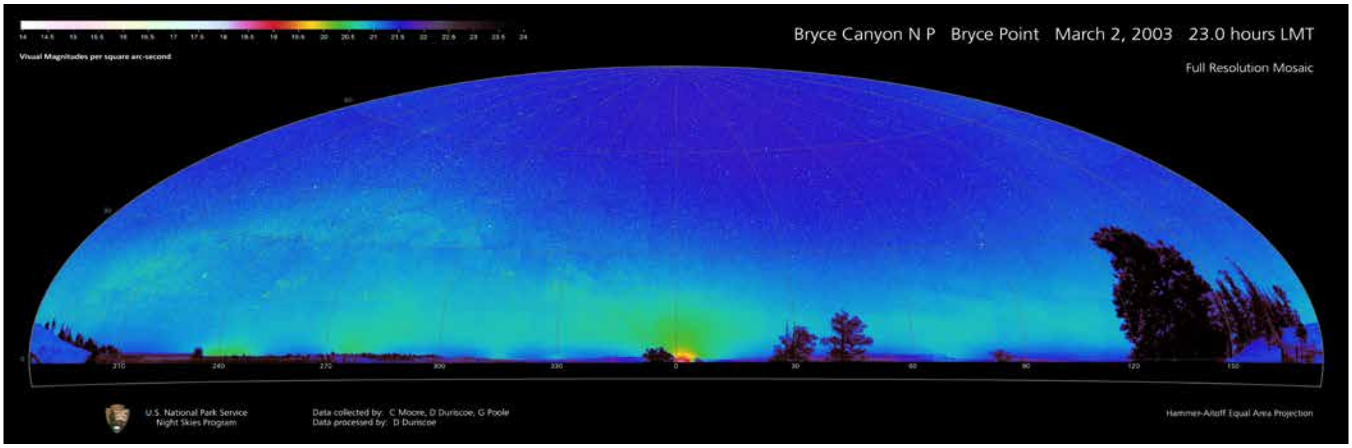

Figure D-1. Panoramic all-sky mosaic of all light sources on 2 March 2003 at Bryce Point. Light sources include natural and anthropogenic. Figure Credit: NPS Natural Sounds and Night Skies Division.

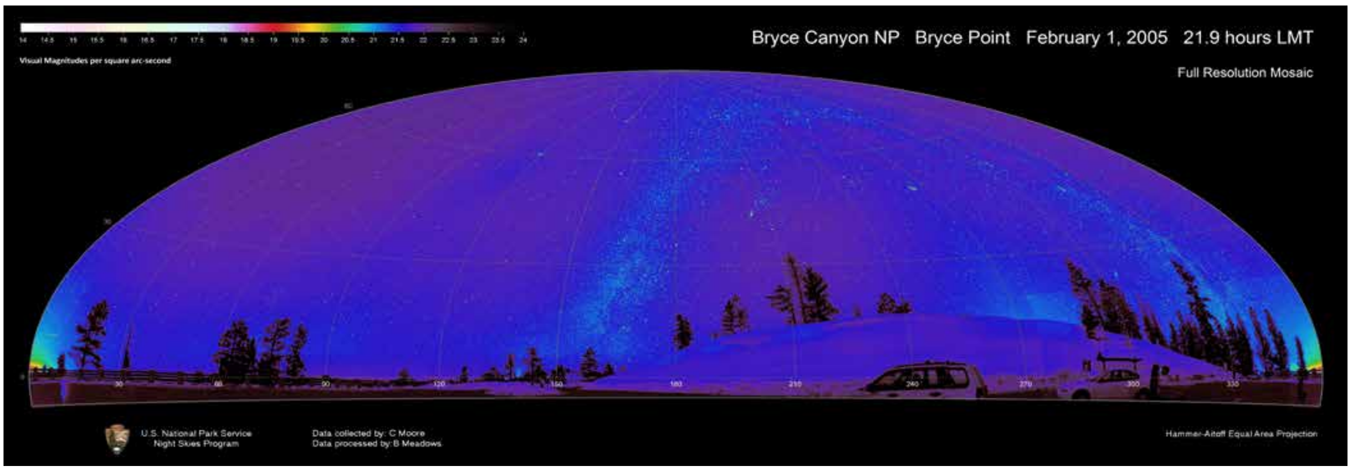

Figure D-2. Panoramic all-sky mosaic of all light sources on 1 February 2005 at Bryce Point. Light sources include natural and anthropogenic. Figure Credit: NPS Natural Sounds and Night Skies Division.

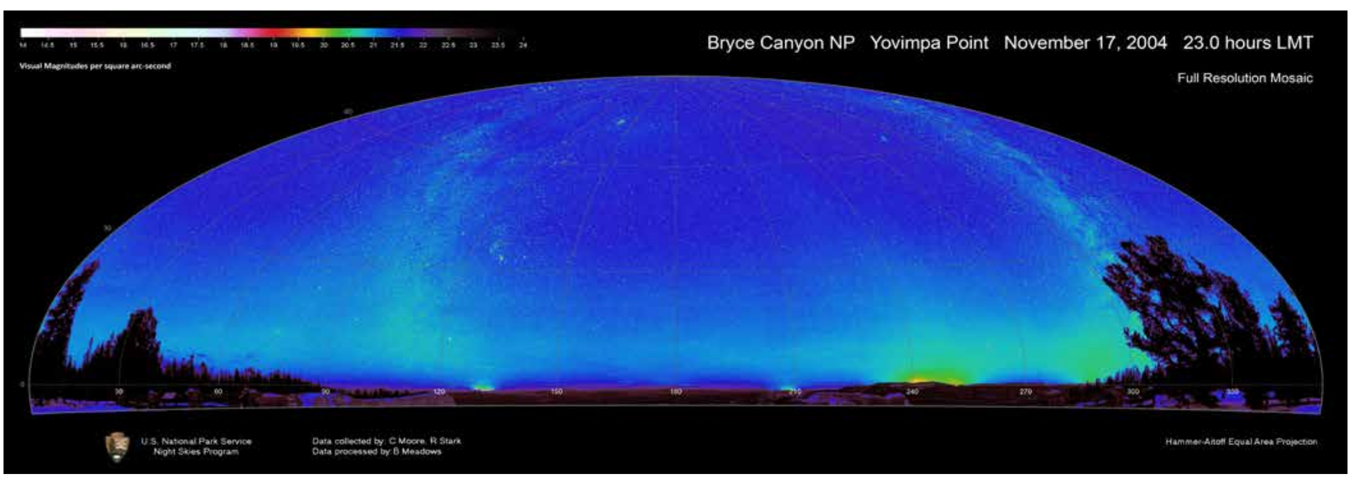

Figure D-3. Panoramic all-sky mosaic of all light sources on 17 November 2004 at Yovimpa Point. Light sources include natural and anthropogenic. Figure Credit: NPS Natural Sounds and Night Skies Division.

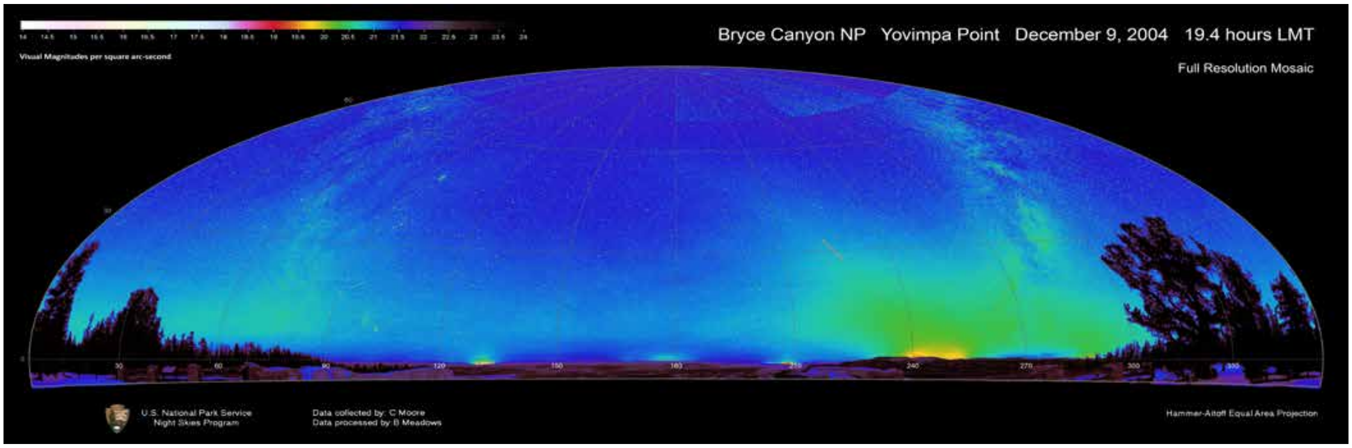

Figure D-4. **Panoramic all-sky mosaic of all light sources on 9 December 2004 at Yovimpa Point. Light sources include natural and anthropogenic. Figure Credit: NPS Natural Sounds and Night Skies Division.**

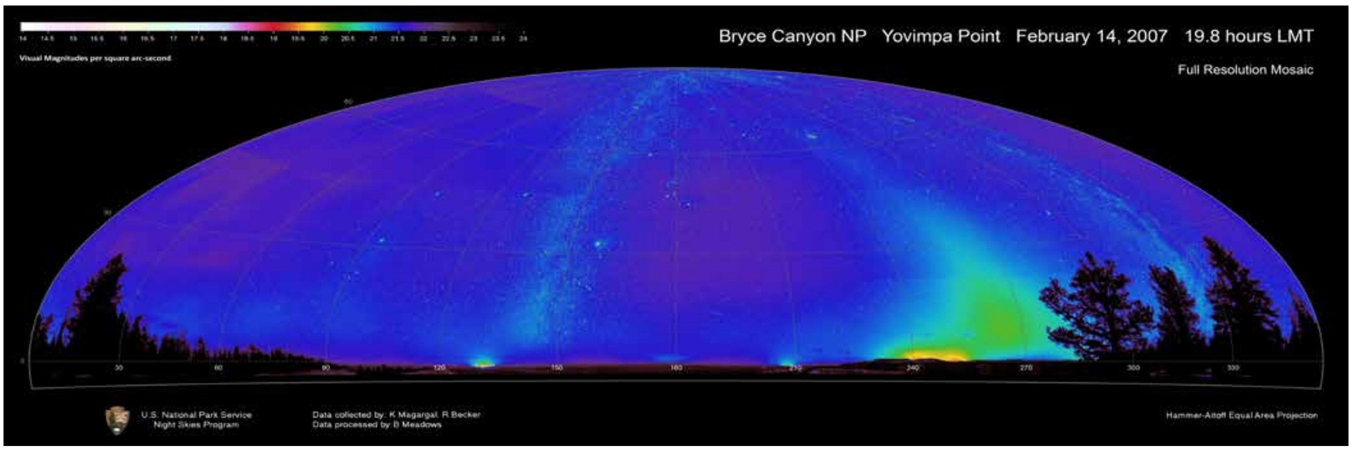

Figure D-5. **Panoramic all-sky mosaic of all light sources on 14 February 2007 at Yovimpa Point. Light sources include natural and anthropogenic. Figure Credit: NPS Natural Sounds and Night Skies Division.**

Figure D-6. **Panoramic all-sky mosaic of all light sources on 13 March 2007 at Yovimpa Point. Light sources include natural and anthropogenic. Figure Credit: NPS Natural Sounds and Night Skies Division.**

Appendix E. Bryce Canyon NP Soundscape Data

Listed below are the sound monitoring data by site and date used in the corresponding soundscape assessment. The data are separated by acoustic zone (i.e., frontcountry and backcountry) and were provided by Bryce Canyon NP natural resources staff.

Table E-1. Percent time above ambient daytime (7:00 am to 7:00 pm) and nighttime (7:00 pm to 7:00 am) sound levels at 21 sites in Bryce Canyon NP.

Park Area	Year	Site Name	Identifier	Daytime % Time Above dBA				Nighttime % Time Above dBA			
				35	45	52	60	35	45	52	60
Frontcountry	2009	Inspiration	13	20.45	1.79	0.20	0.01	5.53	0.24	0.02	0.00
	2010	Inspiration	18	33.88	2.81	0.27	0.03	18.77	0.34	0.01	0.00
	2009	Inspiration	14	5.74	0.47	0.07	0.00	1.15	0.05	0.00	0.00
	2009	Sheep/Swamp	7	60.76	14.96	2.89	0.23	17.04	0.43	0.01	0.00
	2009	Yovimpa	8	31.95	3.13	0.36	0.02	32.72	2.66	0.16	0.00
	2010	Yovimpa	19	39.45	7.94	0.79	0.05	57.18	22.39	2.84	0.03
	2013	Yovimpa	43	52.29	11.95	0.64	0.02	64.80	34.69	2.58	0.00
	2010	Farview	17	77.48	29.73	3.99	0.11	72.13	37.38	5.64	0.06
	2010	Paria	16	74.35	27.09	3.55	0.10	69.41	33.98	4.66	0.02
	2010	Sunset Point	25	79.30	14.29	1.38	0.02	14.03	0.71	0.09	0.00
	2011	Sunset Point	26	81.66	17.32	1.86	0.04	32.03	2.97	0.20	0.00
	2012	Sunset Point	33	77.58	12.44	0.72	0.01	33.22	1.79	0.09	0.00
	2010	VC Meadow/ Visitor's Center	24	96.26	33.87	4.49	0.06	27.41	6.09	0.42	0.00
	2013	VC Meadow/ Visitor's Center	42	96.67	37.18	4.18	0.12	26.05	5.01	0.25	0.00
	2011	Bryce Creek	29	8.25	0.52	0.03	0.00	6.11	0.40	0.05	0.00
	2011	Bryce Point	27	62.88	14.20	2.35	0.06	45.90	12.90	2.08	0.02
	2011	Lodge	28	97.86	6.55	0.59	0.03	91.52	2.98	0.50	0.02
	2011	Mixing Circle	30	24.43	2.81	0.46	0.06	7.57	0.80	0.16	0.02
	2011	Peek-a-Boo!	31	11.74	0.88	0.11	0.00	2.06	0.09	0.00	0.00
	2012	Bryce Point Junction	39	88.71	52.87	16.96	1.89	20.58	8.43	1.27	0.08
	2012	Fairyland	36	33.12	3.09	0.28	0.01	9.51	0.40	0.03	0.00
	2012	Sunset Campground	35	73.71	5.97	0.34	0.00	29.41	1.76	0.22	0.00
Backcountry	2009	Paria	9	22.51	2.88	0.56	0.01	61.12	0.80	0.00	0.00
	2009	Yovimpa	12	18.06	1.01	0.18	0.01	16.17	0.33	0.01	0.00
	2010	Farview	22	11.75	1.16	0.10	0.00	2.30	0.13	0.00	0.00
	2010	Paria	20	35.57	3.04	0.23	0.00	5.61	0.20	0.00	0.00
	2010	Sheep/Swamp	21	29.25	1.82	0.13	0.00	3.59	0.05	0.00	0.00
	2010	Yovimpa	23	82.34	1.96	0.26	0.01	95.20	0.21	0.01	0.00
	2012	Riggs Spring	34	25.42	1.04	0.07	0.00	10.11	0.24	0.01	0.00
	2013	Riggs Spring	40	27.42	4.62	0.47	0.02	3.23	0.14	0.00	0.00
	2012	Sheep Creek Flat	37	5.41	0.64	0.13	0.00	1.13	0.03	0.00	0.00
	2012	Yovimpa Pass	38	19.03	1.44	0.16	0.01	2.34	0.14	0.01	0.00
	2013	Yovimpa Pass	41	22.25	1.16	0.08	0.00	2.52	0.13	0.01	0.00

Table E-2. Natural and existing ambient sound L_{50} sound levels in Bryce Canyon NP.

Park Area	Year	Site Name	Identifier	Natural Ambient L_{50} (dBA)	Existing Ambient L_{50} (dBA)
Frontcountry	2009	Inspiration	13	23.7	28 (63%)
	2010	Inspiration	18	27	32.4 (71%)
	2009	Sheep/Swamp	7	32	37.4 (71%)
	2009	Inspiration	14	18.7	21.7 (50%)
	2009	Yovimpa	8	27.1	30.6 (55%)
	2010	Yovimpa	19	29.1	33.4 (63%)
	2013	Yovimpa	43	–	37.8
	2010	Farview	17	37.4	42.1 (66%)
	2010	Paria	16	39	41 (37%)
	2011	Bryce Creek	29	20.4	25.1 (66%)
	2011	Peak-a-Boo!	31	22.8	25.9 (51%)
	2012	Bryce Point Junction	39	28.9	45.7 (98%)
	2012	Fairyland	36	–	32.1
	2012	Sunset Campground	35	–	38.2
	2012	Sunset Point	33	29.6	39.3 (89%)
	2013	VC Meadow/Visitor's Center	42	36.4	43.8 (82%)
Backcountry	2009	Paria	9	27.9	28.5 (13%)
	2009	Yovimpa	12	24.5	26.1 (31%)
	2010	Fariview	22	21.5	23.7 (40%)
	2010	Paria	20	31.2	32.4 (24%)
	2010	Sheep/Swamp	21	28.9	31.2 (41%)
	2010	Yovimpa	23	36.2	36.5 (8%)
	2012	Sheep Creek Flat	37	18.0	20.9 (49%)
	2012	Yovimpa Pass	38	–	26.6
	2013	Yovimpa Pass	41	26.0	28.7 (46%)
	2013	Riggs Spring	34	29.1	31.2 (38%)
	2013	Riggs Spring	40	27.9	30.4 (44%)

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

Table E-3. Results of off-site listening.

Park Area	Year	Site Name	Identifier	Daytime Extrinsic	Nighttime Extrinsic	People	Vehicles	Jets	Fixed-Wing	Helicopters
Frontcountry	2009	Inspiration	13	63.21	31.43	14.90	10.89	24.26	4.54	0.07
	2010	Inspiration	18	68.10	37.15	15.70	25.42	18.55	2.42	0.10
	2009	Inspiration	14	57.41	30.34	5.30	13.07	25.56	3.10	0.00
	2009	Sheep/Swamp	7	75.38	32.05	6.90	35.90	19.10	1.00	0.00
	2009	Yovimpa	8	50.21	15.17	6.27	7.49	17.34	3.13	0.02
	2010	Yovimpa	19	64.98	17.65	7.18	15.43	18.34	2.57	0.00
	2010	Farview	17	60.56	17.18	0.50	24.90	16.01	1.66	0.00
	2010	Paria	16	31.99	16.01	0.41	6.85	17.22	0.97	0.00
	2010	Sunset Point	25	95.90	64.98	20.20	60.70	7.86	0.60	0.00
	2011	Sunset Point	26	94.54	80.18	21.41	66.26	9.07	1.01	0.00
	2012	Sunset Point	33	98.92	66.39	27.80	70.59	24.95	1.42	0.17
	2010	VC Meadow/Visitor's Center	24	99.06	75.52	9.92	78.56	6.96	0.38	0.00
	2013	VC Meadow/Visitor's Center	42	95.35	99.72	7.42	72.25	6.60	0.00	0.14
	2011	Bryce Creek	29	78.43	40.18	42.22	7.36	24.89	2.33	0.05
	2011	Bryce Point	27	92.83	38.93	47.60	48.50	10.10	1.70	0.10
	2011	Lodge	28	98.55	99.08	32.10	63.50	8.00	1.10	0.00
	2011	Peek-a-Boo!	31	74.62	31.02	29.47	4.98	25.60	2.13	0.00
	2011	Mixing Circle	30	70.23	97.47	8.40	11.40	13.60	1.00	0.00
	2012	Bryce Point Junction	39	98.86	84.97	3.53	80.46	15.99	0.79	0.00
Backcountry	2009	Paria	9	15.80	7.36	0.25	0.00	9.74	1.61	0.00
	2009	Yovimpa	12	22.28	10.75	0.01	0.00	14.54	1.93	0.00
	2010	Farview	22	30.29	11.58	0.00	0.03	18.20	2.60	0.10
	2010	Paria	20	18.32	11.16	0.00	0.00	12.65	2.10	0.00
	2010	Sheep/Swamp	21	31.84	14.31	0.01	0.02	21.30	1.67	0.00
	2010	Yovimpa	23	20.75	9.42	0.00	0.00	12.50	2.50	0.00
	2012	Riggs Spring	34	30.49	20.88	0.00	0.20	22.08	3.18	0.02
	2013	Riggs Spring	40	35.48	27.88	1.17	0.53	27.92	1.50	0.01
	2012	Sheep Creek Flat	37	43.93	35.93	0.00	1.44	31.80	4.26	0.09
	2013	Yovimpa Pass	41	39.75	30.57	0.87	0.79	32.12	3.73	0.74

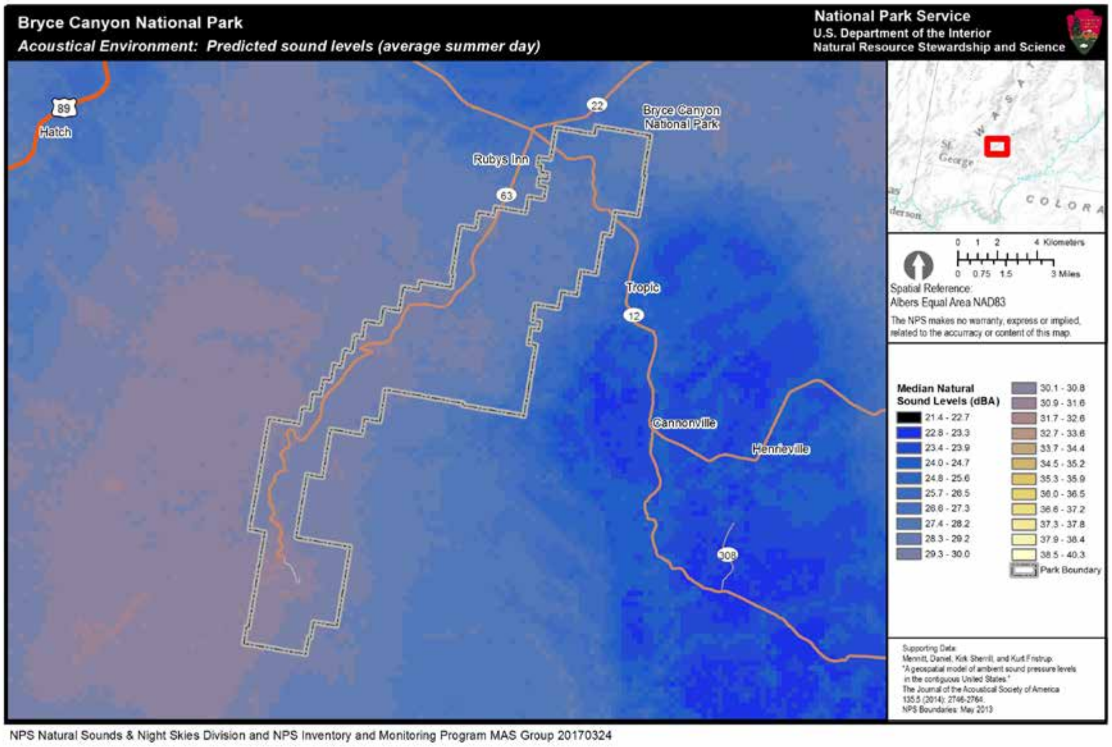

Figure E-1. Natural CONUS soundscape model zoomed to Bryce Canyon NP. Figure Credit: NPS Natural Sounds and Night Skies Division.

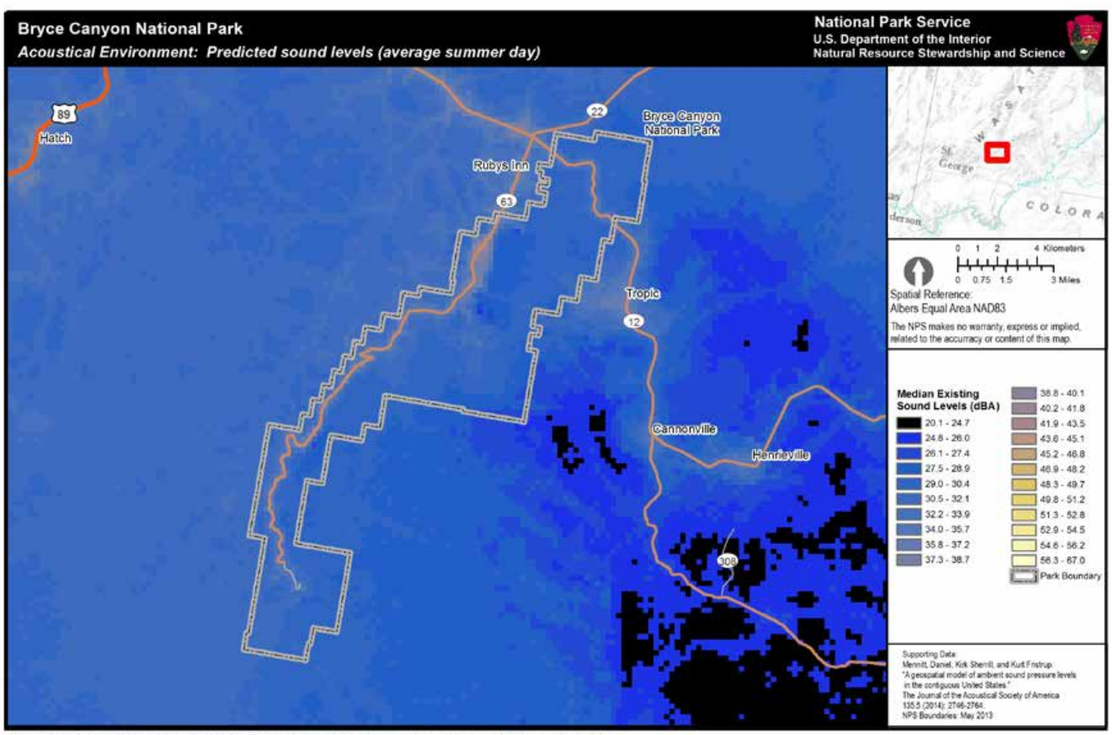

Figure E-2. Existing CONUS soundscape model zoomed to Bryce Canyon NP. Figure Credit: NPS Natural Sounds and Night Skies Division.

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 Bryce Canyon NP had a natural L_{50} dBA average of 29.0 (Figure E-1) and an existing L_{50} dBA average of 30.6 (Figure E-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 park's soundscape, which is the existing L_{50} dBA minus natural L_{50} dBA, was estimated to be an average of 1.7 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 park staff anticipate impacts by projecting future developments that have the potential to degrade soundscape condition.

Appendix F. Visibility Monitoring Images

Figure F-1. A view of Navajo Mountain with layered haze taken at 9:00 am on 10/29/1984.

Figure F-2. A scenic view of Navajo Mountain taken at 3:00 pm on 3/4/1992.

Figure F-3. A representative image of a clear day as seen from the webcam monitor at Yovimpa Point.

Figure F-4. A representative image of a hazy day as seen from the webcam monitor at Yovimpa Point.

Figure F-5. A representative image of night sky visibility as seen from monitor near Yovimpa Point.

Appendix G. Upland Vegetation: 2015-2016 Data

The following tables include 2015 and 2016 upland vegetation data collected at Bryce Canyon National Park by the Northern Colorado Plateau Inventory and Monitoring Network. Data collected in 2015 represent the first year of the second round of sampling in the park and were therefore not included in the upland vegetation assessment. Details on data collection methods and locations are provided in Witwicki (2012) and Witwicki et al. (2013).

G-1. Density of trees for plots sampled during 2015-2016.

		Pinyon-Juniper Woodlands				Mixed Coniferous Forest			
Year	Size Class	Utah juniper	Rocky Mountain juniper	Two-needle pinyon	Ponderosa pine	White fir	Ponderosa pine	Quaking aspen	Douglas fir
2015	Seedlings (<2.5 cm)	183	267	190	178	3,283	267	433	500
	Saplings (2.5-5.0 cm)	69	67	74	0	180	20	0	16
	Saplings (5.1-10.0 cm)	97	40	114	0	130	0	0	56
	Saplings (10.01-15.0 cm)	40	67	114	40	70	40	0	16
	Trees (>15.0 cm)	219	32	112	112	120	56	0	37
2016	Seedlings (<2.5 cm)	107	183	289	293	3,644	100	520	560
	Saplings (2.5-5.0 cm)	90	120	120	80	520	0	0	20
	Saplings (5.1-10.0 cm)	80	80	160	120	267	0	0	40
	Saplings (10.01-15.0 cm)	80	100	128	40	147	0	0	20
	Trees (>15.0 cm)	195	64	119	122	100	35	0	32

Source: NCPN data.

G-2. Fuel volume and litter and duff depth for 2015 and 2016.

Forest Type	Fuel Volume (tonnes/ha)						Depth (cm)	
	Total	1-hr	10-hr	100-hr	1,000-hr Sound	1,000-hr Rotten	Litter	Duff
Pinyon-juniper Woodlands (2015)	19.13	0.45	2.02	2.45	11.88	2.34	0.94	0.33
Pinyon-juniper Woodlands (2016)	9.30	0.38	2.23	1.54	3.48	1.68	1.49	0.53
Mixed coniferous forest (2015)	87.69	1.92	8.18	10.60	57.35	9.64	1.02	0.58
Mixed coniferous forest (2016)	70.14	1.18	4.41	4.31	55.65	4.60	0.74	0.40

Source: NCPN data.

G-3. Crown health of trees in mixed coniferous forest plots sampled during 2015 and 2016.

Year	Proportion Live (%)	White fir	Ponderosa pine	Quaking aspen	Douglas fir
2015	90-100	52	29	–	19
	50-89	24	33	–	13
	16-49	3	24	–	17
	0.1-15	0	0	–	2
	Standing Dead	21	15	–	50
2016	90-100	27	8	0	15
	50-89	25	23	0	8
	16-49	5	7	0	19
	0.1-15	0	0	0	1
	Standing Dead	43	29	100	58

Source: NCPN data.

G-4. Crown health of trees in pinyon-juniper woodlands plots sampled during 2015 and 2016.

Year	Crown Health	Utah juniper	Rocky Mountain juniper	Two-needle pinyon	Ponderosa pine
2015	Live Cover	87	100	88	79
	Standing Dead	13	0	12	21
2016	Live Cover	89	100	88	77
	Standing Dead	11	0	12	23

Source: NCPN data.

G-5. Soil stability class for plots sampled during 2015 and 2016 in pinyon-juniper woodlands.

Year	Total Mean	Mean Protected	Mean Unprotected
2015	3.3	3.9	3.1
2016	2.9	3.5	2.7

Source: NCPN data.

Appendix H. Bryce Canyon NP Bird List

Listed in the table below are the bird species recorded at Bryce Canyon National Park (NP) according to: a study of nesting birds in ponderosa pine (*Pinus ponderosa*) habitat (Gerstenberg 1972); a summer 1982 (June-August) study of birds in all habitat types within the national park (Hallows 1982); a study similar to Hallows (1982), with observations from September of 1982 to August 1983 (Hallows 1983); the 2005-2015 Northern Colorado Plateau Inventory and Monitoring Network (NCPN) annual landbird monitoring surveys in pinyon-juniper and sage shrubland (McLaren and White 2016); and the NPSpecies list of birds for the park (NPS 2017a). The shaded rows represent the 137 species used to assess current condition. The last column in the table indicates whether NPS (2017a) notes the species as present, probably present, or unconfirmed in the national park. The NCPN surveys were conducted using standardized bird sampling methods. For descriptions of each survey effort, see the Data and Methods section of the birds condition assessment. Note that for the surveys conducted during the breeding season, the species observed were not necessarily breeding during the surveys in the park (although evidence of breeding was recorded for some species). Also, the Hallows (1983) and NPSpecies lists (NPS 2017a) included birds recorded outside of the breeding season. A total of 215 species are contained in the table.

Table H-1. Bird species list for Bryce Canyon NP.

Common Name	Scientific Name	Gerstenberg (1972)	Hallows (1982)	Hallows (1983)	McLaren and White (2016)	NPS (2017a) Occurrence
American avocet	*Recurvirostra americana*	–	–	–	–	Probably Present
American coot	*Fulica americana*	–	–	–	–	Present
American crow	*Corvus brachyrhynchos*	–	–	–	X	Present
American goldfinch	*Carduelis tristis*	–	–	–	X	Present
American kestrel	*Falco sparverius*	X	X	X	X	Present
American pipit	*Anthus rubescens*	–	–	–	–	Unconfirmed
American redstart	*Setophaga ruticilla*	–	–	–	–	Present
American robin	*Turdus migratorius*	X	X	X	X	Present
American three-toed woodpecker	*Picoides dorsalis*	–	–	–	–	Present
American tree sparrow	*Spizella arborea*	–	–	–	–	Unconfirmed
American white pelican	*Pelecanus erythrorhynchos*	–	–	–	–	Present
American wigeon	*Anas americana*	–	–	–	–	Present
Ash-throated flycatcher	*Myiarchus cinerascens*	–	X	–	X	Present
Bald eagle	*Haliaeetus leucocephalus*	–	–	–	–	Present
Band-tailed pigeon	*Patagioenas fasciata*	–	X	X	–	Present
Barn swallow	*Hirundo rustica*	–	X	X	X	Present
Belted kingfisher	*Ceryle alcyon*	–	–	–	–	Probably Present
Bewick's wren	*Thryomanes bewickii*	–	–	–	X	Present
Black rosy-finch	*Leucosticte atrata*	–	–	–	–	Present
Black-bellied plover	*Pluvialis squatarola*	–	–	–	–	Present
Black-billed magpie	*Pica hudsonia*	–	–	X	X	Present
Black-capped chickadee	*Poecile atricapillus*	–	X	X	X	Present
Black-chinned hummingbird	*Archilochus alexandri*	–	X	X	X	Present
Black-chinned sparrow	*Spizella atrogularis*	–	–	–	–	Present
Black-crowned night-heron	*Nycticorax nycticorax*	–	–	–	–	Probably Present

[1] Species is non-native.

[2] One individual (an immature bird) was recorded by Hallows (1983) and noted as "accidental."

[3] Western scrub-jay was recently split into two species; Woodhouse's scrub-jay occurs in Arizona.

[4] Species was recorded by both Hallows (1982) and Hallows (1983), but NPS (2017) notes the species as "not in the park."

Note: X = Present.

Table H-1 continued. **Bird species list for Bryce Canyon NP.**

Common Name	Scientific Name	Gerstenberg (1972)	Hallows (1982)	Hallows (1983)	McLaren and White (2016)	NPS (2017a) Occurrence
Black-headed grosbeak	*Pheucticus melanocephalus*	–	X	X	X	Present
Black-necked stilt	*Himantopus mexicanus*	–	–	–	–	Probably Present
Black-throated gray warbler	*Dendroica nigrescens*	–	X	X	X	Present
Black-throated sparrow	*Amphispiza bilineata*	–	X	X	–	Present
Blue grosbeak	*Passerina caerulea*	–	–	–	–	Probably Present
Blue-gray gnatcatcher	*Polioptila caerulea*	–	X	X	X	Present
Blue-winged teal	*Anas discors*	–	–	–	–	Present
Bohemian waxwing	*Bombycilla garrulus*	–	–	–	–	Probably Present
Brewer's blackbird	*Euphagus cyanocephalus*	–	X	X	X	Present
Brewer's sparrow	*Spizella breweri*	–	X	X	X	Present
Broad-tailed hummingbird	*Selasphorus platycercus*	X	X	X	X	Present
Brown creeper	*Certhia americana*	–	X	X	X	Present
Brown-headed cowbird	*Molothrus ater*	X	X	X	X	Present
Bufflehead	*Bucephala albeola*	–	–	–	–	Probably Present
Bullock's oriole	*Icterus bullockii*	–	–	–	X	Present
Bushtit	*Psaltriparus minimus*	–	X	X	X	Present
California condor	*Gymnogyps californianus*	–	–	–	–	Present
California gull	*Larus californicus*	–	–	–	–	Probably Present
Calliope hummingbird	*Stellula calliope*	–	–	–	–	Present
Canada goose	*Branta canadensis*	–	–	–	–	Present
Canyon wren	*Catherpes mexicanus*	–	X	X	X	Present
Cassin's finch	*Carpodacus cassinii*	X	X	X	X	Present
Cassin's kingbird	*Tyrannus vociferans*	–	–	–	–	Probably Present
Cedar waxwing	*Bombycilla cedrorum*	–	–	–	X	Present
Chipping sparrow	*Spizella passerina*	X	X	X	X	Present
Chukar [1]	*Alectoris chukar* [1]	–	–	–	–	Probably Present
Cinnamon teal	*Anas cyanoptera*	–	–	–	–	Present
Clark's nutcracker	*Nucifraga columbiana*	–	X	X	X	Present
Cliff swallow	*Petrochelidon pyrrhonota*	–	X	X	X	Present
Common goldeneye	*Bucephala clangula*	–	–	–	–	Probably Present
Common loon	*Gavia immer*	–	–	–	–	Probably Present
Common merganser	*Mergus merganser*	–	–	–	–	Present
Common nighthawk	*Chordeiles minor*	–	X	X	–	Present
Common poorwill	*Phalaenoptilus nuttallii*	–	X	–	X	Present
Common raven	*Corvus corax*	–	X	X	X	Present
Common snipe	*Gallinago gallinago*	–	–	–	–	Probably Present
Common yellowthroat	*Geothlypis trichas*	–	–	–	X	Present
Cooper's hawk	*Accipiter cooperii*	–	X	X	X	Present
Cordilleran flycatcher	*Empidonax occidentalis*	–	X	X	X	Present
Dark-eyed junco	*Junco hyemalis*	X	X	X	X	Present
Downy woodpecker	*Picoides pubescens*	–	–	–	X	Present

[1] Species is non-native.

[2] One individual (an immature bird) was recorded by Hallows (1983) and noted as "accidental."

[3] Western scrub-jay was recently split into two species; Woodhouse's scrub-jay occurs in Arizona.

[4] Species was recorded by both Hallows (1982) and Hallows (1983), but NPS (2017) notes the species as "not in the park."

Note: X = Present.

Table H-1 continued. Bird species list for Bryce Canyon NP.

Common Name	Scientific Name	Gerstenberg (1972)	Hallows (1982)	Hallows (1983)	McLaren and White (2016)	NPS (2017a) Occurrence
Dusky flycatcher	*Empidonax oberholseri*	–	X	X	X	Present
Dusky grouse	*Dendragapus obscurus*	–	X	X	X	Present
Eared grebe	*Podiceps nigricollis*	–	–	–	–	Present
European starling [1]	*Sturnus vulgaris* [1]	X	X	X	–	Present
Evening grosbeak	*Coccothraustes vespertinus*	X	–	X	X	Present
Ferruginous hawk	*Buteo regalis*	–	–	–	–	Probably Present
Flammulated owl	*Otus flammeolus*	–	–	–	–	Probably Present
Forster's tern	*Sterna forsteri*	–	–	–	–	Probably Present
Franklin's gull	*Larus pipixcan*	–	–	–	–	Probably Present
Gadwall	*Anas strepera*	–	–	–	–	Probably Present
Gambel's quail	*Callipepla gambelii*	–	–	–	X	Present
Golden eagle	*Aquila chrysaetos*	–	X	–	X	Present
Golden-crowned kinglet	*Regulus satrapa*	–	X	–	–	Present
Grace's warbler	*Setophaga graciae*	X	X	X	X	Present
Gray catbird	*Dumetella carolinensis*	–	–	–	–	Present
Gray flycatcher	*Empidonax wrightii*	–	X	X	X	Present
Gray jay	*Perisoreus canadensis*	–	–	–	–	Present
Gray vireo	*Vireo vicinior*	–	X	X	X	Present
Gray-crowned rosy-finch	*Leucosticte tephrocotis*	–	–	X	–	Present
Great blue heron	*Ardea herodias*	–	–	–	–	Probably Present
Great horned owl	*Bubo virginianus*	X	X	X	–	Present
Greater sage-grouse	*Centrocercus urophasianus*	–	–	–	–	Probably Present
Greater yellowlegs	*Tringa melanoleuca*	–	–	–	–	Present
Green-tailed towhee	*Pipilo chlorurus*	X	X	X	X	Present
Green-winged teal	*Anas crecca*	–	–	X	–	Present
Hairy woodpecker	*Picoides villosus*	X	X	X	X	Present
Hammond's flycatcher	*Empidonax hammondii*	–	X	X	X	Present
Hermit thrush	Catharus guttatus	–	X	X	X	Present
Hooded oriole	*Icterus cucullatus*	–	–	X [2]	–	Unconfirmed
Horned lark	*Eremophila alpestris*	–	X	–	X	Present
House finch	*Carpodacus mexicanus*	X	X	X	X	Present
House sparrow [1]	*Passer domesticus* [1]	–	–	–	–	Present
House wren	*Troglodytes aedon*	X	X	–	X	Present
Indigo bunting	*Passerina cyanea*	–	–	–	–	Probably Present
Juniper titmouse	*Baeolophus ridgwayi*	–	X	X	X	Present
Killdeer	*Charadrius vociferus*	–	X	X	–	Present
Lark sparrow	*Chondestes grammacus*	–	–	–	X	Present
Lazuli bunting	*Passerina amoena*	–	X	X	–	Present
Least sandpiper	*Calidris minutilla*	–	–	–	–	Present
Lesser goldfinch	*Carduelis psaltria*	–	–	X	X	Present
Lesser scaup	*Aythya affinis*	–	–	–	–	Probably Present

[1] Species is non-native.

[2] One individual (an immature bird) was recorded by Hallows (1983) and noted as "accidental."

[3] Western scrub-jay was recently split into two species; Woodhouse's scrub-jay occurs in Arizona.

[4] Species was recorded by both Hallows (1982) and Hallows (1983), but NPS (2017) notes the species as "not in the park."

Note: X = Present.

Table H-1 continued. Bird species list for Bryce Canyon NP.

Common Name	Scientific Name	Gerstenberg (1972)	Hallows (1982)	Hallows (1983)	McLaren and White (2016)	NPS (2017a) Occurrence
Lesser yellowlegs	*Tringa flavipes*	–	–	–	–	Probably Present
Lewis' woodpecker	*Melanerpes lewis*	–	–	–	–	Unconfirmed
Lincoln's sparrow	*Melospiza lincolnii*	–	X	X	–	Present
Loggerhead shrike	*Lanius ludovicianus*	–	–	–	–	Present
Long-billed curlew	*Numenius americanus*	–	–	–	–	Present
Long-billed dowitcher	*Limnodromus scolopaceus*	–	–	–	–	Present
Long-eared owl	*Asio otus*	–	–	–	–	Present
MacGillivray's warbler	*Oporornis tolmiei*	–	–	X	–	Present
Mallard	*Anas platyrhynchos*	–	–	X	X	Present
Marsh wren	*Cistothorus palustris*	–	–	–	–	Present
Merlin	*Falco columbarius*	–	–	–	–	Present
Mountain bluebird	*Sialia currucoides*	–	X	X	X	Present
Mountain chickadee	*Poecile gambeli*	X	X	X	X	Present
Mourning dove	*Zenaida macroura*	X	X	X	X	Present
Nashville warbler	*Vermivora ruficapilla*	–	–	–	–	Present
Northern flicker	*Colaptes auratus*	X	X	X	X	Present
Northern goshawk	*Accipiter gentilis*	X	X	X	X	Present
Northern harrier	*Circus cyaneus*	–	–	–	X	Present
Northern mockingbird	*Mimus polyglottos*	–	–	–	X	Present
Northern pintail	*Anas acuta*	–	–	X	–	Present
Northern pygmy-owl	*Glaucidium gnoma*	–	–	–	–	Present
Northern rough-winged swallow	*Stelgidopteryx serripennis*	–	X	X	–	Present
Northern saw-whet owl	*Aegolius acadicus*	–	–	–	–	Present
Northern shoveler	*Anas clypeata*	–	–	–	–	Probably Present
Northern shrike	*Lanius excubitor*	–	–	–	–	Unconfirmed
Olive-sided flycatcher	*Contopus cooperi*	X	X	X	X	Present
Orange-crowned warbler	*Vermivora celata*	–	–	–	X	Present
Osprey	*Pandion haliaetus*	–	–	–	–	Present
Peregrine falcon	*Falco peregrinus*	–	X	X	X	Present
Pied-billed grebe	*Podilymbus podiceps*	–	–	–	–	Present
Pine grosbeak	*Pinicola enucleator*	–	–	–	–	Probably Present
Pine siskin	*Carduelis pinus*	X	X	X	X	Present
Pinyon jay	*Gymnorhinus cyanocephalus*	–	X	X	X	Present
Plumbeous vireo	*Vireo plumbeus*	X	X	–	X	Present
Prairie falcon	*Falco mexicanus*	–	X	X	X	Present
Pygmy nuthatch	*Sitta pygmaea*	X	X	X	X	Present
Red crossbill	*Loxia curvirostra*	X	X	X	X	Present
Red-breasted merganser	*Mergus serrator*	–	–	–	–	Probably Present
Red-breasted nuthatch	*Sitta canadensis*	–	X	–	X	Present
Redhead	*Aythya americana*	–	–	–	–	Probably Present

[1] Species is non-native.

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[3] Western scrub-jay was recently split into two species; Woodhouse's scrub-jay occurs in Arizona.

[4] Species was recorded by both Hallows (1982) and Hallows (1983), but NPS (2017) notes the species as "not in the park."

Note: X = Present.

Table H-1 continued. *Bird species list for Bryce Canyon NP.*

Common Name	Scientific Name	Gerstenberg (1972)	Hallows (1982)	Hallows (1983)	McLaren and White (2016)	NPS (2017a) Occurrence
Red-naped sapsucker	*Sphyrapicus nuchalis*	–	–	–	–	Present
Red-necked phalarope	*Phalaropus lobatus*	–	–	–	–	Probably Present
Red-tailed hawk	*Buteo jamaicensis*	–	X	X	X	Present
Red-winged blackbird	*Agelaius phoeniceus*	–	X	X	–	Present
Ring-billed gull	*Larus delawarensis*	–	–	–	–	Present
Ring-necked duck	*Aythya collaris*	–	–	–	–	Probably Present
Ring-necked pheasant [1]	*Phasianus colchicus* [1]	–	–	–	–	Probably Present
Rock pigeon	*Columba livia*	–	–	–	–	Unconfirmed
Rock wren	*Salpinctes obsoletus*	–	X	X	X	Present
Rose-breasted grosbeak	*Pheucticus ludovicianus*	–	X	–	–	Unconfirmed
Rough-legged hawk	*Buteo lagopus*	–	–	–	–	Present
Ruby-crowned kinglet	*Regulus calendula*	–	X	X	X	Present
Ruddy duck	*Oxyura jamaicensis*	–	–	–	–	Present
Rufous hummingbird	*Selasphorus rufus*	–	X	X	–	Present
Sage sparrow (now Bell's sparrow)	*Amphispiza belli*	–	–	–	–	Present
Sage thrasher	*Oreoscoptes montanus*	–	X	X	X	Present
Savannah sparrow	*Passerculus sandwichensis*	–	–	–	–	Unconfirmed
Say's phoebe	*Sayornis saya*	–	X	X	X	Present
Scott's oriole	*Icterus parisorum*	–	–	–	–	Present
Sharp-shinned hawk	*Accipiter striatus*	–	X	X	–	Present
Snow goose	*Chen caerulescens*	–	–	–	–	Unconfirmed
Snowy egret	*Egretta thula*	–	–	–	–	Probably Present
Solitary sandpiper	*Tringa solitaria*	–	–	–	–	Unconfirmed
Song sparrow	*Melospiza melodia*	–	X	X	–	Present
Sora	*Porzana carolina*	–	–	–	–	Probably Present
Southwestern willow flycatcher	*Empidonax traillii extimus*	–	–	–	–	Unconfirmed
Spotted sandpiper	*Actitis macularius*	–	–	–	–	Present
Spotted towhee	*Pipilo maculatus*	–	X	X	X	Present
Steller's jay	*Cyanocitta stelleri*	X	X	X	X	Present
Swainson's hawk	*Buteo swainsoni*	–	–	–	–	Present
Swainson's thrush	*Catharus ustulatus*	–	–	–	–	Probably Present
Tennessee warbler	*Vermivora peregrina*	–	–	–	–	Unconfirmed
Townsend's solitaire	*Myadestes townsendi*	X	X	X	X	Present
Townsend's warbler	*Dendroica townsendi*	–	X	–	–	Present
Tree swallow	*Tachycineta bicolor*	–	–	–	X	Present
Tundra swan	*Cygnus columbianus*	–	–	–	–	Probably Present
Turkey vulture	*Cathartes aura*	–	–	–	X	Present
Veery	*Catharus fuscescens*	–	–	–	X	Present
Vesper sparrow	*Pooecetes gramineus*	–	X	X	X	Present
Violet-green swallow	*Tachycineta thalassina*	X	X	X	X	Present

[1] Species is non-native.

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[3] Western scrub-jay was recently split into two species; Woodhouse's scrub-jay occurs in Arizona.

[4] Species was recorded by both Hallows (1982) and Hallows (1983), but NPS (2017) notes the species as "not in the park."

Note: X = Present.

Table H-1 continued. Bird species list for Bryce Canyon NP.

Common Name	Scientific Name	Gerstenberg (1972)	Hallows (1982)	Hallows (1983)	McLaren and White (2016)	NPS (2017a) Occurrence
Virginia rail	*Rallus limicola*	–	–	–	–	Unconfirmed
Virginia's warbler	*Vermivora virginiae*	–	X	X	X	Present
Warbling vireo	*Vireo gilvus*	–	X	X	X	Present
Western bluebird	*Sialia mexicana*	X	X	X	X	Present
Western grebe	*Aechmophorus occidentalis*	–	–	–	–	Probably Present
Western kingbird	*Tyrannus verticalis*	–	X	–	X	Present
Western meadowlark	*Sturnella neglecta*	–	X	X	X	Present
Western sandpiper	*Calidris mauri*	–	–	–	–	Probably Present
Western screech-owl	*Megascops kennicottii*	–	–	–	–	Unconfirmed
Western tanager	*Piranga ludoviciana*	X	X	X	X	Present
Western wood-pewee	*Contopus sordidulus*	X	X	–	X	Present
White-breasted nuthatch	*Sitta carolinensis*	–	X	X	X	Present
White-crowned sparrow	*Zonotrichia leucophrys*	–	–	–	–	Present
White-faced ibis	*Plegadis chihi*	–	–	–	–	Probably Present
White-throated swift	*Aeronautes saxatalis*	–	X	X	X	Present
Wild turkey	*Meleagris gallopavo*	–	–	–	X	Present
Willet	*Catoptrophorus semipalmatus*	–	–	–	–	Probably Present
Williamson's sapsucker	*Sphyrapicus thyroideus*	X	X	X	X	Present
Willow flycatcher	*Empidonax traillii*	–	–	–	–	Present
Wilson's phalarope	*Phalaropus tricolor*	–	–	–	–	Present
Wilson's warbler	*Wilsonia pusilla*	–	X	–	–	Present
Winter wren	*Troglodytes troglodytes*	–	–	–	–	Present
Woodhouse's scrub-jay [3]	*Aphelocoma woodhouseii*	–	X	X	X	Present
Yellow warbler	*Setophaga petechia*	–	–	–	X	Present
Yellow-bellied sapsucker [4]	*Sphyrapicus varius*	–	X	X	–	Not In Park
Yellow-breasted chat	*Icteria virens*	–	–	–	–	Present
Yellow-headed blackbird	*Xanthocephalus xanthocephalus*	–	–	–	–	Present
Yellow-rumped warbler	*Setophaga coronata*	X	X	X	X	Present
TOTAL NUMBER	215 species	32	93	89	96	–

[1] Species is non-native.

[2] One individual (an immature bird) was recorded by Hallows (1983) and noted as "accidental."

[3] Western scrub-jay was recently split into two species; Woodhouse's scrub-jay occurs in Arizona.

[4] Species was recorded by both Hallows (1982) and Hallows (1983), but NPS (2017) notes the species as "not in the park."

Note: X = Present.

Appendix I. 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 Bryce Canyon National Park (NP) 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.

I.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 (ESA), 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 J. Utah Prairie Dog Roadkill Mortality Rate Analysis

The number of the road-killed Utah prairie dogs (UPD) in Bryce Canyon National Park (NP) has been recorded since 1978, except for seven years (1982, 1984, 1986-1990). Using the roadkill dataset, we calculated Bryce Canyon NP's UPD roadkill mortality rate and trend relative to the park's annual estimated population for two time periods (1978-2017, Figure J-1 and 1991-2017, Figure J-2). We selected 1991-2017 to eliminate the seven year data gap that occurred prior to 1991. Figures J-1 and J-2 include the combined spring counts for eight years when the East Creek Meadow colony, which is located on both park and U.S. Forest Service (USFS) lands, were counted as one colony instead of individual colonies. The U.S. Fish and Wildlife Service UPD reporting protocol is such that each land management agency is required to report its individual colony counts annually, so the eight years (1992, 1994-1999, 2002) of combined NPS/USFS East Creek Meadow colony counts represent exceptions to the reporting requirement.

The roadkill mortality rate trend from 1978-2017, which includes the combined park and USFS East Creek Meadow counts for eight years and a seven year data gap, shows a decreasing trend, meaning it's improving (Figure J-1). However, the roadkill mortality rate trend from 1991-2017, which also reflects the combined park and USFS East Creek Meadow counts for eight years, shows a increasing trend, meaning it's deteriorating (Figure J-2).

To evaluate how sensitive the roadkill mortality rate trend was to the eight years of combined NPS/USFS annual UPD counts, we omitted those numbers from the dataset and recalculated the roadkill mortality rate and trend from 1978-2017, Figure J-3 and 1991-2017, Figure J-4.

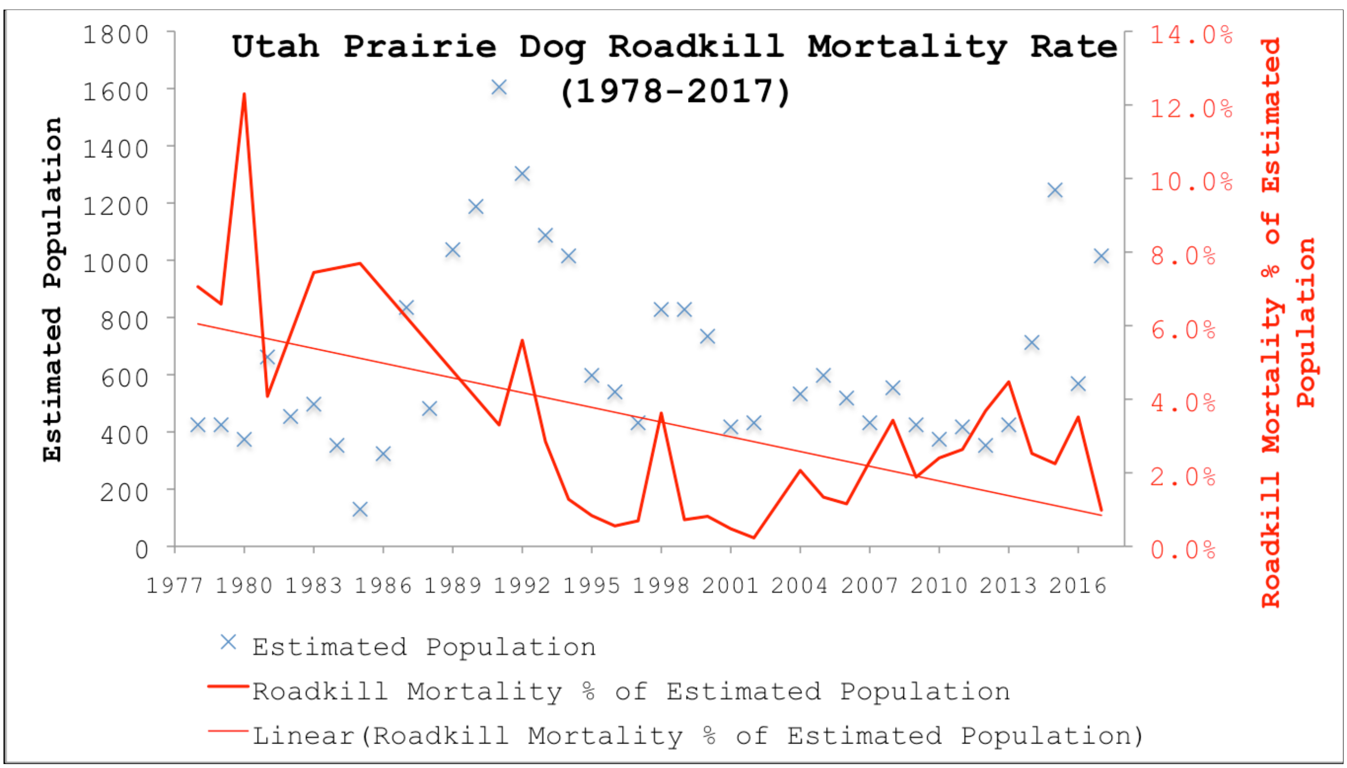

Figure J-1. Graph showing UPD road mortality rate from 1978-2017 for Bryce Canyon NP's UPD population, including East Creek Meadow USFS/NPS combined counts for eight years. Red line shows a decreasing mortality rate trend, meaning it's improving.

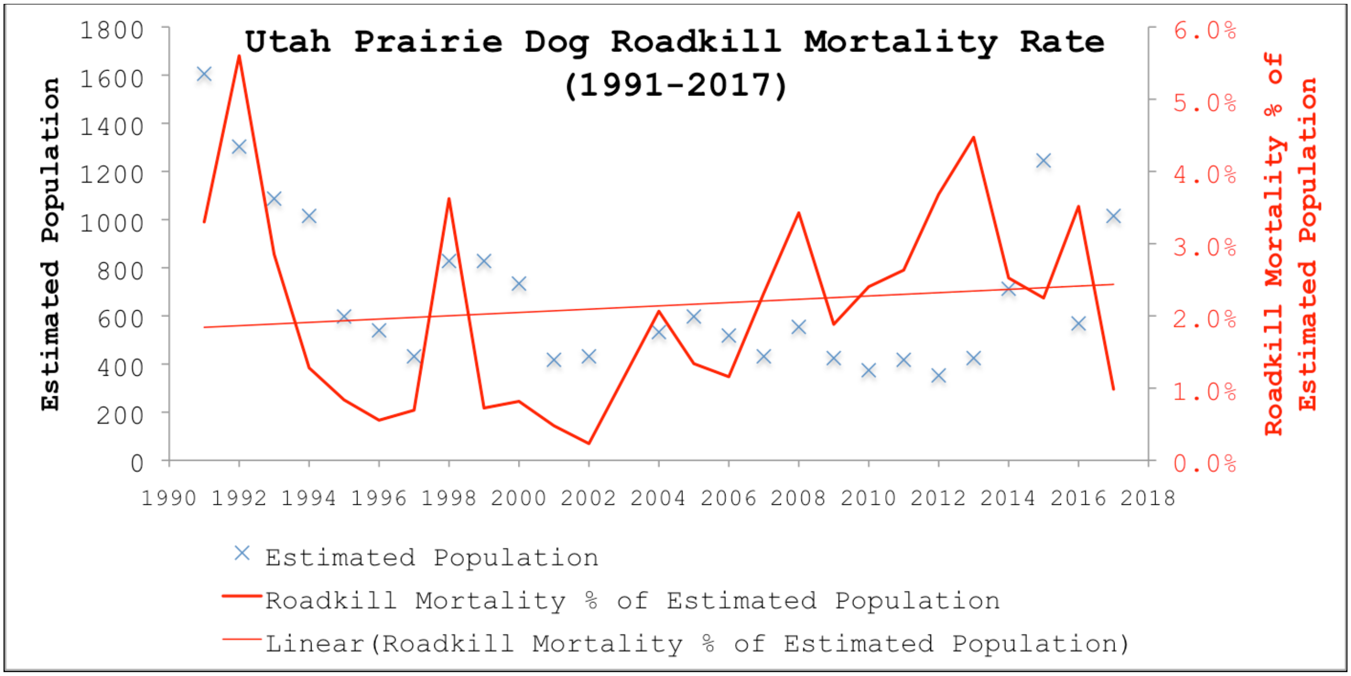

Figure J-2. Graph showing UPD road mortality rate from 1991-2017 for Bryce Canyon NP's UPD population, including East Creek Meadow USFS/NPS combined counts for eight years. Red line shows an increasing mortality rate trend, meaning it's deteriorating.

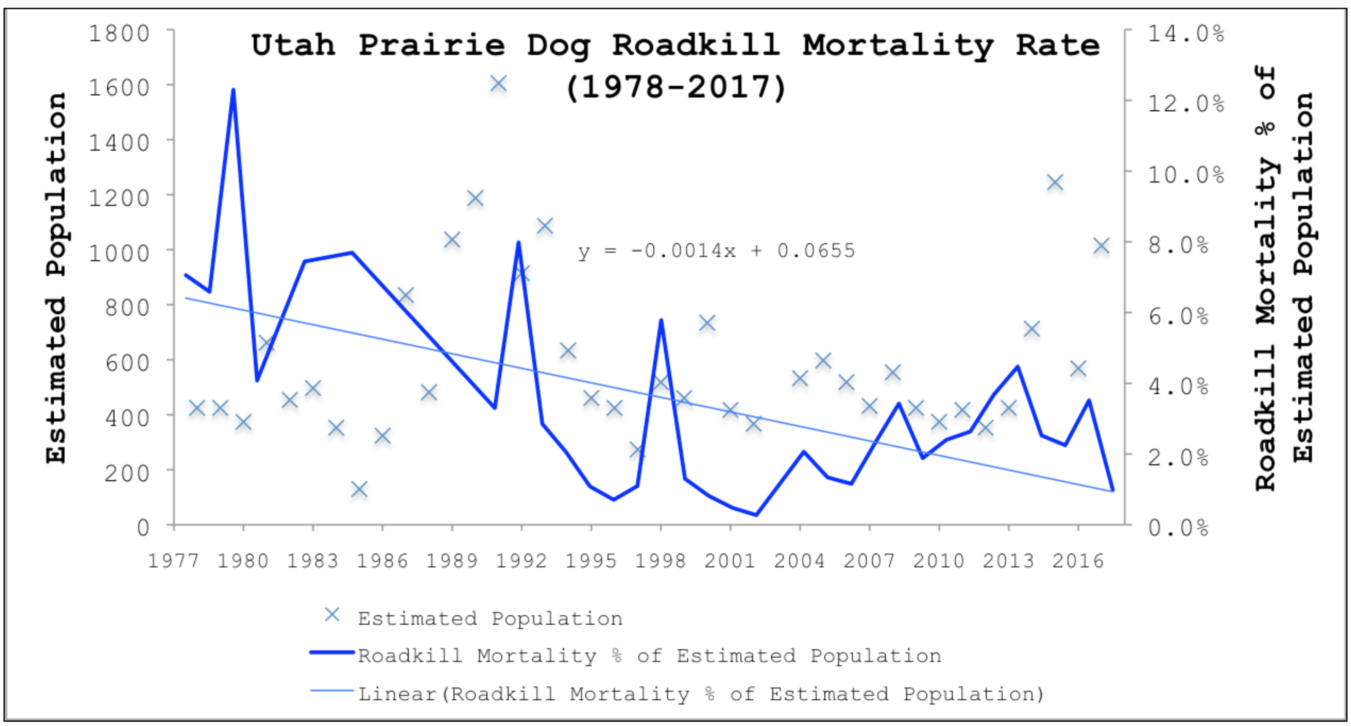

Figure J-3. Graph showing UPD road mortality rate from 1978-2017 for Bryce Canyon NP's UPD population except for East Creek Meadow USFS/NPS combined counts for eight years. Blue line shows decreasing mortality rate trend, meaning it's improving.

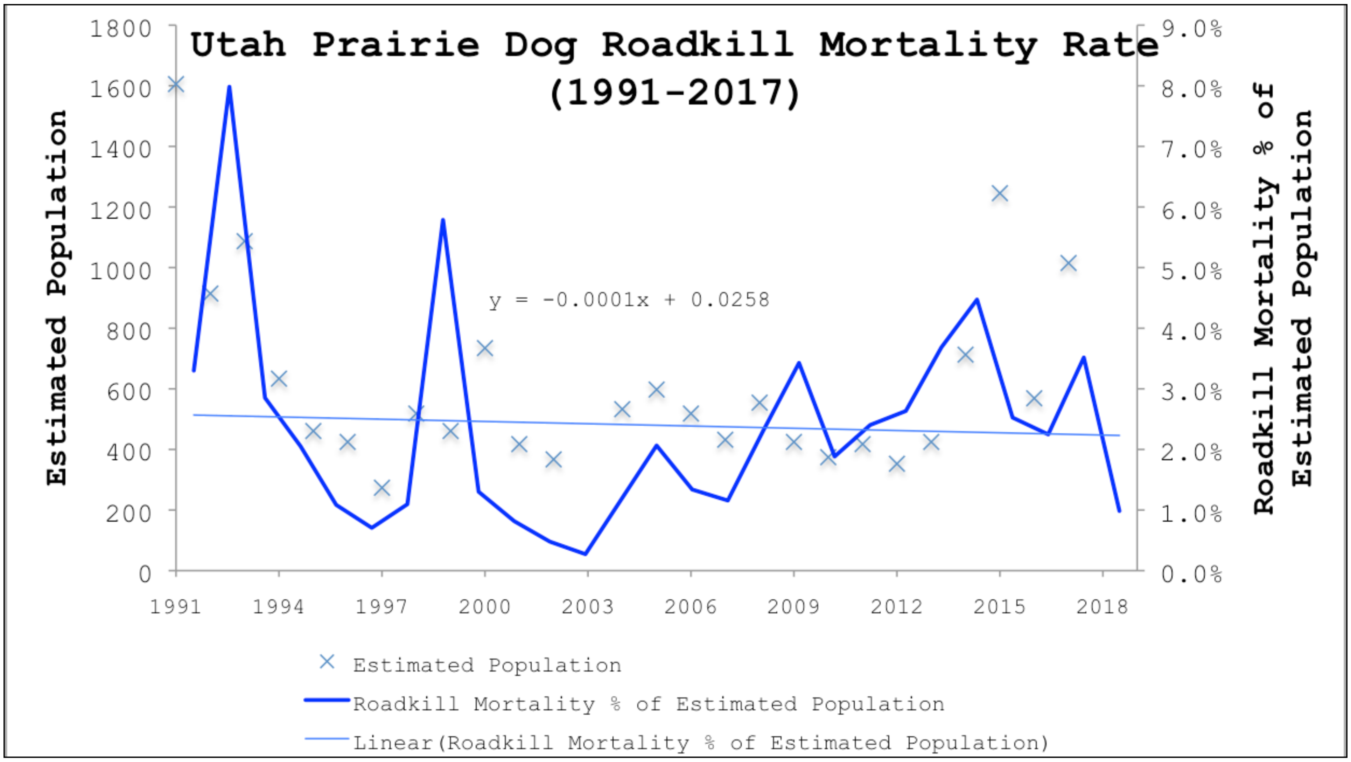

Figure J-4. Graph showing UPD road mortality rate from 1991-2017 for Bryce Canyon NP's UPD population except for East Creek Meadow USFS/NPS combined counts for eight years. Blue line shows a slightly decreasing mortality rate trend, meaning it's improving.

The roadkill mortality rate trend from 1978-2017, without the combined park and USFS East Creek Meadow counts for eight years, shows a decreasing trend, meaning it's improving (Figure J-3). The roadkill mortality rate trend from 1991-2017, without the combined park and USFS East Creek Meadow counts for eight years, shows a slightly decreasing trend, meaning it's improving (Figure J-4).

While the trends from 1978-2017 for the dataset with and without the combined NPS/USFS counts for East Creek Meadow remained the same (i.e., improving trend), the trends with and without the combined NPS/USFS counts from 1991-2017 were different. While we know that UPD roadkill under-reporting has occurred consistently and/or randomly over time, the combined annual counts did affect the 1991-2017 trend analysis; therefore, we reported an unknown condition and trend for the roadkill mortality rate measure. However, we believed this analysis and discussion was worth including for future reference.

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