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Natural Resource Condition Assessment, Scotts Bluff National Monument

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Natural Resource Stewardship and Science

Natural Resource Condition Assessment

Scotts Bluff National Monument

Natural Resource Report NPS/SCBL/NRR—2018/1682

ON THE COVER
Panorama of Scotts Bluff National Monument
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Natural Resource Condition Assessment

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The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

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Appendices

Executive Summary

In collaboration with the National Park Service, the University of Wyoming Ruckelshaus Institute of Environment and Natural Resources and the Wyoming Natural Diversity Database completed the Natural Resource Condition Assessment (NRCA) for Scotts Bluff National Monument (NM). The purpose of the NRCA is to provide park leaders and resource managers with information on resource conditions to support near-term planning and management, long-term strategic planning, and effective science communication to decision-makers and the public.

Scotts Bluff NM was established in 1919. The purposes of the park include protecting and preserving the Mitchell Pass portion of the Oregon Trail and the geologic features of the bluffs.

The assessment for Scotts Bluff NM began in 2015 with a facilitated discussion among park leadership and natural resource managers to identify high-priority natural resources and existing data with which to assess condition of those resources. Data were synthesized to evaluate each resource according to condition, trend in the condition, and confidence in the assessment. Natural resource conditions were the basis for a discussion with park leadership and natural resource managers, who then identified critical data gaps and management issues specific to Scotts Bluff NM. Resource experts, park staff, and network personnel reviewed this assessment.

Priority natural resources were grouped into three categories: Landscape Condition Context, Supporting Environment, and Biological Integrity.

The resources categorized as Landscape Condition Context included viewshed, night sky, and soundscape. At the time of this assessment, viewshed condition was of moderate concern and condition of night sky and soundscape warranted significant concern.

Supporting Environment—or physical environment—resources included air quality, surface water quality, geology, and paleontological resources. Air quality warranted moderate concern, and condition of surface water quality, geology, and paleontological resources warranted significant concern.

The natural resources that composed the Biological Integrity category included vegetation, birds, prairie dogs, and pollinators. Vegetation, prairie dogs, and pollinators were of moderate concern; we were unable to assign a condition to birds in the absence of specific management goals.

This assessment includes a general background on the NRCA process (Chapter 1), an introduction to Scotts Bluff NM and the natural resources included in the assessment (Chapter 2), a description of methods (Chapter 3), condition assessments for 11 natural resources (Chapter 4), and a summary of findings accompanied by management considerations (Chapter 5).

Acknowledgments

Many individuals contributed to this Natural Resource Condition Assessment. In particular, we thank Kara Paintner-Green, Network Coordinator in the Northern Great Plains Network of the National Park Service (NPS), and Carmen Thomson, Midwest Region Inventory Monitoring Program Manager of the NPS, for their guidance and review throughout the project. Bob Manasek, Resource Management Specialist at Scotts Bluff National Monument, provided site-specific details about natural resources that substantially improved the quality of this assessment, and Dan Morford, Superintendent of the Monument, provided input on data gaps and management implications. Subject matter experts were critical to this process and provided content review, technical expertise, and guidance on regulatory standards.

We extend particular thanks to Mark Meyer (NPS), Emma Brown (NPS), Ksienya Taylor (NPS), Rachel Benton (NPS), Isabel Ashton (NPS), Lusha Tronstad (Wyoming Natural Diversity Database), Dave Ihrie (Nebraska Department of Environmental Quality), Pete Penoyer (NPS), Isabel Ashton (NPS), Angela Jarding (NPS), Adam Green (Bird Conservancy of the Rockies), Tim Nuttle (Civil and Environmental Consultants, Inc.), Tim O'Connell (Oklahoma State University), Daniel Licht (NPS), Lyman McDonald (WEST, Inc.), and Dean Biggins (US Geologic Survey). Kim Messersmith, University of Wyoming Ruckelshaus Institute of Environment and Natural Resources, managed the financial side of this project, and we thank her for her work. Finally, we thank all other reviewers whose comments contributed to the quality of this assessment.

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 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*

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

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

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

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

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

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

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

understanding current conditions, and/or present-day threats and stressors that are best interpreted at park, watershed, or landscape scales (though NRCAs do not report on condition status for land areas and natural resources beyond park boundaries). Intensive cause-and-effect analyses of threats and stressors, and development of detailed treatment options, are outside the scope of NRCAs.

Due to their modest funding, relatively quick timeframe for completion, and reliance on existing data and information, NRCAs are not intended to be exhaustive. Their methodology typically involves an informal synthesis of scientific data and information from multiple and diverse sources. Level of rigor and statistical repeatability will vary by resource or indicator, reflecting differences in existing data and knowledge bases across the varied study components.

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

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

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*

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 an 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.

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)***

Over the next several years, the NPS plans to fund an NRCA project for each of the approximately 270 parks served by the NPS I&M Program. For more information visit the NRCA Program website.

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[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.

Chapter 2. Introduction and Resource Setting

Ridges and plains at Scotts Bluff National Monument. Photo © KAHYC7 2006.

2.1. Introduction

2.1.1. Enabling Legislation

Scotts Bluff National Monument was established on December 12, 1919, by Presidential Proclamation No. 1547 (41 Stat. 1779; Cockerell 1983). The purpose of the site is:

- To protect and preserve the historic Mitchell Pass portion of the Oregon Trail
- To protect and preserve the unique geologic features of the bluffs (NPS 2009).

2.1.2. Geographic Setting

Scotts Bluff NM is located in the western short grassland prairie of the Nebraska panhandle, approximately 20 miles east of the Nebraska-Wyoming state line. Bordered on the north by the North Platte River, the site is dominated by the Scotts Bluff geologic feature—a massive promontory rising nearly 800 feet above the Platte River Valley. Scotts Bluff NM is situated amid a 100-mile ridge of bluffs and is surrounded primarily by crop land and other agriculture (Cockerell 1983).

Nearby towns include Gering (three miles east) Scottsbluff (five miles northeast), and Mitchell (10 miles northwest). The monument represents a significant landmark for Native Americans and an important stop for emigrants traveling on the Oregon, California, and Mormon Trails.

2.1.3. Visitation Statistics

Annual visitation data for Scotts Bluff NM are available for 1920–2015. The total number of annual visitors ranged from 5,000 in 1920 to 217,522 in 1978, with an average of 99,814 visitors, annually. The number of recreation visitors in 2015 was 131,122. Visitation data by month are available for 1979–2015. Although there has been monthly variation by year, the months receiving the greatest number of average visitors over the recording period were June through August (NPS 2016).

2.2. Natural Resources

A summary of the natural resources at Scotts Bluff National Monument is presented in this section and includes information known prior to the completion of this condition assessment. Resource sections include: Viewshed, Night Sky, Soundscape, Air Quality, Surface Water Quality, Geology, Paleontological Resources, Vegetation, Birds, Prairie Dogs, Pollinators.

2.2.1. Ecological Units and Watersheds

Scotts Bluff NM is located in the Western Short Grassland ecoregion of the Northern Great Plains in the panhandle of western Nebraska. This ecoregion is distinguished from other grassland units by low rainfall, relatively long growing seasons, and warm temperatures, and is among the most biologically rich ecoregions in the United States for species of butterflies, birds, and mammals (Ricketts 1999).

2.2.2. Resource Descriptions

In this section we have summarized background information about key natural resources at Scotts Bluff NM. The assessment does not include all important resources present in the park, but focuses instead on particularly high priority resources as identified by park staff.

The descriptions included here are direct excerpts from the resource assessment sections in Chapter 4 of this NRCA. We have included these introductions to each resource verbatim, but have removed the literature citations for readability. Please refer to the full resource sections for appropriate literature citations and acknowledgment of intellectual property.

Viewshed

At Scotts Bluff NM, exposed geologic history, cultural landscapes, and expansive views of western Nebraska are an important part of the visitor experience. The landscapes in and around the park, including Scotts Bluff landmark and Chimney Rock, offer visitors an opportunity to enjoy a visual setting with features that served as landmarks for peoples from Native Americans to emigrants on the Oregon, California, and Mormon Trails. To settlers traveling along these migration trails, Scotts Bluff was more than a scenic feature of the western landscape; it was a guiding landmark that signaled the end of the plains and the beginning of the mountains on the journey west. Today the bluff is visible from miles away, as it was in the 1800s, and dominates the skyline within park unit boundaries. Views from the top of the bluff add to the aesthetic value of the park, and the preservation of these views is a high priority for the park unit.

Despite the preserved grandeur of the bluff itself, the landscapes of the region and the National Monument are now very different than they were 150 years ago. Tribes and early settlers would have likely seen mixed grassland prairie, once the dominant land cover in the region, stretching for miles in all directions. Most of the prairie has since been converted to agriculture or developed for residential and industrial use. A large portion of the native prairie in what is now Scotts Bluff NM has also been altered. Many of the natural processes that helped shape the landscape, such as grazing by bison, are now gone. These changes to the landscape likely affect visitor experience and visual interpretation of the historical features within the park unit.

Night Sky

Spectacular starry skies and dark nights are highlights of national parks for anyone who camps out or visits after dusk. The patterns among constellations are essentially the same ones that have been visible to humans for thousands of years, though the moon phase and position of celestial objects constantly change. More than a visual resource, dark skies play an important role in healthy ecosystems. The absence of light is important to nocturnal wildlife, light-sensitive amphibians, reptiles, insects, plants, and migrating birds requiring starry skies for navigation.

Natural nocturnal lightscapes are crucial to the integrity of park settings. Dark skies and natural lightscapes are necessary for both human and natural resource values in the parks. Limiting light pollution, caused by the introduction of artificial light into the environment, helps to ensure that this timeless resource will continue to be shared by future generations. Increases in light pollution in North America over the past century have placed the US as the country with the sixth greatest amount of light pollution, as of 2016. Night skies helped to guide early settlers, fur trappers, and traders to Nebraska, and park visitors can still come to Scotts Bluff NM for stargazing experiences.

A night sky talk took place at Scotts Bluff NM in 2015 for the first time and was attended by about thirty people. In 2016, the park unit ran a constellation program, and a planets program is schedule for late summer 2016 using the newly purchased Celestron telescope.

Soundscape

Visitors to national parks indicate that an important reason for visiting the parks is to enjoy the relative quiet that parks can offer. Sound also plays a critical role in intra- and inter-species communication, including courtship and mating, predation and predator avoidance, and effective use of habitat.

Scotts Bluff NM is surrounded by agricultural fields, residential areas, a golf course, the North Platte River, and some remnant prairie. Primary sources of non-natural sounds within the park include noise from the nearby cities of Scottsbluff and Gering, train traffic passing through the city, agricultural activities, automobile traffic within the park and on surrounding roads, and air traffic passing overhead.

Air Quality

Scotts Bluff NM is designated a Class II air quality area. This protective classification means that the NPS unit receives federal assistance to protect and improve its air quality. Similar to other small park units, many of the threats to clean air at Scotts Bluff NM come from pollution sources outside of park boundaries. As a result, protection and improvement of air quality within the park requires collaboration with other stakeholders. The Clean Air Act makes a provision for federal land managers to participate in regulatory decision making when protected federal lands, such as NPS units, might be affected. Participation may include consultations, written comments, recommendations, and review.

The American Lung Association compiles a State of the Air report for each state, and gives grades for air quality by county. Scotts Bluff NM is located in Scottsbluff County where there were not enough monitoring data from 2013–2015 to assign a grade for ozone pollution, but short-term particle pollution received the best possible grade (A) for that time period. Three of Nebraska's 93 counties had sufficient data for the ALA to assign an overall grade to ozone pollution, and six counties received a grade for particle pollution; grades ranged from A to C, indicating heterogeneity in air quality.

Surface Water Quality

Surface waters form complex ecosystems that support a vast number of uses. They provide critical wildlife and plant habitat, sources and sinks in water and nutrient cycles, and numerous recreational opportunities. Surface waters are also aesthetic resources and, often, public health resource when they connect to a drinking water supply.

Scotts Bluff NM is located in southwest Nebraska in the North Platte River Drainage (Middle North Platte-Scotts Bluff Watershed) that flows into the Platte River, which eventually flows east into the Missouri River. The Platte River was a guiding natural feature on the western migration of settlers, explorers, and trappers on the Oregon/California/Mormon Trails in the 1800s, and remains an important resource for agriculture, recreation, and wildlife in the region today. Surface water features at Scotts Bluff NM include several canals, including Central Canal, Fort Laramie Canal, and Gering Canal, and a once formed a natural spring—Scotts Spring—that has been dry since about 2010. Additionally, the 1.25 miles of the North Platte River that border the park unit are the highest-priority waterbody at Scotts Bluff NM.

The North Platte River adjacent to the north boundary of Scotts Bluff NM is a Class B Coldwater stream for aquatic life, which means that is does not support naturally reproducing salmonid populations, but supports other coldwater organisms, including various fish, and may support seasonal salmonid migrations. The North Platte River is also designated as Class A for Agriculture, which means that this water supply may be used for general agricultural purposes without treatment (117 Nebraska Administrative Code § 81.1501 2014).

Geology

Geological resources underlie and affect many other resources within National Park System units. In Northern Great Plains area where Scotts Bluff NM is located, most of the bedrock is composed of soft Upper Cretaceous and Tertiary sediment strata. Surface and subsurface strata of the Great Plains physiographic province represent many different paleoenvironments spanning millions of years. While older rocks are present in the subsurface, the oldest rocks exposed within Scotts Bluff NM are those of the Orella Member of the Brule Formation, a subdivision of the widespread White River Group of Eocene–Oligocene age (~36–30 million years ago).

These White River strata of the northern Great Plains are an important sequence of rocks, in that they hold the best-preserved record of a climactic transition in the terrestrial rock record (Prothero 1994). This transition, termed the Eocene–Oligocene climate transition (EOT), records gradual changes from generally warmer and wetter to cooler and drier conditions. During this time the change in environmental conditions reduced forest cover and correspondingly increased open grasslands, as reflected in fossil soils.

Paleontological Resources

The principal mission of the National Park Service is the preservation, protection, and stewardship of natural and historic resources. Fossils, and the natural geologic processes that form, preserve, and expose them, are included in this mission (NPS 2016). Paleontological resources are non-renewable, and they hold the keys to understanding the complex history of life on Earth.

In the northern Great Plains area where Scotts Bluff NM is located, most of the fossiliferous bedrock deposits represent two general time periods and environments: the Late Cretaceous Western Interior Seaway, with remains of invertebrates such as ammonites and vertebrates such as bony fish, sharks, and marine reptiles; and the Tertiary terrestrial deposits of Oligocene and Miocene age that record the spread of grasslands across the region and the rise of large grazing mammals.

Although Scotts Bluff NM was not established specifically to protect fossil resources, many vertebrate fossils are known and have been collected from the monument. Most fossils have been collected from the Orella Member of the Brule Formation, White River Group, which is exposed in badlands within the Monument. Taxa from this rock unit include numerous tortoises, oreodonts and other artiodactyls, nimravids, canids, and lagomorphs.

Vegetation

During the last century, much of the prairie within the Northern Great Plains has been plowed for cropland, planted with non-natives to maximize livestock production, or otherwise developed, making one of the most threatened ecosystems in the United States. Within Nebraska, greater than 77% of the area of native mixed grass prairie has been lost since European settlement.

Scotts Bluff NM, established in 1919 to protect and preserve two iconic bluffs and the associated heritage of western expansion, covers 3,003 acres and is dominated by mixed-grass prairie with smaller areas of juniper woodlands, badlands, and riparian forests.

Birds

Birds are a critical natural resource that provide an array of ecological, aesthetic, and recreational values. As a species-rich group, they encompass a broad range of habitat requirements, and thus may serve as indicators of landscape health. Bird communities can reflect changes in habitat, climate, ecological interactions, and other factors of concern in ecological systems. Scotts Bluff NM is small, but it contains a variety of habitat types in addition to grasslands. One source of important bird habitat is the riparian area along the northern border of the park. Loss of riparian habitat is a major cause of bird declines regionally.

Prairie Dogs

Black-tailed prairie dogs may have once covered ~35 million hectares (~86 million acres) of shortgrass prairie, mixed-grass prairie, sagebrush steppe, and desert grasslands. Occupied acreage has decreased as much as 98% over the range of the species since the early 1900s to the current estimated area of ~800,000 hectares (~2 million acres) across 11 states.

The causes of prairie dog decline include land conversion, wide-scale poisoning, shooting, and, more recently, sylvatic plague. Upon initial settlement of the West, many native grasslands were converted to agriculture. During the first half of the 20th century, there were large-scale, government-sponsored exterminations of prairie dogs to reduce competition with livestock. Poisoning and shooting still occur today to varying degrees. In protected areas or other areas that are minimally disturbed, epizootic plague outbreaks are the primary threat to prairie dog populations. The largest management issue facing prairie dogs across much of their range is sylvatic plague caused by *Yersinia pestis*, a lethal, generalist, non-native bacterium. Plague may have reduced the acreage of active prairie dog colonies within Scotts Bluff NM in 1987–1989 and again in 1995.

Pollinators

Invertebrate pollinators in Nebraska include native insects and honey bees, all of which have varying food and habitat needs. Scotts Bluff NM is home to a total of 19 confirmed butterfly species, and may be host to even more species. Monarch butterflies (*Danaus plexippus*) were present in the park, where the endangered species spends summer; also present were two-tailed swallowtails (*Papilio multicaudata*) and red admirals (*Vanessa atalanta rubria*). While bumble bees (*Bombus* sp.) and other invertebrate pollinators are likely present in Scotts Bluff NM, local census data are lacking for the park.

2.2.3. Resource Issues Overview

The natural resources found in Scotts Bluff provide enjoyment for visitors and opportunity for outreach and research. Maintaining the health of the natural resources is critical to attracting visitors and protecting the geologic and paleontological resources, in particular, in the park is central to the founding goal of Scotts Bluff NM.

The resources within the park and in the surrounding area have been altered by changes in land use, climate, invasive species, natural disturbances, and natural succession, and many of these forces are unlikely to change in the future. In particular, erosion rates are high on Scotts Bluff, one of the most heavily used areas of the park and pose a risk to park visitors. Climate change and consequent shifts in precipitation patterns may be responsible for observed and future increases in erosion rates within the park.

2.3. Resource Stewardship

2.3.1. Management Directives and Planning Guidance

From the NGPN should be Northern Great Plain Network (NGPN) website of the NPS Inventory & Monitoring program (NPS 2016):

> *"The NGPN I&M Program is one of 32 National Park Service I&M Networks across the country established to facilitate collaboration, information sharing, and economies of scale in natural resource monitoring. It is comprised of 13 national park units, each of which contain a rich and varied array of natural and cultural resources.*
>
> *The parks support unique natural resources, including large areas of northern mixed-grass prairie communities, critical river and riparian habitats, large herds of bison, and two of the*

> *four longest caves in the world. These parks and their partners are dedicated to understanding and preserving the region's unique resources through science and education."*

2.3.2. Status of Supporting Science

Availability of data, background information, and assessment protocols varied among natural resources. We describe our approach to identifying appropriate methods in Chapter 3 (Study Design and Methods) of this NRCA.

2.3.3. Literature Cited

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Chapter 3. Study Methods

3.1. Introduction and Overview

This NRCA was produced by the University of Wyoming Ruckelshaus Institute of Environment and Natural Resources and the Wyoming Natural Diversity Database in collaboration with the National Park Service. The purpose of the NRCA is to provide natural resource managers and leadership at Scotts Bluff NM with information to support management decisions, strategic planning, and effective science communication to decision-makers and the public on resource conditions. To deliver this information, we:

- Used a collaborative approach to tailor analyses to park-specific needs and opportunities;
- Identified the unique biophysical and cultural resources of management interest;
- Identified existing data (and critical data gaps) and available expert knowledge for understanding and assessing park resources;
- Used a spatially explicit analytic approach to evaluate the current conditions of resources, trends in their status, and drivers of change.

3.2. Project Design and Methods

3.2.1. Project Phases

We used a two-phase process for completing the assessment for Scotts Bluff NM. Phase 1 was conducted in close cooperation with the park and involved selecting a framework for the assessment. During this phase we identified key natural resources, data needs and sources, indicators, and measures to use in the assessment. Phase 2 focused on reviewing scientific literature, gathering and analyzing data, summarizing findings, and corresponding with Scotts Bluff NM leadership and natural resource managers to incorporate feedback.

To provide a forum for cross-unit idea exchanges and the establishment of a common analytical process at the beginning of the project, we convened an initial planning meeting with representatives from Scotts Bluff NM, Agate Fossil Beds NM, Fort Laramie NHS, and NGPN to start the project.

<u>Phase 1 – Assessment and planning</u>

During Phase 1 we established communication and identified shared expectations among NPS representatives, UW staff, and key resource experts. Through conference calls, electronic communication, and ultimately a facilitated scoping workshop, we tailored the NRCA structure to the specific needs, resource types, and data availability for Scotts Bluff NM.

Specific goals for Phase 1 included:

- Review of existing NRCAs for best practices (UW team)
- Establishing the NPS/UW NRCA teams that guided the process
- Project Scoping Meeting and iterative discussions to:
    - Review the NRCA process and goals generally with UW/NPS team

  - Select the appropriate study framework to guide the NRCA
  - Identify critical, park-specific biophysical resources for assessment
  - Identify the key indicators of resource condition
  - Identify measures to quantify and/or qualify indicators
- Assess data needs, major data sources, and obvious data gaps
- Refine the timeline and specific deliverables
- Assign team member roles in gathering data and reviewing deliverables/products

We agreed that an appropriate framework (Table 3.2.1) for our purpose was one adapted from the H. John Heinz II Center for Science, Economics, and the Environment (2008). This framework gave us a hierarchical structure to assess natural resource conditions using indicators and their quantitative and qualitative measures, and to identify data gaps and stressors.

Table 3.2.1. Natural Resource Condition Assessment Framework for Scotts Bluff NM.

Context	Resource	Indicator	Measure
I. Landscape condition context	Viewshed	Scenic quality	Landscape character integrity
	Viewshed	Scenic quality	Vividness
	Viewshed	Scenic quality	Visual harmony
	Viewshed	Land cover content	Mid-ground % natural cover
	Viewshed	Land cover content	Mid-ground % developed cover
	Viewshed	Land cover content	Mid-ground % agricultural cover
	Night sky	Night sky quality	Bortle Dark-Sky class
	Night sky	Night sky quality	Synthetic Sky Quality Meter (SQM)
	Night sky	Night sky quality	Sky Quality Index (SQI)
	Night sky	Natural light environment	Anthropogenic Light Ratio (ALR)
	Soundscape	Anthropogenic impact	Mean L_{50} impact
	Soundscape	Anthropogenic impact	Qualitative assessment
II. Supporting environment	Air quality	Visibility	Haze index
	Air quality	Ozone	Human health (ozone concentration)
	Air quality	Ozone	Vegetation health (W126 measure)
	Air quality	Particulate matter	$PM_{2.5}$
	Air quality	Particulate matter	PM_{10}
	Air quality	Nitrogen	Wet deposition of nitrogen
	Air quality	Sulfur	Wet deposition of sulfur
	Air quality	Mercury	Wet deposition of mercury

Table 3.2.1 (continued). Natural Resource Condition Assessment Framework for Scotts Bluff NM.

Context	Resource	Indicator	Measure
II. Supporting environment (continued)	Air quality	Mercury	Methlymercury rating
	Water quality	Acidity	pH
	Water quality	Dissolved oxygen	mg/L
	Water quality	Specific conductivity	s/m
	Water quality	Temperature	°C
	Water quality	Turbidity	Qualitative aesthetic assessment
	Water quality	Invertebrate assemblage	HBI
	Water quality	Invertebrate assemblage	EPT index
	Water quality	Invertebrate assemblage	% EPT
	Water quality	Invertebrate assemblage	Evenness
	Water quality	Fecal indicator bacteria	*E. coli* concentration
	Geology	Weathering and erosion	Amount of erosion (mm/year)
	Paleontological resources	Fossil loss	Amount of weathering and erosion
	Paleontological resources	Fossil loss	Fossil poaching and vandalism
III. Biological integrity	Vegetation	Upland plant community structure and composition	Native species richness
	Vegetation	Upland plant community structure and composition	Evenness
	Vegetation	Exotic plant early detection and management	Relative cover of exotic species
	Vegetation	Exotic plant early detection and management	Annual brome cover
	Vegetation	Riparian forest	Plains cottonwood stand seral stage
	Vegetation	Riparian forest	Percent of 20 riparian plots with native deciduous seedlings
	Breeding birds	Species diversity	Species richness
	Breeding birds	Species abundance	Mean density
	Breeding birds	Conservation value	Mean priority ranking
	Black-tailed prairie dog	Colony area	Percentage of suitable habitat occupied
	Invertebrate pollinators	Diversity	Shannon index

Table 3.2.1 (continued). Natural Resource Condition Assessment Framework for Scotts Bluff NM.

Context	Resource	Indicator	Measure
III. Biological integrity (continued)	Invertebrate pollinators	Abundance	Observed visitation rate
	Invertebrate pollinators	Abundance	Mean density in traps
	Invertebrate pollinators	Vulnerable species	Level of conservation concern

Phase 2 – Analysis and Reporting

During Phase 2 we gathered data, conducted quantitative and qualitative analyses, corresponded with subject matter experts, and summarized our findings. We solicited feedback from leadership and mangers at Scotts Bluff NM and incorporated their edits and comments. In Chapter 5 we summarize management goals and data gaps, and to write these summaries we relied heavily on input from park managers and leaders.

Specific goals for Phase 2 were to:

- Gather existing data for analysis
- Review scientific literature and available data for key natural resources identified in the scoping process
- Use selected measures to evaluate the condition of each of the components
- Identify threats and stressors for each component
- Organize natural resource components, reference conditions, and threats/stressors in the study framework
- Summarize key findings for each park unit
- Correspond with park leadership, resource managers, and subject matter experts and incorporate feedback on resource sections

3.2.2. Assessment Methods

To identify the most relevant indicators of resource condition, and the measures of those indicators (Table 3.2.1), we relied upon to NPS protocol, peer-reviewed scientific literature, state and federal regulations, technical reports, and resource experts. We described key indicators and appropriate measures, even if data were not available for that resource at the time of our assessment, so that our assessment methods could be repeated in the future and improved should data become available. Specific methods for evaluating the conditions of natural resources are described in detail in the relevant sections of Chapter 4.

Data

In this assessment we searched for data that were collected within the boundaries of Scotts Bluff NM or as near to the park as possible. If these data were unavailable, we considered data in the broader region, as acceptable to natural resource managers and leadership at Scotts Bluff NM. We used the NPS database, Integrated Resource Management Applications (NPS 2016); other state and federal databases; online databases of scientific literature and technical reports; and consultation with experts to identify the most recent and relevant data for each resource.

Analyses

Condition

We used quantitative methods when possible and relied upon to the most rigorous assessment methods available, whether quantitative or qualitative. Measures determined the condition category of each indicator, which could be*: Resource in Good Condition, Warrants Moderate Concern, Warrants Significant Concern,* or *Not Available* (Table 3.2.2). To select analytical approaches for each measure, and to identify appropriate category value ranges for those measures, we again deferred to NPS protocol, peer-reviewed scientific literature, state and federal regulations, technical reports, and resource experts.

Table 3.2.2. Symbolism for condition, confidence, and trend.

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
No Color	Current Condition is Unknown or Indeterminate	No Arrow	Trend in Condition is Unknown or Not Applicable	–	–

Several resources had only one indicator or a dominant indicator that had the potential to overshadow the other indicators (e.g., an indicator out of federal compliance). For these natural resources, the single or dominant indicator determined the overall condition of the resource. More frequently, multiple indicators determined resource condition. In these cases, we used a quantitative approach to calculate overall resource condition from indicator conditions. We modified an approach developed by the NPS Air Resources Division (NPS-ARD) to assess air quality; this approach uses a point system to assign the indicator to a category (NPS-ARD 2015). Measures that placed the indicator in the *Warrants Significant Concern* category were assigned zero points, *Warrants Moderate Concern* measures were given 50 points, and *Resource in Good Condition* measures were given 100 points. We used the average of these points to assign the indicator to an overall category. The overall condition was *Resource in Good Condition* if the average of these values was between 67 and 100, *Warrants Moderate Concern* between 34 and 66, and *Warrants Significant Concern* between 0 and 33 (Table 3.2.3).

Table 3.2.3. Points determining overall indicator condition.

Resource condition		Points for overall condition
Warrants significant concern	🔴	0 – 33
Warrants moderate concern	🟡	34 – 66
Resource in good condition	🟢	67 – 100

Confidence

Confidence ratings were based on the quality of available data. We gave a rating of *High* confidence (Table 3.2.3) when data were collected on site or nearby, data were collected recently, and the data were collected methodically. We assigned a *Medium* confidence rating when data were not collected on site or in close enough proximity to satisfy a *High* rating according to protocol, data were not collected recently, or data collection was not repeatable or methodical. We assigned *Low* confidence when there were no good data sources to support the condition. We calculated overall confidence—*High, Medium, or Low*—using a points system similar to overall condition confidence; categories with *High* confidence received 100 points, *Medium* confidence received 50 points, and *Low* confidence received zero points. The overall confidence was *High* if the average of these values was between 67 and 100, *Medium* between 34 and 66, and *Low* between 0 and 33.

Trend

Trend categories were *Improving, Unchanging, Deteriorating*, or *Not Available* (Table 3.2.3). To calculate a trend estimate, data requirements varied among resources according to NPS protocol, peer-reviewed scientific literature, state and federal regulations, technical reports, and resource experts. If there were no data available that met these resource-specific requirements for a particular indicator, we indicated that trend was *Not Available* for that indicator. If trend data were available for all key indicators, we calculated overall trend using a points system (NPS-ARD 2015) to assign an overall trend category of *Improving, Unchanging, or Deteriorating.* Specifically, we subtracted the number of deteriorating trends from improving trends. If the result of this calculation was three or greater, the overall trend was *Improving*. If the result was negative three or lower, the overall trend was *Deteriorating*. If the result was between negative two and positive two, the overall trend was *Unchanging*. If any measure did not have a trend, then there was no trend for overall condition.

3.3. Literature Cited

National Park Service (NPS). 2016. Integrated Resource Management Applications. https://irma.nps.gov. Accessed 30 September 2016.

National Park Service, Air Resources Division (NPS-ARD). 2015. DRAFT National Park Service Air Quality Analysis Methods.

Chapter 4. Natural Resource Conditions

In this chapter we present the natural resource condition assessments. Each of these assessments includes background information about the resource, a discussion of Regional Context, specific methods, and results of the assessment. We used quantitative measures whenever possible and applied qualitative methods when relevant. We describe the indicators and measure of condition for each resource and, at the end of each section, present an overall condition for the resource.

4.1. Viewshed

4.1.1. Background and Importance

In the mid to late 19th century, artists who accompanied surveys and expeditions were inspired in their travels to produce paintings that contributed to a romantic vision of western landscapes. The beauty portrayed in their paintings, as well as in photographs captured during surveys and expeditions, promoted national interest in scenic western landscapes and help to convince the U.S. Congress to create the first national park at Yellowstone in 1872 (Haines 1974, 1996).

The aesthetic value associated with this park became a founding principle of the 1916 Organic Act (16 U.S.C. § 1–4) that established the National Park Service (NPS) and other park units, such as Scotts Bluff National Monument (Figure 4.1.1). The National Park Service prioritizes conserving scenery for the enjoyment of visitors and current and future generations (16 U.S.C. § 1–4). Scenic park resources are protected from impairment, which is any change that harms the integrity of the park unit (NPS 2006). NPS encourages park units to protect the iconic and spectacular scenery of the national parks by preserving visual resources (NPS 2015a). Protecting park viewsheds, the geographic area visible from a given location, is key to this goal. The viewshed within a park unit is the visible area from all locations within the park (Figure 4.1.2). While park units can manage visual resources within their boundaries, protecting the viewshed beyond those boundaries can be more challenging. If planned development in surrounding communities threatens the integrity of viewshed within a park unit, NPS can work to preserve viewsheds by participating in local planning processes. Although no management policy currently exists exclusively for scenic resources, the NPS has shown a century-long commitment to the inventory, assessment, and preservation of the park system's visual resources.

Figure 4.1.1. 1937 William Henry Jackson painting of Scotts Bluff, based on an 1866 print by the same artist. Scotts Bluff was a prominent landscape feature for navigation along the westward migration trails and remains an iconic feature today. Image courtesy of Scotts Bluff NM.

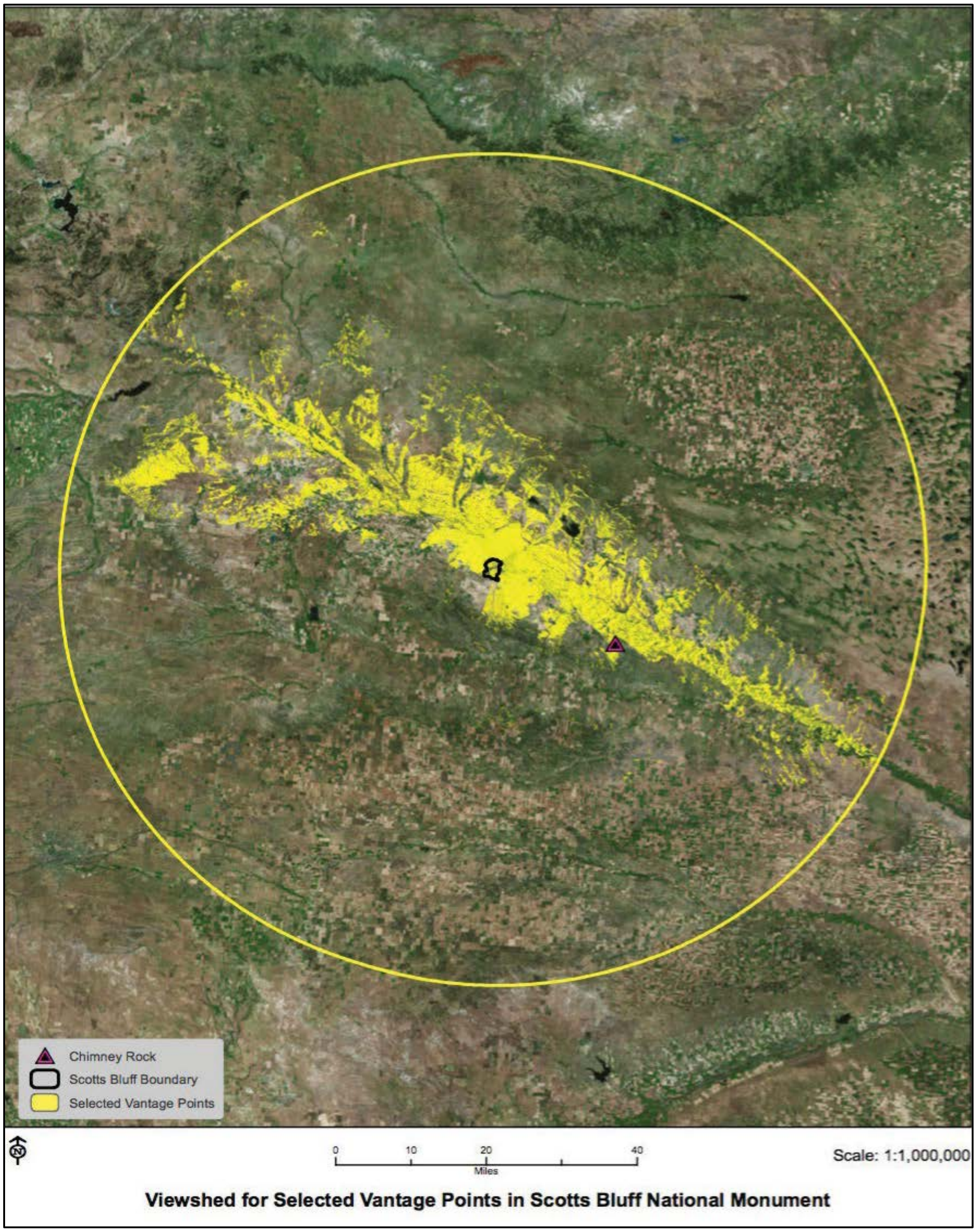


Figure 4.1.2. Viewshed of all areas visible from one or more vantage points at Scotts Bluff NM used in this assessment. Chimney Rock National Monument, another prominent feature along the North Platte River, is visible to the southeast of Scotts Bluff NM. Map created by WyGISC (2016) from Landsat imagery.

Regional Context

At Scotts Bluff NM, exposed geologic history, cultural landscapes, and expansive views of western Nebraska are an important part of the visitor experience. The landscapes in and around the park, including Scotts Bluff landmark and Chimney Rock, offer visitors an opportunity to enjoy a visual setting with features that served as landmarks for peoples from Native Americans to emigrants on the Oregon, California, and Mormon Trails.

To settlers traveling along these migration trails, Scotts Bluff was more than a scenic feature of the western landscape; it was a guiding landmark that signaled the end of the plains and the beginning of the mountains on the journey west. Today the bluff is visible from miles away, as it was in the 1800s, and dominates the skyline within park unit boundaries. Views from the top of the bluff add to the aesthetic value of the park, and the preservation of these views is a high priority for the park unit (National Parks Conservation Association 2009).

Despite the preserved grandeur of the bluff itself, the landscapes of the region and the National Monument are now very different than they were 150 years ago. Tribes and early settlers would have likely seen mixed grassland prairie, once the dominant land cover in the region (Ricketts et al. 1999), stretching for miles in all directions. Most of the prairie has since been converted to agriculture or developed for residential and industrial use. A large portion of the native prairie in what is now Scotts Bluff NM has also been altered. Many of the natural processes that helped shape the landscape, such as grazing by bison, are now gone (Ricketts et al. 1999). These changes to the landscape likely affect visitor experience and visual interpretation of the historical features within the park unit (National Parks Conservation Association 2009).

4.1.2. Viewshed Standards

National standards for visual resources within NPS units do not currently exist. The diverse nature of the lands within the park system and the attractions they provide require that each park is considered individually for visual resource goals.

President Wilson created Scotts Bluff National Monument in 1919 and the proclamation identified the prominent feature as a resource needing formal protection to preserve the view of and from Scotts Bluff within the surrounding landscape. Mitchell Pass and remnants of the Oregon Trail added historic significance to the resource. The scenic, historic, and cultural resources of Scotts Bluff NM remain the primary preservation objectives for the NPS (National Parks Conservation Association 2009)

4.1.3. Methods

We assessed viewshed condition within Scotts Bluff NM using a combination of quantitative GIS analyses and an approach used for assessing visual resource indicators developed by the National Park Service Air Resources Division (NPS-ARD) for Visual Resource Inventories (VRI) (NPS 2015b). To select key representative views— vantage points—for viewshed analyses, we adapted criteria from intensive viewshed studies of other NPS units (The Walker Collaborative et al. 2008).

We tailored vantage point selection to match the interpretive focus of the park. Vantage points included locations defined by one or more of the following characteristics: high elevation overlook, popular visitor attraction, iconic park resource (either natural or historic), park entrance, and/or major infrastructure developments such as visitor or interpretive centers. To pinpoint the specific locations of potential vantage points, we used enabling legislation, interpretive materials for Scotts Bluff NM

(NPS 2016), planning documents (National Parks Conservation Association 2009), narrative histories of the park unit (Mattes 1958, Harris 1962, Cockrell 1983), topographic maps, and geotagged photographs on Google Earth.

From these candidate vantage points, we then identified five points that were most likely to be of high importance to the park (Figure 4.1.3, Appendix A). We adapted the VRI process developed by NPS-ARD (Sullivan and Meyer 2015) to use in this NRCA. This adaptation was necessary because full viewshed assessments have not yet been completed for Scotts Bluff National Monument. The VRI process is a systematic description of the scenic quality and the importance to NPS visitor experience and interpretive goals for important views inside and outside NPS units.

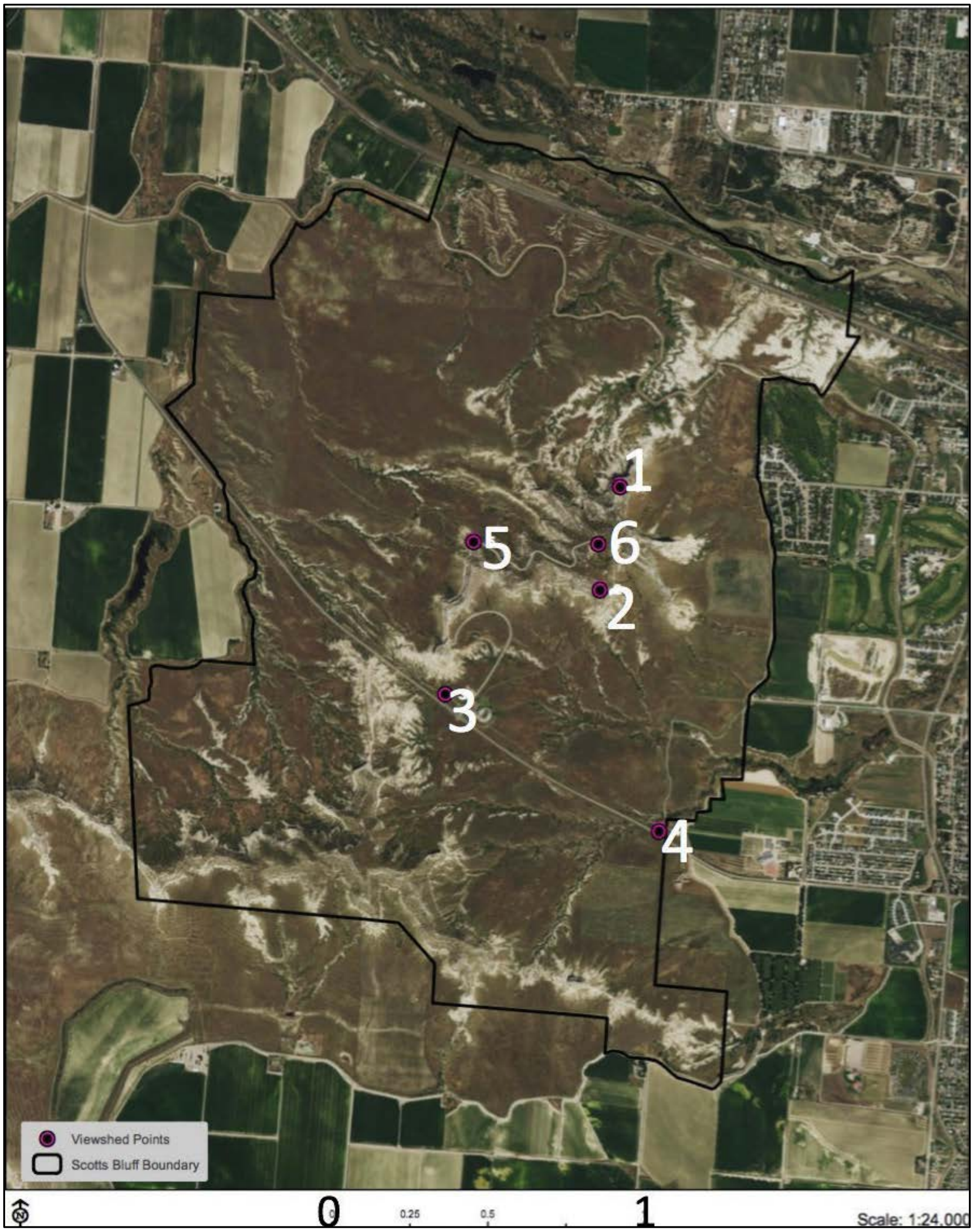


Figure 4.1.3. Vantage points (1, 2, 3, 4, and 6) used in the viewshed analysis for Scotts Bluff NM. Vantage point 5 was excluded from the final analysis as an unimportant point at which visitors could not safely stop vehicles or travel by foot to view the landscape. Map created by WyGISC (2016) from Landsat imagery.

An important difference between our approach and a full VRI assessment is that we used the importance criteria to select vantage points that we included in the assessment, instead of incorporating view importance into the overall viewshed condition. This approach allowed us to focus on the condition of particularly iconic points vantage points, well-visited points, and points that are currently developed or are being developed to draw visitor attention.

In future viewshed condition assessments, the importance criteria may be applied to all points at the park to identify management priorities and development potential. While the full NPS-ARD VRI evaluation also includes an evaluation of historical importance and threats or opportunities that may negatively or positively affect scenic values of a park unit, we limited our assessment to the present condition of important views. We applied the scenic quality evaluation to important points only to avoid biasing viewshed condition by evaluating importance of unimportant viewpoints. We quantified view importance by following the VRI rating process, combining scores for viewpoint importance, viewed landscape importance, and the level of viewer concern. The importance values capture the unseen, non-scenic qualities of a vantage point such as cultural and historic context, and NPS and visitor values (Sullivan and Meyer 2015). We used descriptive information of the view importance elements from academic literature, local knowledge, and park interpretive materials to assign an importance rating to each potential vantage point. We then selected points with importance ratings of 4 (high) or 5 (very high) to use for the viewshed resource condition assessment. When possible, we compared the results of our modified viewshed analyses to rating data from full VRI evaluations.

Indicators and Measures

We assessed viewshed condition using two indicators: scenic quality of view and land cover content within viewshed. To assign a condition to each indicator, we conducted both qualitative and quantitative analyses of viewshed from each vantage point. We then considered the indicator conditions together to assess overall viewshed condition.

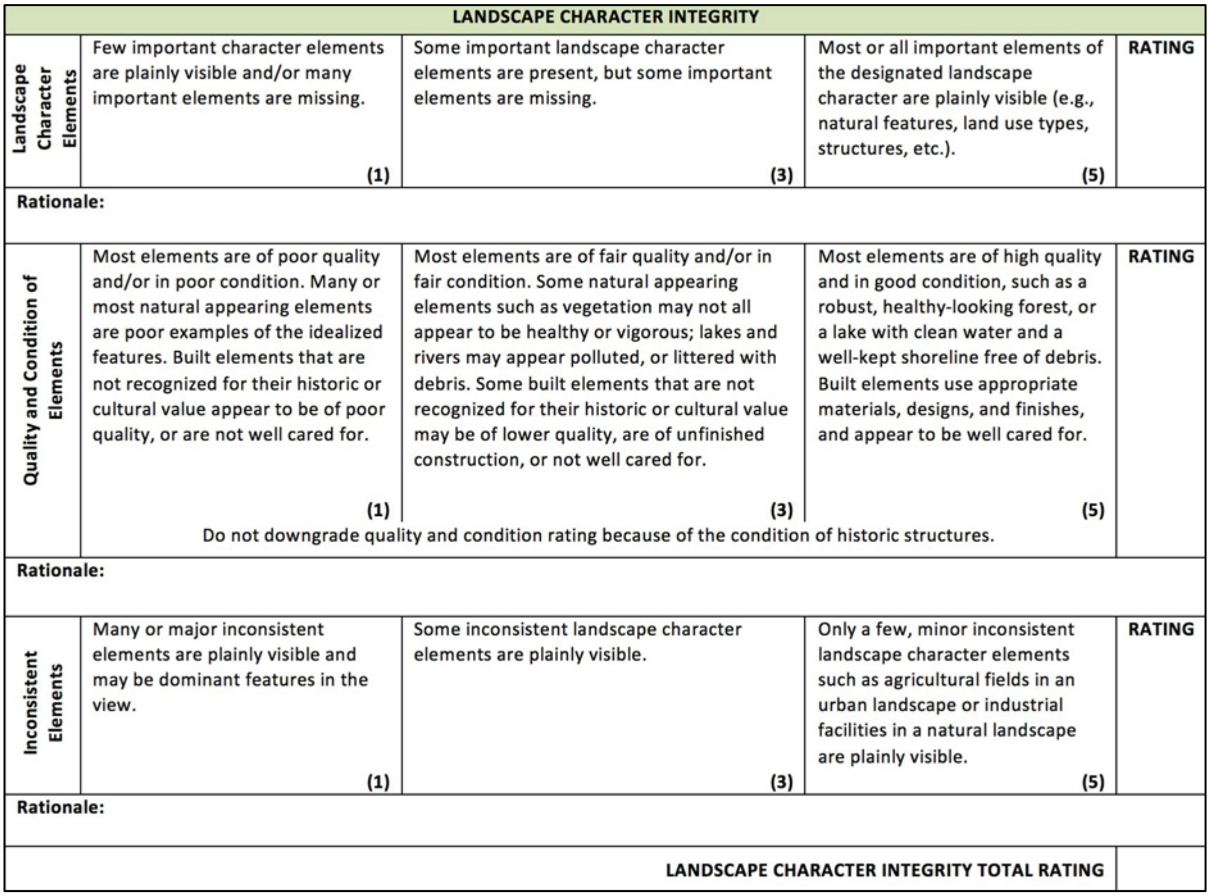
Indicator: Scenic Quality

Scenic quality is, in short, the visual attractiveness of a landscape. Spectacular scenery draws visitors who appreciate attractive landscapes, so conserving scenic values is important for promoting park visitation. Several primary factors affect landscape attractiveness: landscape character relates to how well the view matches the idealized expectation of the visitor, such as the inclusion of iconic park resources or the exclusion of elements that are inconsistent with the ideal view. Aesthetic composition of visual elements describes the extent to which the viewed landscape corresponds with pleasing artistic principles such as vivid focal points or harmonious relationships between the scales and colors within the view. When possible, we compared the results of our scenic quality analyses to rating data from full VRI evaluations.

Measure of Scenic Quality: Landscape Character Integrity

Landscape character integrity is the extent to which a view resembles the idealized version of the viewed landscape. This measure is subjective and individual visitors may have different interpretations of what landscape characteristics constitute ideal landscapes. If many people participate in viewshed assessments, however, an average score is likely to reflect overall visitor perception of any given view. Landscape character integrity accounts for three view components: the elements, the quality and condition of the elements within the view, and the presence of inconsistencies in an otherwise natural landscape (e.g., power lines, cell towers, roads). A high landscape character integrity value would include a view containing iconic or important elements in good condition, with few elements inconsistent with the ideal character of the landscape (Sullivan and Meyer 2015).

To assign a score to landscape character, we used digital imagery in lieu of on-site surveys. We used the NPS Scenery Conservation Program (NPS 2015b) methods for this assessment (Figure 4.1.4) and assigned an overall rating based on equally weighted scores of the three landscape character components. We assigned ratings to the three components on a 1–5 scale, for a total possible landscape character integrity score of 15 (Table 4.1.1). Our condition ratings correspond to the contribution each component has to overall scenic quality ratings of A-E, which are used to identify the conservation value of a view when applied to the Scenic Inventory Value Matrix (NPS 2015b). Our condition ratings correspond to the contribution each component has to overall scenic quality ratings of A-E. Landscape character integrity rating values of 1–5 (E) put this measure in the category, *Warrants Significant Concern*. Values of 6–10 (C/D) put this measure in the category, *Warrants Moderate Concern*. A value higher than 10 (A/B) put this measure in the category, *Resource in Good Condition.*



LANDSCAPE CHARACTER INTEGRITY				
Landscape Character Elements	Few important character elements are plainly visible and/or many important elements are missing. **(1)**	Some important landscape character elements are present, but some important elements are missing. **(3)**	Most or all important elements of the designated landscape character are plainly visible (e.g., natural features, land use types, structures, etc.). **(5)**	**RATING**
Rationale:				
Quality and Condition of Elements	Most elements are of poor quality and/or in poor condition. Many or most natural appearing elements are poor examples of the idealized features. Built elements that are not recognized for their historic or cultural value appear to be of poor quality, or are not well cared for. **(1)**	Most elements are of fair quality and/or in fair condition. Some natural appearing elements such as vegetation may not all appear to be healthy or vigorous; lakes and rivers may appear polluted, or littered with debris. Some built elements that are not recognized for their historic or cultural value may be of lower quality, are of unfinished construction, or not well cared for. **(3)**	Most elements are of high quality and in good condition, such as a robust, healthy-looking forest, or a lake with clean water and a well-kept shoreline free of debris. Built elements use appropriate materials, designs, and finishes, and appear to be well cared for. **(5)**	**RATING**
	Do not downgrade quality and condition rating because of the condition of historic structures.			
Rationale:				
Inconsistent Elements	Many or major inconsistent elements are plainly visible and may be dominant features in the view. **(1)**	Some inconsistent landscape character elements are plainly visible. **(3)**	Only a few, minor inconsistent landscape character elements such as agricultural fields in an urban landscape or industrial facilities in a natural landscape are plainly visible. **(5)**	**RATING**
Rationale:				
			LANDSCAPE CHARACTER INTEGRITY TOTAL RATING	

Figure 4.1.4. Methods to assign a score to landscape character integrity (NPS 2015).

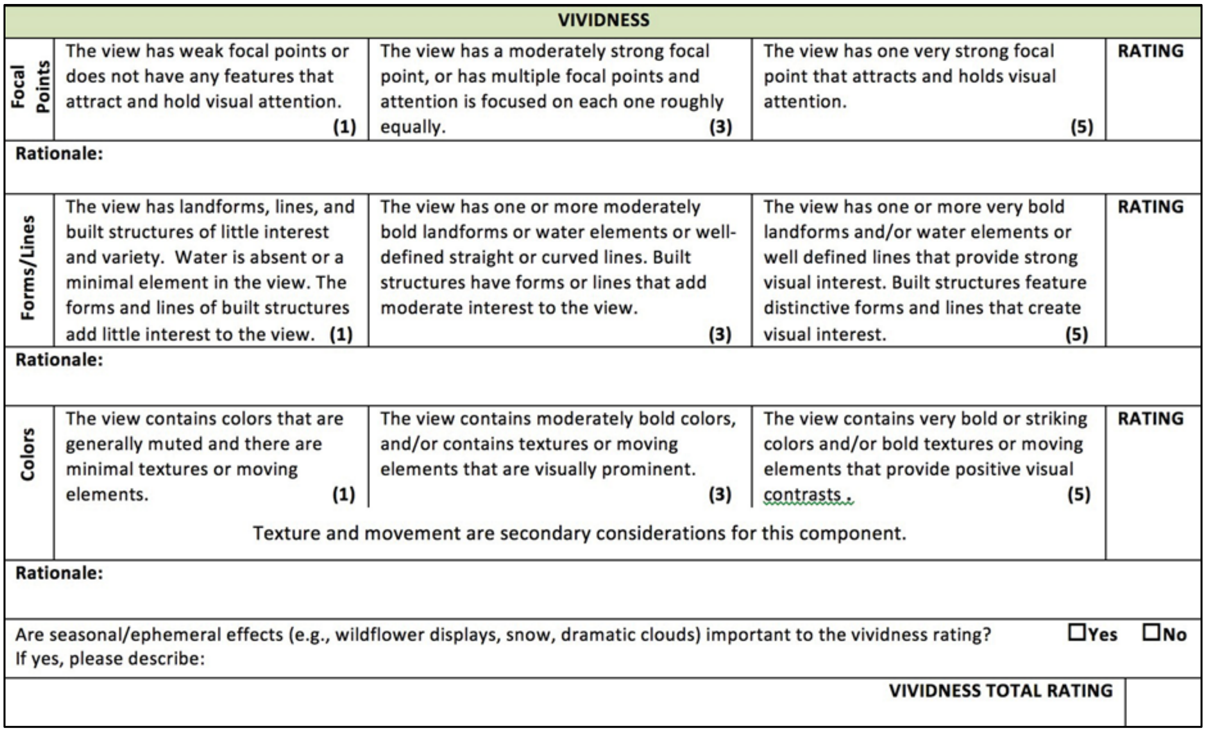
Table 4.1.1. Viewshed condition categories for landscape character integrity.

Resource condition		Character integrity value
Warrants significant concern	🔴	1 – 5
Warrants moderate concern	🟡	6 – 10
Resource in good condition	🟢	> 10

Measure of Scenic Quality: Vividness

Vividness is the memorable distinctiveness of the landscape within a viewshed. Distinctive or visually striking landscapes contain dominant visual features that are easily identifiable and distinguished from other visual resources. El Capitan in Yosemite NP, the Grand Teton in Grand Teton NP, or Old Faithful in Yellowstone NP are park resources that exemplify this measure and are easily identified due to high levels of vividness.

Three components (focal points, forms/lines, and colors) constitute the vividness of a viewshed (NPS 2015b). High scores for vividness would likely include multiple focal points, vibrant colors, striking features, and rich textures (Sullivan and Meyer 2015). To assign a score to landscape character, we used digital imagery in lieu of on-site surveys. We used the NPS Scenery Conservation Program (NPS 2015b) methods for this assessment (Figure 4.1.5) and assigned an overall rating based on equally weighted scores of the three vividness components.



VIVIDNESS				
Focal Points	The view has weak focal points or does not have any features that attract and hold visual attention. **(1)**	The view has a moderately strong focal point, or has multiple focal points and attention is focused on each one roughly equally. **(3)**	The view has one very strong focal point that attracts and holds visual attention. **(5)**	**RATING**
Rationale:				
Forms/Lines	The view has landforms, lines, and built structures of little interest and variety. Water is absent or a minimal element in the view. The forms and lines of built structures add little interest to the view. **(1)**	The view has one or more moderately bold landforms or water elements or well-defined straight or curved lines. Built structures have forms or lines that add moderate interest to the view. **(3)**	The view has one or more very bold landforms and/or water elements or well defined lines that provide strong visual interest. Built structures feature distinctive forms and lines that create visual interest. **(5)**	**RATING**
Rationale:				
Colors	The view contains colors that are generally muted and there are minimal textures or moving elements. **(1)**	The view contains moderately bold colors, and/or contains textures or moving elements that are visually prominent. **(3)**	The view contains very bold or striking colors and/or bold textures or moving elements that provide positive visual contrasts . **(5)**	**RATING**
	Texture and movement are secondary considerations for this component.			
Rationale:				
Are seasonal/ephemeral effects (e.g., wildflower displays, snow, dramatic clouds) important to the vividness rating? If yes, please describe:				☐**Yes** ☐**No**
			VIVIDNESS TOTAL RATING	

Figure 4.1.5. Methods to assign a score to vividness (NPS 2015).

We assigned ratings to the three components on a 1–5 scale, for a total possible vividness score of 15 (Table 4.1.2). The condition categories were based on Scenic Inventory Matrix ratings (NPS 2015b). Vividness values of 1–5 put this measure in the category, *Warrants Significant Concern*. Values of 6–10 put this measure in the category, *Warrants Moderate Concern*, and a value higher than 10 put this measure in the category, *Resource in Good Condition*.

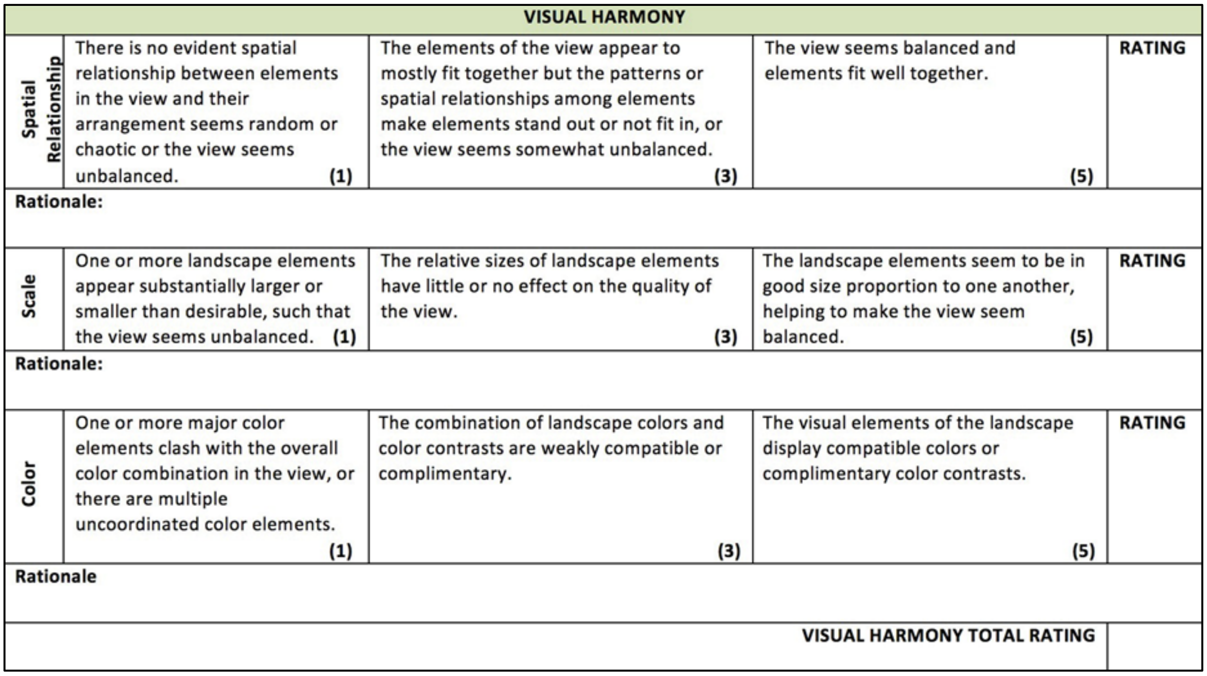
Table 4.1.2. Viewshed condition categories for vividness of the view.

Resource condition		Vividness rating
Warrants significant concern	🔴	1 – 5
Warrants moderate concern	🟡	6 – 10
Resource in good condition	🟢	> 10

Measure of Scenic Quality: Visual Harmony

We used visual harmony to measure the relationship between visual elements in a viewed landscape. Visual harmony has three components: spatial relationship, scale, and color. Landscapes with high visual harmony score have elements that fit well together spatially and complement each other in scale and color leaving the viewer with a sense of completeness or unity, whereas low visual harmony scores indicate views that do not achieve a complex and appealing unity of subjects, or seem monotonous.

To assign a score to visual harmony, we used digital imagery in lieu of on-site surveys. We used the NPS Scenery Conservation Program (NPS 2015b) methods for this assessment (Figure 4.1.6) and assigned an overall rating based on equally weighted scores of the three visual harmony components. We assigned ratings to the three components of visual harmony on a 1–5 scale, for a total possible rating of 15 (Table 4.1.3). The condition categories are based on the Scenic Inventory Matrix ratings (Sullivan and Meyer 2015). Visual harmony values of 1–5 put this measure in the category, *Warrants Significant Concern*, values of 6–10 put this measure in the category, *Warrants Moderate Concern*, and values higher than 10 put this measure in the category, *Resource in Good Condition*.



VISUAL HARMONY				
Spatial Relationship	There is no evident spatial relationship between elements in the view and their arrangement seems random or chaotic or the view seems unbalanced. **(1)**	The elements of the view appear to mostly fit together but the patterns or spatial relationships among elements make elements stand out or not fit in, or the view seems somewhat unbalanced. **(3)**	The view seems balanced and elements fit well together. **(5)**	**RATING**
Rationale:				
Scale	One or more landscape elements appear substantially larger or smaller than desirable, such that the view seems unbalanced. **(1)**	The relative sizes of landscape elements have little or no effect on the quality of the view. **(3)**	The landscape elements seem to be in good size proportion to one another, helping to make the view seem balanced. **(5)**	**RATING**
Rationale:				
Color	One or more major color elements clash with the overall color combination in the view, or there are multiple uncoordinated color elements. **(1)**	The combination of landscape colors and color contrasts are weakly compatible or complimentary. **(3)**	The visual elements of the landscape display compatible colors or complimentary color contrasts. **(5)**	**RATING**
Rationale				
			VISUAL HARMONY TOTAL RATING	

Figure 4.1.6. Methods to assign a score to visual harmony (NPS 2015).

Table 4.1.3. Viewshed condition categories for visual harmony.

Resource condition		Visual harmony rating
Warrants significant concern	🔴	1 – 5
Warrants moderate concern	🟡	6 – 10
Resource in good condition	🟢	> 10

Indicator: Land Cover Content

Land cover is all physical material covering the surface of the earth, from trees and water to roads and buildings. The type of land cover within the range of vision largely defines the viewed landscape. Generally, the visual appeal of a landscape increases with increased degree of wilderness, amount and type of vegetation, bodies of water and horizon features (Arriaza et al. 2004).

We sought to use an objective quantitative metric to evaluate viewshed condition, such that managers could gain some sense of viewshed condition even when no on site survey data exist for a park unit (see Appendix A for maps, Appendix B for methods). We worked with the Wyoming Geographic Information Science Center (WyGISC) to calculate land cover percentage estimates within the viewshed from all vantage points using the most recent National Land Cover Dataset (USGS 2011). We grouped all cover types into three classes—natural, developed, and agriculture—and calculated the percentage of each class in the foreground (0–0.5 miles from vantage point), middle ground (0.5–3 miles), and background (3–60 miles).

In our effort to identify a basic quantitative of measure of viewshed condition, we tested for correlations between land cover percentages and scenic quality values. We pooled data from 18 vantage points at Scotts Bluff NM, Agate Fossil Beds NM, Fort Laramie National Historic Site, and Badlands National Park for this analysis. Our efforts to include an objective, quantitative assessment of scenic quality to complement the measurements provided by the NPS-ARD resulted in significant correlations ($p < 0.01$) between land cover and scenic quality for all three cover classes (natural, developed, and agriculture) within the middle ground distance (Figure 4.1.7).

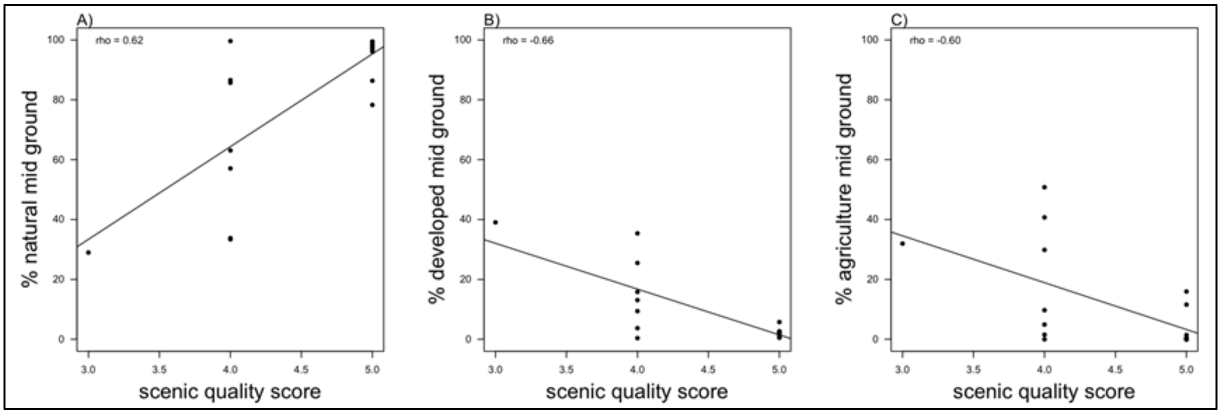


Figure 4.1.7. Relationships between scenic quality score and land cover. Rho is the correlation between scenic quality score and the percentage of each ground cover type.

Measure of Land Cover Content: Percentage of Natural Cover in Mid-Ground

Natural land cover correlated positively with scenic quality score in the middle ground distance (0.5-3.0 miles) from vantage points (rho = 0.62, P < 0.01) (Figure 4.1.7A). We used a quartile approach to assign condition categories to land cover percentages, with higher natural land cover percentages corresponding to higher scenic value scores (Table 4.1.4). If the percentage of natural land cover in the middle ground was ≤ 50%, the condition was *Warrants Significant Concern*. If the percentage of natural land cover in the middle ground was > 50% and ≤ 75%, the condition was *Warrants Moderate Concern*. If the percentage of natural land cover in the middle ground was > 76% the condition was *Resource in Good Condition*.

Table 4.1.4. Viewshed condition categories for the percentage of natural land cover in the mid-ground.

Resource condition		Percentage natural cover
Warrants significant concern	🔴	≤ 50
Warrants moderate concern	🟡	50 < and ≤ 75
Resource in good condition	🟢	76 – 100

Measure of Land Cover Content: Percentage of Developed Cover in Mid-Ground

Developed land cover was negatively correlated with scenic quality score in the middle ground distance (0.5 – 3.0 miles) from vantage points (rho = -0.66, P < 0.01). Only vantage points with < 10% developed land in the middle ground received the highest scenic quality score, and highest scenic quality scores had < 20% developed land in the middle ground (Figure 4.1.7B). We used a quartile approach to assign categories to land cover percentages, within the observed range of values for developed land percentages in the middle ground (Table 4.1.5). If developed land cover percentage of viewshed was > 20%, we assigned the condition *Warrants Significant Concern*. If the percentage of developed land cover in the middle ground was ≤ 20% and > 10%, the condition was *Warrants Moderate Concern*. If the percentage of developed land cover in the middle ground was ≤ 10% the condition was *Resource in Good Condition*.

Table 4.1.5. Viewshed condition categories for the percentage of developed land cover in the mid-ground.

Resource condition		Percentage developed cover
Warrants significant concern	🔴	> 20
Warrants moderate concern	🟡	> 10 and ≤ 20
Resource in good condition	🟢	≤ 10

Measure of Land Cover Content: Percentage of Agricultural Cover in Mid-Ground

Agricultural land cover was negatively correlated with scenic quality score in the middle ground distance (0.5 – 3.0 miles) from vantage points (rho = -0.60, P < 0.01). Only vantage points with < 13% agricultural land in the middle ground received the highest scenic quality score (Figure 4.1.7C).

We used a quartile approach to assign categories to land cover percentages, within the observed range of values for agricultural land percentages in the middle ground (Table 4.1.6). If agricultural land cover percentage of viewshed was > 25%, we assigned the condition *Warrants Significant Concern*. If the percentage of agricultural land cover in the middle ground was ≤ 25% and > 13%, the condition was *Warrants Moderate Concern*. If the percentage of developed land cover in the middle ground was ≤ 13% the condition was *Resource in Good Condition*.

Table 4.1.6. Viewshed condition categories for the percentage of agricultural land cover in the mid-ground.

Resource condition		Percentage agricultural cover
Warrants significant concern	🔴	> 25
Warrants moderate concern	🟡	> 13 and < 25
Resource in good condition	🟢	< 13

Data Sources

To evaluate viewpoints for scenic quality, we used scenic photos available online from Scotts Bluff NM, photographs taken by visitors and linked to vantage locations in Google Earth, and, when available, digitally “stitched” panoramic photos from Google Earth street and ground views at five locations (Google Earth 2014a, 2014b, 2014c, 2014d, 2014e, 2014f). We used these available “photographic surrogates” (Shuttleworth 1890) to complete viewshed assessments in accordance with the NPS-ARD viewshed assessment guidance. When available, we received additional scenic quality data from a previous visual resource inventory conducted by NPS-ARD (NPS 2015c). Digital viewshed analyses (Appendix A) were completed by the Wyoming Geographic Information Science Center (WyGISC) for each vantage point. Land cover data was based on the most recent National Land Cover Dataset (USGS 2011).

Quantifying Viewshed Condition, Confidence, and Trend

Indicator Condition

We created condition categories based on expert opinion and the scientific literature. We used a point system to assign each indicator to a category. This point system is based on the NPS methods that were developed to calculate overall air quality condition (NPS-ARD 2015), a methodical and rigorous assessment approach that can be applied to other resources as well. In this approach, we assigned zero points to the condition *Warrants Significant Concern*, 50 points to *Warrants Moderate Concern*, and 100 points to *Resource in Good Condition*. The average of all measures determined the condition category of the indicator; scores from 0–33 fell in the *Warrants Significant Concern* category, scores from 34–66 were in the *Warrants Moderate Concern category*, and scores from 67–100 indicated *Resource in Good Condition*.

Indicator Trend

Potential trend categories were *Improving, Unchanging*, or *Deteriorating*. To calculate a trend estimate for indicators, we sought viewshed data that were collected at least twice over a five-year period and met the conditions for a *High* confidence rating. If there were no data available that met these monitoring requirements for a particular indicator, we indicated that trend was *Not Available* for that indicator.

Indicator Confidence

Confidence ratings were based on availability of data collected about the indicator. For Scenic Quality, we gave a rating of *High* confidence when data from full VRI assessments conducted within the park from selected views were available in conjunction with remote assessments using geo-tagged photographs and digitally stitched panoramas. We assigned a *Medium* confidence rating when data was remotely assessed using only geotagged photographs and digitally stitched panoramas and the viewed landscape was presented in 360° natural perspective imagery. *Low* confidence ratings were assigned when data was limited to only single perspective photography or "ground view" Google Earth images. We gave a rating of *High* confidence when data for land cover were collected recently and methodically. We assigned a *Medium* confidence rating when data were methodically collected, but recent land cover data were not available. *Low* confidence ratings were assigned if data were either missing or unavailable within a recent time period.

Overall Viewshed Condition, Confidence, and Trend

We used the general approach for combining indicator conditions, trends, and confidence described in Chapter 3 (Methods 3.2.2) to calculate overall resource condition, trend, and confidence.

4.1.4. Viewshed Condition, Confidence, and Trend

Scenic Quality

🟢

Condition: Resource in Good Condition
Confidence: Medium
Trend: Not Available

Condition

The average scores for landscape character integrity, vividness, and visual harmony of the view were all > 10 (Table 4.1.7). The combined scores placed scenic quality for Scotts Bluff NM in the *Resource in Good Condition* category.

Table 4.1.7. Ratings for each measure and indicator at each vantage point, plus park average for indicator and measures at all vantage points.

Measure	Components	Vantage point ratings					
		North overlook	South overlook	Covered wagons	Entrance sign	Summit parking lot	Park average
Landscape character integrity	Landscape character elements	4	5	5	5	3.5	4.5
	Quality and Condition of Elements	3.5	4	3.5	4.5	4	3.9
	Inconsistent elements	3	3.5	3	4	4	3.5
	Total	**10.5**	**12.5**	**11.5**	**11.5**	**11.5**	**11.5**
Vividness	Focal points	2.5	3.5	4	4	3	3.2
	Forms/lines	4	4.5	4	4	3.5	4
	Colors	4	3.5	3	3	4	3.5
	Total	**10.5**	**11.5**	**11**	**11**	**10.5**	**10.7**
Visual harmony	Spatial relationship	3	3	3.5	4	4	3.5
	Scale	3	4	3.5	4	4	3.7
	Color	3	4	4	4	4	3.8
	Total	**9**	**11**	**12**	**12**	**12**	**11**

Confidence

Scenic quality data were available from a full VRI assessment that NPS-ARD had conducted within the park from the North Overlook vantage point; in conjunction with these data, we conducted remote assessments using geo-tagged photographs and digitally stitched panoramas. The confidence rating was *Medium*.

Trend

Scenic quality data were insufficient to assign a trend to the resource, so trend was *Not Available*.

Land Cover Content

🔴

Condition: Warrants Significant Concern
Confidence: Medium
Trend: Not Available

Condition

Land cover content percentages for natural cover, developed cover and agricultural cover at mid-ground distances were 48.99, 25.03, and 25.98 respectively (Figure 4.1.5). Each of these measurements placed land cover content in the *Warrants Significant Concern* category.

Confidence

Land cover content calculations were calculated using the most recent available data from the National Land Cover Database (NLCD) (USGS 2011), so the confidence was *High*.

Trend

Land cover data were insufficient to assign a trend to the resource, so trend was *Not Available*.

Viewshed Overall Condition

Condition

The overall viewshed condition was determined by the average of the indicator conditions (Table 4.1.8). We summarized the condition, confidence, and trend for each indicator, and assigned condition points as specified by NPS–ARD (Table 4.1.9). Scenic quality at Scotts Bluff NM was placed in the *Resource in Good Condition* category and scored 100 points. Land cover content was placed in the *Warrants Significant Concern* category and scored 0 points. The total score for overall viewshed condition was 50 points, which placed Scotts Bluff NM in the *Warrants Moderate Concern* category.

Table 4.1.8. Viewshed overall condition.

Indicators	Measures	Condition
Scenic quality	• Landscape character integrity • Vividness • Visual harmony	🟢
Land cover content	• Mid-ground % natural cover • Mid-ground % developed cover • Mid-ground % agricultural cover	🔴
Overall condition for all indicators and measures		🟡

Table 4.1.9. Summary of viewshed indicators and measures.

Indicator	Measure	Condition	Confidence	Trend	Condition rational
Scenic quality	Landscape character integrity	Resource in good condition	Medium	Not available	The average landscape character integrity score from five different viewpoints in Scotts Bluff NM was 11.5; this placed landscape character integrity in the *Resource in Good Condition* category. Full VRI assessments conducted at the park were available for one vantage point, so confidence was *Medium*. Trend was *Not Available*.
Scenic quality (continued)	Vividness	Resource in good condition	Medium	Not available	The average vividness score from five different viewpoints in Scotts Bluff NM was 10.7; this placed vividness in the *Resource in Good Condition* category. Full VRI assessments conducted at the park were available for one vantage point, so confidence was *Medium*. Trend was *Not Available*.
	Visual harmony	Resource in good condition	Medium	Not available	The visual harmony score from five different viewpoints in Scotts Bluff NM was 11; this placed visual harmony in the *Resource in Good Condition* category. Full VRI assessments conducted at the park were available for one vantage point, so confidence was *Medium*. Trend was *Not Available*.
Land cover content	Mid-ground percent natural cover	Warrants significant concern	High	Not available	Average 2011 mid-ground natural land cover visible from the five different Scottsbluff NM viewpoints comprised 48.99% of the viewed landscape; this placed mid-ground natural land cover in the *Warrants Significant Concern* category. The GIS analysis of land cover used the most recent NLCD data so confidence was *High*. Trend was *Not Available*.
	Mid-ground percent developed cover	Warrants significant concern	High	Not available	Average 2011 mid-ground developed land cover visible from the five different Scottsbluff NM viewpoints comprised 25.03% of the viewed landscape; this placed mid-ground developed land cover in the *Warrants Significant Concern* category. The GIS analysis of land cover used the most recent NLCD data so confidence was *High*. Trend was *Not Available*.

Table 4.1.9 (continued). Summary of viewshed indicators and measures.

Indicator	Measure	Condition	Confidence	Trend	Condition rational
Land cover content (continued)	Mid-ground percent agricultural cover	Warrants significant concern	High	Not available	Average 2011 mid-ground agricultural land cover visible from the five different Scottsbluff NM viewpoints comprised 25.98% of the viewed landscape; this placed mid-ground agricultural land cover in the *Warrants Significant Concern* category. The GIS analysis of land cover used the most recent NLCD data so confidence was *High*. Trend was *Not Available.*

Confidence

Confidence was *Medium* for Scenic Quality and *High* for Land Cover Content, so the score for overall confidence was 75, which met the requirements for *High* confidence in overall viewshed condition.

Trend

Trend data were *Not Available* for any indicators, so overall trend for viewshed condition was *Not Available*.

4.1.5. Stressors

Viewshed Vulnerability

A viewshed is composed of the geographic area visible from a particular point or area at a particular time. Visible environments are subject to dynamic processes, such as development of land or natural events such as fire, which can change the characteristics of a given viewshed. Assessing the vulnerability of a particular viewshed to change can help to identify potential stressors and their effects to the overall resource condition. Three aspects contribute to the potential effects of stressors on the viewshed condition; likelihood of visual change, magnitude of visual change and mitigation constraints (Meyer 2016).

We collected data to identify stressors related to viewshed vulnerability from the city of Scottsbluff and Scotts Bluff County. The city of Scottsbluff recently released its 2016 comprehensive plan identifying growth trends and directing development for the foreseeable future (City of Scottsbluff 2016). Scotts Bluff County dictates zoning regulations for the lands surrounding Scotts Bluff NM (Scotts Bluff County 2013a, 2013b). Zoning regulations dictate the pattern and type of development occurring within the viewshed of Scotts Bluff NM.

Based on the unpublished developmental guidance of the NPS-ARD (Meyer 2016), we evaluated the level of viewshed vulnerability at Scotts Bluff NM, using likelihood of visual change, magnitude of visual change and mitigation constraints as basis for our assessment of stressors to this resource. The likelihood of visual change to the Scotts Bluff NM viewshed is medium to high. Projected population growth in Scottsbluff, NE is 6.4% by 2035. The city plans to expand utilities and open 200 acres to new development. Plans to meet increased energy demand have identified solar and wind developments within the viewshed area (City of Scottsbluff 2016).

The potential magnitude of visual change is medium to high. The wind and solar developments would be within the viewshed of Scotts Bluff NM and have a large effect on the character of the viewed landscape (City of Scottsbluff 2016). Proposed developments within the city boundaries would not have a negative effect on viewsheds. The changes would be long-term and persistent.

Constraints to mitigation are medium. Both the county and cities surrounding Scotts Bluff NM value the presence of the park, but decisions that may affect the views can come from private land use decisions in accordance with zoning regulations (Scotts Bluff County 2013a, 2013b). Minimizing visual intrusions is possible with continued engagement in community planning.

4.1.6. Data Gaps

The views of and from Scotts Bluff NM are primary to the purpose of the park unit. The lack of available viewshed data limits the ability to identify trends and maintain accurate resource condition data for viewshed within the park. A collection of high quality panoramic photographs with 360° natural perspective imagery for selected viewpoints would provide accurate and efficient monitoring of viewsheds within the park. Continued assessments of important park views will be important to understand potential stressors could impact visual resources of Scotts Bluff NM. In such assessments, NPS has opportunities to engage visitors in the monitoring process through the use of interactive viewshed signs. For example, visitors are likely to take photographs at important vantage points; signs that 1) show specific reference points to align in photographs of the landscape, and 2) present links via social media to upload those images may garner all the imagery required for rigorous viewshed assessments and long term monitoring.

Our attempt to add a quantitative indicator of assessment to the qualitative approach presented by the NPS-ARD brings an objective measurement to the assessment of visual park resource. Continued monitoring of vantage points and the corresponding views in the park offers the opportunity to increase the effectiveness of this effort to protect viewsheds in park units. Additionally, knowing the average number of visitors at each viewpoint would allow managers and analysts to assign importance level with more confidence. Long term monitoring that tracks disturbances within viewsheds would facilitate any assessment of trend. Further quantitative assessments could include analyses of how spatial distributions of landcover types and developments affect park goals for viewsheds.

Acknowledgments

- Mark Meyer (NPS)

4.1.7. Literature Cited

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4.2. Night Sky

4.2.1. Background and Importance

Spectacular starry skies and dark nights are highlights of national parks for anyone who camps out or visits after dusk. The patterns among constellations are essentially the same ones that have been visible to humans for thousands of years (NPS 2012a), though the moon phase and position of celestial objects constantly change. The night sky is the “Ultimate Cultural Resource” (Rogers and Sovick 2001, NPS 2012a), because of the impressions it has made on humanity through time. More than a visual resource, dark skies play an important role in healthy ecosystems (Rich and Longcore 2006). The absence of light is important to nocturnal wildlife, light-sensitive amphibians, reptiles, insects, plants (NPS 2012b), and migrating birds requiring starry skies for navigation.

The NPS is dedicated to the protection and preservation of the natural lightscapes, those areas existing in the absence of human-caused light at night, within the parks (NPS 2012a). The parks managed by the NPS are some of the last remaining dark sky areas in the United States, providing a unique but endangered opportunity to visitors (NPS 2012c) so experience dark nights and star-gazing activities. Fewer than one-third of the population in the United States has the ability to view the

Milky Way with the naked eye from their homes (Cinzano et al. 2001, Falchi et al. 2016), due to light pollution, which highlights the importance of dark sky preservation within the parks. Clear, dark skies are increasingly rare; 99% of the United States population lives in areas where light pollution is above threshold levels (Cinzano et al. 2001, Falchi et al 2016) for viewing many astronomical objects. Stargazing in parks is a popular activity (NPS 2012d).

Managing lightscapes for dark skies and minimal light pollution not only provides enhanced visitor enjoyment of the parks, but also preserves an important cultural, natural, and scientific resource (NPS 2012e). Natural nocturnal lightscapes are crucial to the integrity of park settings. Dark skies and natural lightscapes are necessary for both human and natural resource values in the parks. Limiting light pollution, caused by the introduction of artificial light into the environment, helps to ensure that this timeless resource will continue to be shared by future generations.

Regional Context

Increases in light pollution in North America (Bennie et al. 2015) over the past century have placed the US as the country with the sixth greatest amount of light pollution, as of 2016 (Falchi et al. 2016). Night skies helped to guide early settlers, fur trappers, and traders to Nebraska, and park visitors can still come to Scotts Bluff NM for stargazing experiences (Figure 4.2.1).

Figure 4.2.1. Satellite image of Scotts Bluff NM and the lower 48 states at night in 2012. Map generated at https://worldview.earthdata.nasa.gov using Earth at Night 2012 base layer from NASA Earth Observatory.

A night sky talk took place at Scotts Bluff NM in 2015 for the first time and was attended by about thirty people (R. Manasek, personal communication, 15 July 2016). In 2016, the park unit ran a constellation program, and a planets program is schedule for late summer 2016 using the newly purchased Celestron telescope.

4.2.2. Resource Standards

National standards for night sky resources within NPS units do not currently exist. The rapid global decline of natural nocturnal nightscapes and the resulting environmental degradation has led the NPS to identify night sky quality as a "vital sign" of park resource health (Manning et al. 2015). The National Park Service is in a leadership position to pioneer protecting natural darkness as a valuable park resource (NPS 2014). Ongoing research and the development of models to enhance night sky protections are leading towards the development of standards and thresholds for acceptable conditions (NPS 2012e, Manning et al. 2015, International Dark-Sky Association 2016a).

4.2.3. Methods

Indicators and Measures

Overall night sky condition depends on the individual conditions of multiple indicators. The NPS Natural Sounds and Night Skies Division (NSNSD) efforts to protect naturally dark environments has led to a concerted effort in the collection of reliable data about existing lightscapes in many NPS units (NPS 2012c). Primary goals of the NSNSD night skies program are to protect against night sky degradation for both visitor enjoyment and healthy ecological processes.

The NSNSD identifies two main distinctions within the management considerations of the nighttime environment. Lightscapes are the human perception of both the night sky and visible terrain, and the photic environment consists of all wavelengths and patterns of light in an area (Moore et al. 2013). The overall quality of the night sky as a park resource is directly related to both the perceived aesthetic quality of the night sky to park visitors, and the effect of the photic environment on species within the park and natural physical processes (Moore et al. 2013).

Indicator: Night Sky Quality

The aesthetic qualities of the night sky within many units of the NPS are, in many cases, the best examples of dark skies in the United States. As light pollution increases nationally, these dark sky areas become more valuable to the visitor experience.

The night sky quality within a park can be understood as the ability to view the night sky free from the intrusion of light pollution. It is estimated that two-thirds of the United States population cannot see the Milky Way on a given night (Cinzano et al. 2001); the NPS strives to provide an excellent night sky experience by preserving the night sky quality within the various park units.

The NSNSD created a dataset of attributes and indicators for night sky quality. We used methods and data provided by the NSNSD to assess the night sky quality at Scotts Bluff NM.

Measure of Night Sky Quality: Bortle Dark-Sky Scale

The Bortle Dark-Sky Scale, developed by John Bortle in 2001, is intended to give astronomers a standardized method of determining the darkness of the night sky. The darkness of sky is rated on a nine-level qualitative scale intended to eliminate observer subjectivity and account for the relative absence of truly dark skies (Bortle 2001) (Table 4.2.1, Figure 4.2.2). The Bortle scale was developed from over 50 years of night sky observations, and has become the accepted descriptor of night sky quality for amateurs and professionals alike (International Dark-Sky Association 2016b).

Table 4.2.1. The Bortle Dark-Sky scale (Bortle 2001).

Bortle scale	**Milky way**	**Astronomical objects**	**Zodiacal light /constellations**	**Airglow and clouds**	**Night time scene**
Class 1 Excellent, dark-sky site	MW shows great detail and light; Scorpio/Sagittarius region casts shadows on the ground.	M33 (the Pinwheel Galaxy) is obvious to the naked eye.	Visible zodiacal light and can stretch across the entire sky.	Bluish airglow is visible near the horizon and clouds appear as dark voids.	Light from Jupiter and Venus degrade night vision. Ground objects are invisible.
Class 2 Typical, truly dark site	MW highly structured to the unaided eye.	M33 is visible with direct vision, as are many globular clusters.	Zodiacal light bright enough to cast weak shadows after dusk and has an apparent color.	Airglow may be weakly apparent and clouds still appear as dark voids.	Ground is mostly dark, but objects projecting into the sky are discernible.
Class 3 Rural sky	MW still appears complex.	Brightest Globular Clusters are distinct, M33 visible with averted vision.	Zodiacal light is striking in Spring and Autumn, color is weakly indicated	Airglow is not visible and clouds are faintly illuminated, except at the zenith.	Some light pollution evident along the horizon. Ground objects are vaguely apparent.
Class 4 Rural /suburban transition	MW visible well above horizon, lacks all but most obvious structure.	M33 is a difficult object, even with averted vision.	Zodiacal light is clearly evident, but extends less than 45 degrees after dusk.	Clouds are faintly illuminated except at the zenith.	Light pollution is obvious in several directions. Ground objects are visible.
Class 5 Suburban sky	MW is washed out overhead, weak or invisible at horizon.	The oval of M31 is detectable, as is the glow in the Orion Nebula.	Only hints of zodiacal light in Spring and Autumn.	Clouds are noticeably brighter than the sky.	Light pollution is evident in most directions. Ground objects are partly lit.
Class 6 Bright, suburban sky	Indication of MW at zenith.	M33 impossible to see without binoculars	No trace of zodiacal light.	Clouds anywhere in the sky appear fairly bright.	Sky from horizon to 35 degrees glows with grayish color. Ground is well lit.
Class 7 Suburban /urban transition	MW is totally invisible or nearly so.	M31 and the Beehive Cluster are indistinct.	The brighter constellations are recognizable.	Clouds are brilliantly lit.	Entire sky background has vague, grayish white hue.
Class 8 City sky	Not visible at all.	M31 and M44 may be barely glimpsed on good nights.	Constellations lack key stars.	Clouds are brilliantly lit.	Sky glows whitish gray or orangish, newspaper headlines are readable.

Table 4.2.1 (continued). The Bortle Dark-Sky scale (Bortle 2001).

Bortle scale	Milky way	Astronomical objects	Zodiacal light /constellations	Airglow and clouds	Night time scene
Class 9 Inner-city sky	Not visible at all.	Pleiades discernable to experienced viewer.	Only the brightest stars in constellations visible.	Clouds are brilliantly lit.	Entire sky is brightly lit.

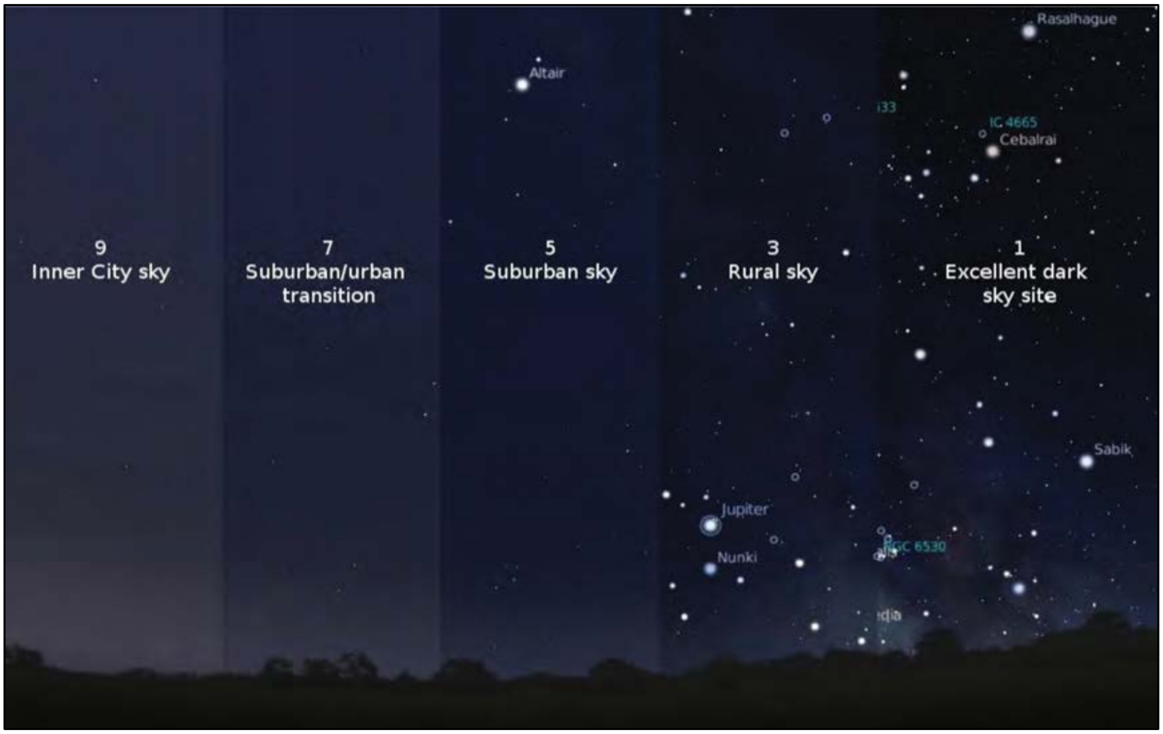

Figure 4.2.2. Bortle Dark-Sky composite image. Image from Struthers et al. (2014), generated from Stellarium (www.stellarium.org).

The 1–9 class ratings of the Bortle Scale correspond to the quality of available night sky viewing opportunities with a class rating of 1 indicating an excellent dark sky and 9 being a severely degraded night sky. The NPS NSNSD uses a categorical designation of quality that defines Bortle Scale classes of 1–3 as within the range of natural skies, we use this designation to correspond to the *Resource in Good Condition* category; classes of 4–6 are considered significantly degraded skies and we assigned these to the *Warrants Moderate Concern* category; and Bortle classes 7–9 are considered severely degraded by the NSNSD, so we assigned these classes to the *Warrants Significant Concern* category (Table 4.2.2).

Table 4.2.2. Night sky condition categories for the Bortle Dark-Sky scale.

Resource condition		Bortle class
Warrants significant concern	🔴	7 – 9
Warrants moderate concern	🟡	4 – 6
Resource in good condition	🟢	1 – 3

Measure of Night Sky Quality: Synthetic Sky Quality Meter (SQM)

The Synthetic Sky Quality Meter (SQM) measurement provides a quantitative assessment of all-sky light measurement. The synthetic SQM uses an algorithm to mimic the measurements of a common sky darkness measurement tool, the Unihedron Sky Quality Meter (NPS 2015). The NPS uses synthetic SQM over actual Unihedron SQM data because synthetic SQM is generally thought to be more accurate in measurement alignment to zenith and accurately calibrated light sensing camera data (NPS 2015). Synthetic SQM measures the brightness of sky 30 degrees above the horizon and higher, discounting bright sources of artificial light along the horizon. The reported units are reported in magnitudes per square arc-second, a standard astronomical measurement that defines the brightness of an object spread over an area of the sky.

We assigned categorical ratings using guidance from the NPS NSNSD. As a quantitative assessment of sky quality, NSNSD has related the synthetic SQM measurements to the corresponding Bortle classes (NPS 2015). Values > 21.3 were assigned to the *Resource in Good Condition* category; we values of 19.5–21.3 to the *Warrants Moderate Concern* category; and we assigned values < 19.5 to the *Warrants Significant Concern* category (Table 4.2.3).

Table 4.2.3. Night sky condition categories for the synthetic Sky Quality Meter (SQM).

Resource condition		Synthetic SQM values
Warrants significant concern	🔴	< 19.5
Warrants moderate concern	🟡	19.5 – 21.3
Resource in good condition	🟢	> 21.3

Measure of Night Sky Quality: Sky Quality Index (SQI)

The Sky Quality Index (SQI) is a synthetic scale that identifies the amount of synthetic or artificial glow in the night sky. The SQI range is 0–100, where 100 is a dark sky free from artificial glow. Values of 80–100 are considered to be representative of skies that retain natural conditions throughout most of the sky (NPS 2015) and we assigned these values to the *Resource in Good Condition* category. Index values between 60 and 79 retain most of the visible natural sky features in areas above 40 degrees from the horizon, and we assigned these values to the *Warrants Moderate Concern* category. Ratings of 40–60 are areas where the Milky Way is not visible, or only slightly visible at zenith, 20–40 are skies in which only stars and planets are visible, and values 0–20 are skies where only the brightest stars are visible and a persistent twilight exists; we assigned ratings < 60 to the *Warrants Significant Concern* category (Table 4.2.4).

Table 4.2.4. Night sky condition categories for the Sky Quality Index (SQI).

Resource condition		SQI values
Warrants significant concern	🔴	< 60
Warrants moderate concern	🟡	60 ≤ and < 80
Resource in good condition	🟢	80 – 100

Indicator: Natural Light Environment

Night skies are a unique resource that unify a human experience; throughout time, people have shared a similar experience when looking into a natural, dark sky. It is important to preserve this experience for current and future generations so that the opportunity to share a timeless experience is not lost. The natural lightscape, those resources that exist free from human caused light are critical for scenery, star viewing, and essential plant and wildlife functions (NPS 2012c). For these reasons, an important indicator to the Night Sky resource is the presence of natural lightscapes and areas free from human caused light pollution.

Measure of Natural Light Environment: Anthropogenic Light Ratio (ALR)

Anthropogenic Light Ratio (ALR) is a measurement that compares the total night sky brightness to the value that would exist under completely natural conditions. This ratio can be measured directly, or modeled when data do not exist or are unavailable. A low ALR value indicates a night sky with low levels of anthropogenic light impacts. A ratio of 0.0 indicates completely natural conditions, while a ratio of 1.0 indicates that anthropogenic light is 100% brighter than that of a naturally dark (0.0) sky and a ratio of 5.0 indicates anthropogenic light 500% brighter than a sky in a naturally dark sky, for example.

Condition thresholds have been developed by the NSNSD and other researchers (Duriscoe et al. 2007, Moore et al. 2013, Manning et al. 2015), and are considered depending on the natural resources of the park. Parks with significant natural resources, like Scotts Bluff NM, are Level 1 parks with relatively low ALR condition thresholds compared to Level 2 parks with few natural resources, generally those situated in suburban and urban areas (Moore et al. 2013). Anthropogenic Light Ratios with a value < 0.33 are representative of a generally natural state and were assigned to the category, *Resource in Good Condition*. Ratios of values 0.33–2.0 were assigned the condition, *Warrants Moderate Concern*, and any ALR values > 2.0 were considered severely degraded and assigned to the *Warrants Significant Concern* category (Table 4.2.5).

Table 4.2.5. Night sky condition categories for the Anthropogenic Light Ratio (ALR).

Resource condition		ALR values
Warrants significant concern	🔴	> 2.0
Warrants moderate concern	🟡	0.33 – 2.0
Resource in good condition	🟢	< 0.33

Data Sources

To assess the condition of night sky, we used synthetic data from a model produced by NPS Natural Sounds and Night Skies Division. Modeled values of Anthropogenic Light Ratio (ALR) were available.

Quantifying Night Sky Condition, Confidence, and Trend

Indicator Condition

We created condition categories based on NPS guidelines, expert opinion and the scientific literature. We used a point system to assign each indicator to a category. This point system is based on the NPS methods that were developed to calculate overall air quality condition (NPS-ARD 2015), a methodical and rigorous assessment approach that can be applied to other resources as well. In this approach, we assigned zero points to the condition *Warrants Significant Concern*, 50 points to *Warrants Moderate Concern*, and 100 points to *Resource in Good Condition*. The average of all measures determined the condition category of the indicator; scores from 0–33 fell in the *Warrants Significant Concern category*, scores from 34–66 were in the *Warrants Moderate Concern* category, and scores from 67–100 indicated *Resource in Good Condition*.

Indicator Confidence

Confidence ratings were based on availability of data collected about the indicator. We gave a rating of *High* confidence when data were collected by the Natural Sounds and Night Skies Division on site at the park unit. We assigned a *Medium* confidence rating when results were generated for a park unit using interpolated remote sensing data. When only less robust or no data were available, we assigned a *Low* confidence rating.

Indicator Trend

Potential trend categories were *Improving, Unchanging*, or *Deteriorating*. To calculate a trend estimate for indicators, we sought night sky data that were collected at least once in at least three different years, covering a five-year time span and met the conditions for a *High* confidence rating. If there were no data available that met these monitoring requirements for a particular indicator, we indicated that trend was *Not Available* for that indicator.

Overall Night Sky Condition, Confidence, and Trend

When good quantitative data were available, we used the general approach for combining indicator conditions, trends, and confidence described in Chapter 3 (Methods 3.2.2) to calculate overall resource condition, trend, and confidence. If only one indicator was available, we based overall condition on that indicator.

4.2.4. Night Sky Conditions, Confidence, and Trends

Night Sky Quality

Data were unavailable for night sky quality.

Natural Light Environment

🔴

Condition: Warrants Significant Concern
Confidence: Medium
Trend: Not Available

Condition

The ALR rating of 2.9 at Scotts Bluff NM was in the category, *Warrants Significant Concern*. Anthropogenic Light Ratio was the only measure of the indicator, Natural Light Environment, so this indicator was in the category, *Warrants Significant Concern* (Table 4.2.6).

Table 4.2.6. Summary of night sky indicators and measures.

Indicator	**Measure**	**Condition**	**Confidence**	**Trend**	**Condition rational**
Night sky quality	Bortle Dark Sky Class	Not available	NA	Not available	Data were *Not Available*
	Synthetic Sky Quality Meter (SQM)	Not available	NA	Not available	Data were *Not Available*
	Sky Quality Index (SQI)	Not available	NA	Not available	Data were *Not Available*
Natural light environment	Anthropogenic Light Ratio (ALR)	Warrants significant concern	High	Not available	Anthropogenic Light Ratio was 0.49, which placed the condition of this measure in the category, *Warrants Moderate Concern.* Results were derived from interpolated data so confidence was *Medium* and trend was *Not Available.*

Confidence

Natural Light Environment data were interpolated through remote sensing, so confidence was *Medium*.

Trend

Trend was *Not Available*.

Night Sky Overall Condition

Condition

The overall condition (Table 4.2.7) of night skies at Scotts Bluff NM depended on the single indicator for which data were available—Natural Light Environment. The condition of this indicator placed the overall condition of night skies in the category, *Warrants Significant Concern*.

Confidence

The only available data were interpolated using remote sensing techniques, so confidence was *Medium*.

Trend

Trend was *Not Available*.

Table 4.2.7. Night sky overall condition.

Indicators	Measures	Condition
Night sky quality	- Bortle Dark-Sky class - Synthetic Sky Quality Meter (SQM) - Sky Quality Index (SQI)	Data unavailable
Natural light environment	- Anthropogenic Light Ratio (ALR)	🔴
Overall condition for all indicators and measures		🔴

4.2.5. Stressors

Light pollution is a concern for night sky quality in Scotts Bluff NM. The cities of Scottsbluff and Gering create a significant amount of light pollution even though the cities are converting to directional (downward) street lights; even with this change in lighting design, light pollution is likely to increase with the growth of the cities (R. Manasek, personal communication, 15 July 2016). Because of SCBL's size (3,000 acres) there are no areas within SCBL to escape this light pollution.

4.2.6. Data Gaps

The Natural Sounds and Night Skies Division attempted to collect night sky data within Scotts Bluff NM, but weather conditions prevented a good capture of night conditions (R. Manasek, personal communication, 15 July 2016). Annual or biennial (every two years) sampling of night sky conditions at Scotts Bluff NM would improve the ability of managers to maintain optimal night sky conditions.

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4.3. Soundscape

The majority of the text in this section was written by the NPS Natural Sounds and Night Skies Division (NSNSD) to guide the NRCA process. We added details specific to Scotts Bluff National Monument and reorganized several subsections herein to follow the structure that we used for the other NRCA natural resource sections.

Scotts Bluff NM, at far left of photo, is subject to the sounds generated by the nearby cities of Scottsbluff and Gering. Photo © BOBAK HA’FRI (Wikimedia Commons 2010).

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. An unimpaired acoustic environment is an important part of overall visitor experience and enjoyment as well as vitally important to overall ecosystem health.

Visitors to national parks often indicate that an important reason for visiting the parks is to enjoy the relative quiet that parks can offer. 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).

Sound plays a critical role in intra- and inter-species communication, including courtship and mating, predation and predator avoidance, and effective use of habitat. Studies have shown that wildlife can be adversely affected by sounds that intrude on their habitats. While the severity of the impacts varies depending on the species being studied and other conditions, research strongly supports the fact that wildlife can suffer adverse behavioral and physiological changes from intrusive sounds (noise) and other human disturbances. Documented responses of wildlife to noise include increased heart rate, startle responses, flight, disruption of behavior, and separation of mothers and young (Selye 1956, Clough 1982, USDA 1992, Anderssen et al. 1993, NPS 1994).

The 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) require the NPS to preserve the park’s natural soundscape and restore the degraded soundscape to the natural condition wherever possible. Additionally, NPS is required to prevent or minimize degradation of the natural soundscape from noise (i.e., inappropriate/undesirable human-caused sound).

Although the management policies currently refer to the term soundscape as the aggregate of all natural sounds that occur in a park, differences exist between the physical sound sources and human perceptions of those sound sources. The 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 acoustic environment, while the human perception of that acoustic environment is defined as the soundscape. Clarifying this distinction will allow managers to create objectives for safeguarding both the acoustic environment and the visitor experience.

Regional Context

Scotts Bluff NM is surrounded by agricultural fields, residential areas, a golf course, the North Platte River, and some remnant prairie. Primary sources of non-natural sounds within the park include noise from the nearby Cities of Scottsbluff and Gering, train traffic passing through the cities, agricultural activities, motor vehicle traffic within the park and on surrounding roads–with substantial noise coming from semi-trucks and motorcycles, and air traffic passing overhead.

4.3.2. Soundscape Standards

Sound Science 101

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 and amplitude (Templeton et al. 1997, Harris 1998). Noise, essentially the negative evaluation of sound, is defined as extraneous or undesired sound (Morfey 2001).

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, and are most 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, low frequency sounds travel farther.

Besides the pitch of a sound, we also perceive the amplitude (or level) of a sound. This metric is described in decibels (dB). The decibel scale is logarithmic, meaning that every 10 dB increase in sound pressure level (SPL) represents a tenfold increase in sound energy. This also means that small variations in sound pressure level can have significant effects on the acoustic environment. For instance, a 6dB increase in a noise source will double the distance at which it can be heard, increasing the affected area by a factor of four. Sound pressure level is commonly summarized in terms of dBA (A-weighted sound pressure level). This metric significantly discounts sounds below 1,000 Hz and above 6,000 Hz to approximate human hearing sensitivity.

The natural acoustic environment is vital to the function and character of a national park. Natural sounds include those sounds upon which ecological processes and interactions depend. Examples of natural sounds in parks include:

- Sounds produced by birds, frogs or insects to define territories or attract mates
- Sounds produced by bats to navigate or locate prey
- Sounds produced by physical processes such as wind in trees, flowing water, or thunder

Although natural sounds often dominate the acoustic environment of a park, human-caused noise (Table 4.3.1) has the potential to mask these sounds. Noise impacts the acoustic environment much like smog impacts the visual environment; obscuring the listening horizon for both wildlife and visitors. Examples of human-caused sounds heard in parks include:

- Aircraft (e.g., high-altitude and military jets, fixed-wing, helicopters)
- Motor Vehicles
- Generators & Air Conditioners
- Watercraft
- Grounds care (lawn mowers, leaf blowers)
- Human voices
- Music

Table 4.3.1. Examples of sound levels measured in national parks (Ambrose and Burson 2004).

Decibel level (dBA)	Sound source	Park unit
10	Volcano crater	Haleakala NP
20	Leaves rustling	Canyonlands NP
40	Crickets at 5 m	Zion NP
60	Conversational speech at 5 m	Whitman Mission NHS
80	Snowcoach at 30 m	Yellowstone NP
100	Thunder	Arches NP
120	Military jet, 100 m above ground level	Yukon-Charley Rivers NP
126	Cannon fire at 150 m	Vicksburg NMP

Characterizing the acoustic environment Oftentimes, managers characterize ambient conditions over the full extent of the park by dividing total area into “acoustic zones” on the basis of different vegetation zones, management zones, visitor use zones, elevations, or climate conditions. Then, the intensity, duration, and distribution of sound sources in each zone can be assessed by collecting sound pressure level (SPL) measurements, digital audio recordings, and meteorological data. Indicators typically summarized in resource assessments include natural and existing ambient sound levels and types of sound sources. Natural ambient sound level refers to the acoustical conditions that exist in the absence of human-caused noise and represents the level from which the NPS measures impacts to the acoustic environment. Existing ambient sound level refers to the current sound intensity of an area, including both natural and human-caused sounds. The influence of anthropogenic noise on the acoustic environment is generally reported in terms of SPL across the full range of human hearing (12.5–20,000 Hz), but it is also useful to report results in a much narrower band (20–1250 Hz) because most human-caused sound is confined to these lower frequencies.

Reference conditions

Reference criteria should address the effects of noise on human health and physiology, the effects of noise on wildlife, the effects of noise on the quality of the visitor experience, and finally, how noise impacts the acoustic environment itself.

Various characteristics of sound can contribute to how noise may affect the acoustic environment. These characteristics may include rate of occurrence, duration, amplitude, pitch, and whether the sound occurs consistently or sporadically. In order to capture these aspects, the quality of the acoustic environment is assessed using a number of different metrics including existing ambient and natural ambient sound level (measured in decibels), percent time human-caused noise is audible, and noise-free interval. In summary, if we are to develop a complete understanding of a park's acoustic environment, we must consider a variety of sound metrics. This can make selecting one reference condition difficult. For example, if we chose to use just the natural ambient sound level for our reference condition, we would focus only on sound pressure level and overlook the other aspects of sound mentioned above.

Ideally, reference conditions would be based on measurements collected in the park, but this is not always logistically feasible. In cases where on-site measurements have not been gathered, one can reference meta-analyses of national park monitoring efforts. Aggregated data from 189 sites in 43 national parks (Lynch et al. 2011) had a median L_{90} across all sites and hours of the day of 21.8 dBA (between 20 and 800 Hz). L_{90} is the sound level that is heard 90% of the time; an estimate of the background against which individual sounds are heard. A similarly comprehensive geospatial modeling effort (Mennitt et al. 2013) assimilated data from 291 park monitoring sites across the nation, revealing that the median daytime existing sound level in national parks rested around 31 dBA. In addition, among 89 acoustic monitoring deployments analyzed for audibility, the median percent time audible of anthropogenic noise during daytime hours was found to be 35%.

4.3.3. Methods

Using acoustic data collected at 244 sites and 109 spatial explanatory layers (such as location, landcover, hydrology, wind speed, and proximity to noise sources such as roads, railroads, and airports), NSNSD developed a geospatial sound model that predicts natural and existing sound levels with 270 meter resolution (Figure 4.3.1, NSNSD 2016).

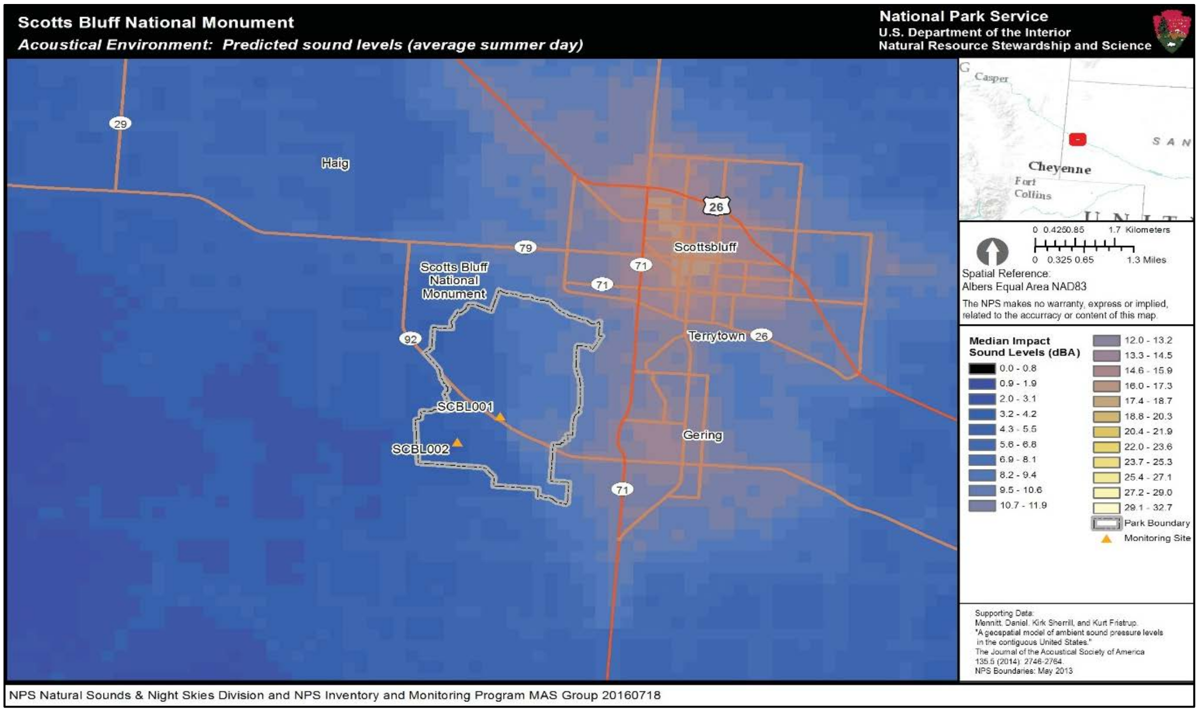

Figure 4.3.1. Modeled L_{50} dBA impact levels in Scotts Bluff NM. Figure provided by E. Lynch, NSNSD 2016.

Indicators and Measures

We assessed overall acoustic environment condition using a single indicator: anthropogenic impact. To assign a condition to this indicator, we used a measurement identified by the NPS Natural Sounds and Night Skies Division. Potential conditions were: *Resource in Good Condition, Warrants Moderate Concern,* and *Warrants Significant Concern*.

Indicator: Anthropogenic Impact

The soundscape of a park is the totality of the perceived acoustical environment. Soundscape usually refers to human perception, but the term could also apply to other species. For example, bat soundscapes include a wealth of ultrasonic information that is not represented in human soundscapes. Park soundscapes, and park acoustical environments, will often include noise from sources inside and outside the park boundaries. Noise is unwanted sound, where extraneous sound serves no function. Much noise comes from anthropogenic sources, so identifying the extent of these sources on the acoustic environment can reveal potential impacts to wildlife and to visitor experience.

Measure of Anthropogenic Impact: L_{50} dBA Impact (Existing Ambient Sound – Natural Ambient Sound)

In addition to predicting existing and natural ambient sound levels, the geospatial model developed by the NPS Natural Sounds and Night Skies Division also calculates the difference between the two metrics. This difference is a measure of impact to the natural acoustic environment from anthropogenic sources. The resulting metric (L_{50} dBA impact) indicates how much anthropogenic noise raises the existing sound pressure levels in a given location. Specifically, L_{50} is the median sound level attributable to anthropogenic sources that is exceeded ≥ 50% of time in a summer day.

Because the National Park System comprises a wide variety of park units, two threshold categories (Table 4.3.2) are generally considered (urban and non-urban), based on proximity to urban areas (U.S. Census Bureau 2010). The urban criteria are applied to park units that have at least 90% of the park property within an urban area. The non-urban criteria were applied to units that have at least 90% of the park property outside an urban Area. Parks that are distant from urban areas possess lower sound levels, and they exhibit less divergence between existing sound levels and predicted natural sound levels. These quiet areas are more susceptible to subtle noise intrusions than urban areas. Visitors to parks have expectations for noise-free environments within their listening area, the area in which they can perceive sound (NPS 2015). Accordingly, the thresholds for the amber and red condition ratings are lower for these park units than for units near urban areas. Urban areas tend to have higher ambient sound levels than non-urban areas (U.S. EPA 1971, Schomer et al. 2011). Higher thresholds are used for parks in urban areas. However, acoustic environments are important in all parks; units in urban areas may seek to preserve or restore low ambient sound levels to offer respite for visitors. We used non-urban threshold to identify condition of anthropogenic impact in Scotts Bluff NM.

Table 4.3.2. Soundscape condition categories for anthropogenic impact.

Resource condition		Mean L_{50} impact (dBA) non-urban
Warrants significant concern	🔴	dBA > 3.0 Listening area reduced by > 50%
Warrants moderate concern	🟡	1.5 < dBA ≤ 3.0 Listening area reduced by 30–50%
Resource in good condition	🟢	dBA ≤ 1.5 Listening area reduced by ≤ 30%

Measure of Anthropogenic Impact: Qualitative Assessment

While quantitative modeled sound data provide a general picture of noise issues within a park, models may miss sounds that are seasonal and/or not directly connected to standard sources of noise (e.g., airports, highways, industrial facilities). We relied on expert opinion among park management to validate the modeled soundscape and to identify additional sources of noise, when relevant.

Data Sources

We used predicted sound level data collected by NPS Natural Sounds and Night Skies Division to identify mean impact levels in Scotts Bluff NM.

Quantifying Soundscape Condition, Confidence, and Trend Indicator Condition

Indicator Condition

To quantify soundscape condition, we used assessment criteria developed by the NPS Natural Sounds and Night Skies Division (Turina et al. 2013).

Indicator Confidence

Confidence ratings were based on availability of data collected about the indicator. We gave a rating of *High* confidence when data were collected using methods approved by the NPS Natural Sounds and Night Skies Division. We assigned a *Medium* confidence rating when data were collected for short periods of time or did not differentiate between ambient natural and ambient existing sounds, and assigned *Low* confidence ratings when acoustic data were unavailable.

Indicator Trend

Potential trend categories were *Improving, Unchanging,* or *Deteriorating*. To calculate a trend estimate for indicators, we required data that were collected on-site or interpolated using geospatial modeling for multiple years. If there were no data available that met these monitoring requirements, we indicated that trend was *Not Available* for that indicator.

Evaluating trends in condition is straightforward for parks where repeated measurements have been conducted because measurements can be compared. But inferences can also be made for parks where fewer data points exist. Nationwide trends indicate that prominent sources of noise in parks (namely vehicular traffic and aircraft) are increasing. However, it is possible that conditions in specific parks differ from national trends. The following events might contribute to a declining trend in the quality of the acoustic environment: expansion of traffic corridors nearby, increases in traffic due to industry, changes in zoning or leases on adjacent lands, changes in land use, planned construction in or near the park, increases in population, and changes to airspace (particularly those that bring more aircraft closer to the park). Most states post data on traffic counts on department of transportation websites, and these can be a good resource for assessing trends in vehicular traffic. Changes to airport operations, air space, and land use will generally be publicized and evaluated through the National Environmental Policy Act (NEPA) process. Conversely, the following events may signal improvements in trend: installation of quiet pavement in or near parks, use of quiet technology for recreation in parks, decrease in vehicle traffic, use of quiet shuttle system instead of passenger cars, building utility retrofits (e.g. replacing a generator with solar array), or installation of "quiet zone" signage.

Overall Soundscape Condition, Confidence, and Trend

We used only one indicator, so the condition, confidence and trend of the indicator were also the overall condition, confidence, and trend.

4.3.4. Soundscape Condition, Confidence, and Trends

Condition

The L_{50} dBA impact level at Scotts Bluff NM was 7.1, which placed overall condition for soundscape at Scotts Bluff NM in the category, *Warrants Significant Concern* (Table 4.3.3). Park managers and staff found the result to be reflective of their qualitative perceptions of soundscape in the park.

Confidence
We used methods developed by NPS NSNSD to assess soundscape condition, and used data supplied by the division to complete the assessment. The confidence was *High*.

Trend
Acoustic data for Scotts Bluff NM were insufficient to calculate a trend. Trend was *Not Available*.

Table 4.3.3. Soundscape overall condition.

Indicators	Measures	Condition
Anthropogenic impact	• L_{50} dBA impact • Qualitative assessment	🔴
Overall condition for all indicators and measures		🔴

4.3.5. Stressors

A common source of noise in national parks is transportation (e.g., airplanes, motor vehicles). Growth in the number of vehicles on the road is increasing faster than is the human population in the US (Barber et al. 2010). Between 1970 and 2007, traffic on US roads nearly tripled to almost 5 trillion vehicle kilometers/year (http://www.fhwa.dot.gov/ohim/tvtw/tvtpage.cfm). Aircraft traffic grew by a factor of three or more between 1981 and 2007 (http://www.bts.gov/programs/airline_information/air_carrier_traffic_statistics/airtraffic/annual/1981_present.html). As these noise sources increase throughout the United States, the ability to protect pristine and quiet natural areas becomes more difficult (Mace et al. 2004). Some possibilities exist for changes to the transportation network in the region, including the addition of a third track on the Union Pacific line, however this is dependent on more coal development in Wyoming.

Scotts Bluff NM now has baseline reference data if these proposed changes materialize, and managers would like to see monitoring continue in the long term to record changes of the soundscape.

4.3.6. Data Gaps

Baseline data were collected in 2014 and were being summarized at the time of this assessment (E. Lynch, personal communication, 19 July 2016). This baseline acoustic ambient data collection will clarify existing conditions and provide greater confidence in resource condition trends. Wherever possible, baseline ambient data collection should be conducted. In addition to providing site specific information, this information can also strengthen the national noise model.

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. Several recommendations have been made for human exposure to noise, but no guidelines exist for wildlife and the habitats we share. The majority of research on wildlife has focused on acute noise events, so further research needs to be dedicated to chronic noise exposure (Barber et al. 2011). In addition to wildlife, standards have not been developed yet for assessing 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.

Acknowledgments

- Emma Brown (NPS)

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4.4. Air Quality

Clear skies over Scotts Bluff NM. Photo © PODRUZNIK (Wikimedia Commons 2009).

4.4.1. Background and Importance

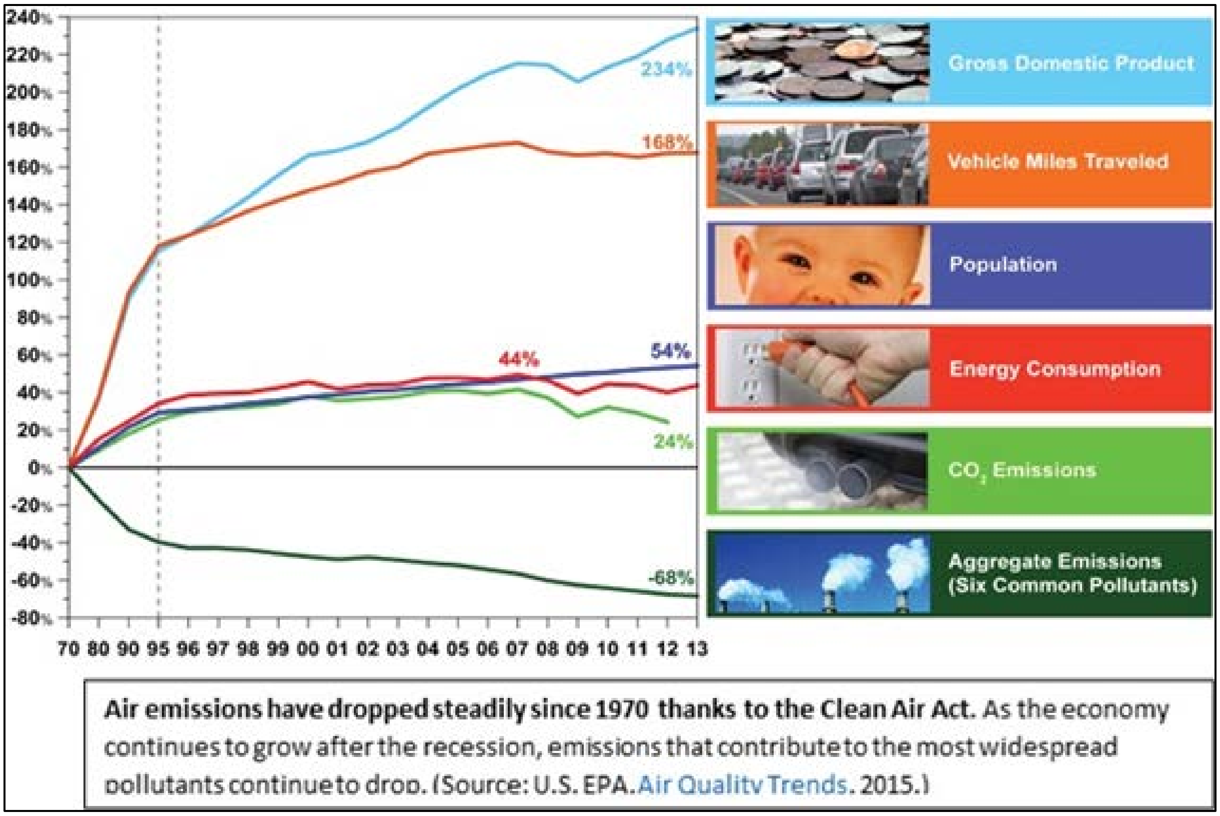
Most visitors expect clean air and clear views in parks. However, air pollution can sometimes affect Scotts Bluff NM. Clean, clear air is critical to human health, the health of ecosystems, and the appreciation of scenic views. Pollution can damage animal health (including human health), plants, water quality, and alter soil chemistry (e.g., Heagle et al. 1973, Schulze 1989, Brunekreef and Holgate 2002). Our ability to clearly see color and detail in distant views (visibility) can also be impacted by air pollution.

The National Park Service (NPS) is dedicated to preserving natural resources, including clear air. The National Park Service Organic Act (16 U.S.C. § 1 1916) and the Clean Air Act (CAA; 42 U.S.C. § 7401 et seq. 1970) codify this commitment, specifying that NPS protect air quality within park units for the integrity of other natural and cultural resources. The Clean Air Act designates three classes (Class I, II, and III) of air quality protection, and the U.S. Environmental Protection Agency (EPA) sets National Ambient Air Quality Standards (NAAQS) for acceptable pollutant levels within these classes. Class I airsheds have the strictest regulations, but all three classes are regulated to specific levels to protect and improve national air quality (42 U.S.C. § 7401 et seq. 1970). Park units smaller than 6,000 acres in area, including Scotts Bluff NM, are typically Class II airsheds. These protective classifications mean that NPS units receive federal assistance to protect and improve their air quality, but regulation within park boundaries may not be enough. Many of the threats to clean air in NPS units come from pollution sources outside of park boundaries (Ross 1990).

As a result, protection and improvement of air quality within parks require active NPS participation and cooperative conservation partnerships with air regulatory agencies, stakeholders, and other federal land managers. The CAA makes a provision for federal land managers to participate in regulatory decision-making when protected federal lands, such as NPS units, may be affected (Ross 1990). Participation may include consultations, written comments, recommendations, and review.

Regional Context

Most emissions that contribute to air pollution have declined substantially in the U.S. since 1970 despite population and economic growth (Figure 4.4.1), but current air quality conditions are mixed across states and regions (ALA 2015). The American Lung Association (ALA) compiles a State of the Air report for each state, and assigns scores for air quality by county. Scotts Bluff NM is located in Scottsbluff County where there were not enough monitoring data from 2013–2015 to assign a grade for ozone pollution, but short-term particle pollution received the best possible grade (A) for that time period (ALA 2015). Three of Nebraska’s 93 counties had sufficient data for the ALA to assign an overall grade to ozone pollution, and six counties received a grade for particle pollution; grades ranged from A to C, indicating heterogeneity in air quality.



Air emissions have dropped steadily since 1970 thanks to the Clean Air Act. As the economy continues to grow after the recession, emissions that contribute to the most widespread pollutants continue to drop. (Source: U.S. EPA. Air Quality Trends. 2015.)

Figure 4.4.1. Air quality trends for the United States from 1970 to 2013. Emissions that contribute to poor air quality in the United States have declined substantially since 1970, in spite of economic and population growth (Figure courtesy of EPA http://www.epa.gov/airtrends/aqtrends.html#comparison).

Coal fired power plants, vehicle exhaust, oil and gas development, agriculture, and fires are contributors to regional air quality. Since 2000, emissions from regional coal-fired power plants have decreased with further reductions anticipated over the next few years. Emissions from regional oil and gas are likely to increase.

4.4.2. Resource Standards

A variety of pollution sources can degrade air quality. Primary pollutants, such as gasses from fossil fuel combustion, wildfires, dust storms, and volcanic eruptions, are emitted directly from a source. Secondary pollutants are indirect, forming when primary pollutants react with natural compounds in the atmosphere. Examples of secondary pollutants include nitrogen dioxide (NO_2) and other nitrogen oxide compounds (NO_x), ozone (O_3), and sulfuric acid (H_2SO_4). Some polluting sources may contribute both primary and secondary pollutants. For example, coal-powered plants produce SO_2, NO_x, particulate matter, and mercury.

The EPA sets standards at levels specific to protecting human and environmental health (40 CFR part 50). Primary standards are set to protect public health, and slightly less stringent secondary standards are set to safeguard animals, plants, structures, and visibility (EPA 2016a). The NPS Air Resources Division uses the EPA's standards, natural visibility goals, and ecological thresholds as benchmarks to assess current conditions of visibility, ozone, and atmospheric deposition throughout parks.

4.4.3. Methods

Indicators and Measures

The approach used for assessing the condition of air quality parameters at the park was developed by the NPS Air Resources Division (NPS-ARD) for use in Natural Resource Condition Assessments (NPS-ARD 2015b). Overall air quality condition was assessed with six main indicators (Figure 4.4.2):

- Visibility
- Ozone
- Particulate matter
- Nitrogen deposition
- Sulfur deposition
- Mercury deposition

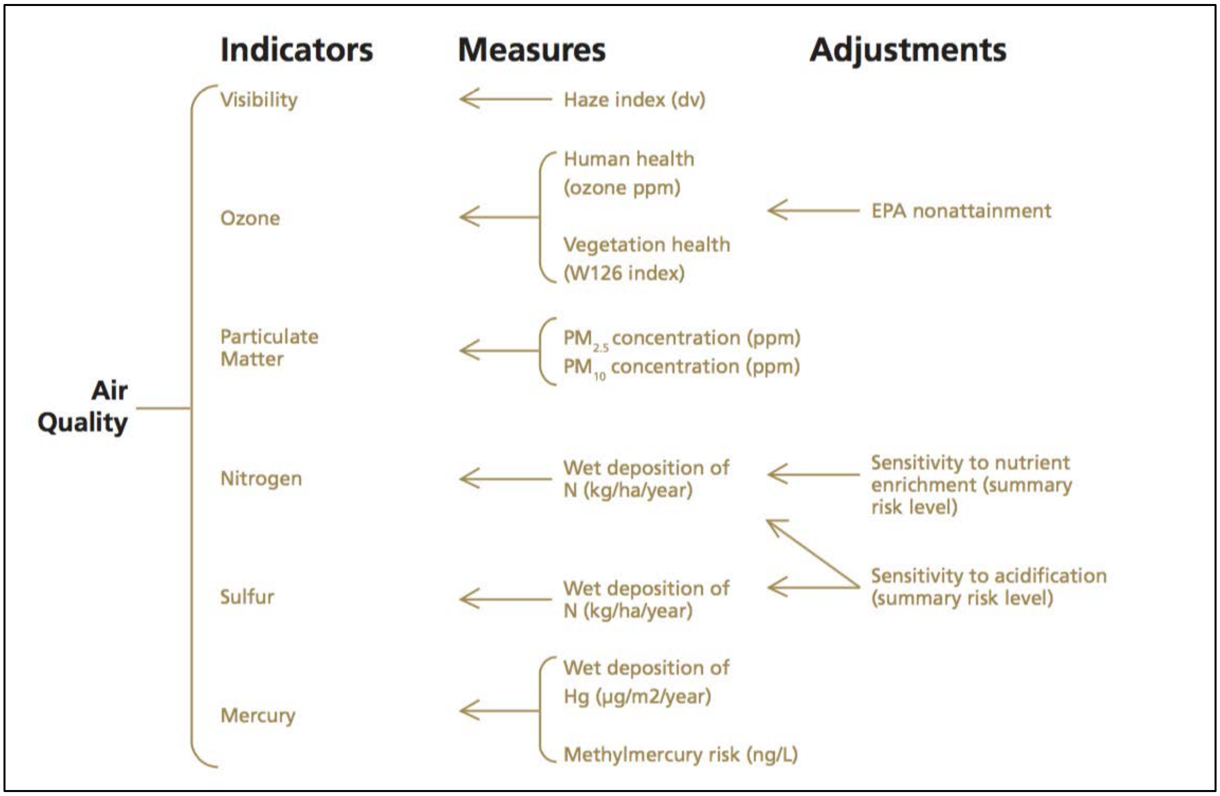


Figure 4.4.2. Schematic of the factors considered in air quality condition assessment.

Each of these indicators contributes to different aspects of air quality and can affect human and environmental health in different ways. To assign a condition to each indicator, we used measurements specified by NPS-ARD and EPA (NPS-ARD 2013, EPA 2016a NPS-ARD 2015a). Measurements were compared to benchmarks recommended by NPS-ARD and EPA to assign one of three condition categories: *Resource in Good Condition*, *Warrants Moderate Concern*, and *Warrants*

Significant Concern. We used additional measurements to support the indicator condition, and then considered all indicator conditions together in an overall air quality condition assessment.

Some lichens (see section below) and plants that are sensitive to air quality conditions may provide an additional qualitative measure of overall air quality. However, because the effects of air quality are not easily teased apart from other environmental conditions that affect flora, lichen presence is best used in conjunction with quantitative measures.

Lichens and Air Quality

Lichens have long been promoted as good indicators of air pollution because 1) lichens concentrate a variety of pollutants in their tissues, 2) pollutants can cause adverse physiological changes in some lichen species, and 3) biomonitoring is less expensive than traditional air quality monitoring with specialized equipment (Pohlman and Maniero 2005).

Unlike air quality monitors that collect data on individual pollutants, the presence and condition of specific lichens can indicate a cumulative biological response to air quality. Some lichens are sensitive to pollutants—particularly N and S—and others are tolerant of poor air quality conditions (e.g. Brodo et al. 2001). The presence of sensitive lichens can be a sign of good air quality in the area, but their absence is not necessarily due to poor air quality. Lichens can be affected by many stressors besides air pollution (e.g., climate change, grazing, habitat alterations, and fire), so it is difficult to establish a cause-and-effect relationship between air quality and lichen health. Therefore, studies to document current or potential future impacts on lichens are most effective when used in conjunction with other data (Pohlman and Maniero 2005).

There are a number of lichens at Scotts Bluff NM that have been rated in their sensitivity to air pollution (Table 4.4.1). Monitoring these species over time could be a valuable addition to the park's understanding of the cumulative effects of air pollution.

Table 4.4.1. Lichen species at Scotts Bluff NM with known level of sensitivity. S= sensitive, I=intermediate sensitivity T=tolerant.

Species name	Sensitivity
Lecanora saligna	I
Physcia adscendens	I
Physcia stellaris	I
Caloplaca holocarpa	I
Xanthoria polycarpa	I
Caloplaca vitellinula	I-T
Caloplaca cerina	S-I
Usnea hirta	S-I
Lecanora dispersa	T
Lecanora hagenii	T

Table 4.4.1 (continued). Lichen species at Scotts Bluff NM with known level of sensitivity. S= sensitive, I=intermediate sensitivity T=tolerant.

Species name	Sensitivity
Lecanora muralis	T
Physcia dubia	T

Indicator: Visibility

Visibility—how well and how far a person can see—can affect visitor experience. 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 (Figure 4.4.3). At night, air pollution scatters artificial light, increasing the effect of light pollution. Visitors expecting to see particular vistas may be disappointed by reduced visibility. Haze can degrade visibility by up to 60% relative to baseline conditions in western parks (EPA 2015a). On the clearest days at Badlands NP, the visibility is about 140 miles, which approaches the 180-mile visual range seen under natural conditions (IMPROVE 2016). However, sometimes hazy days occur when the visibility is only about 55 miles.

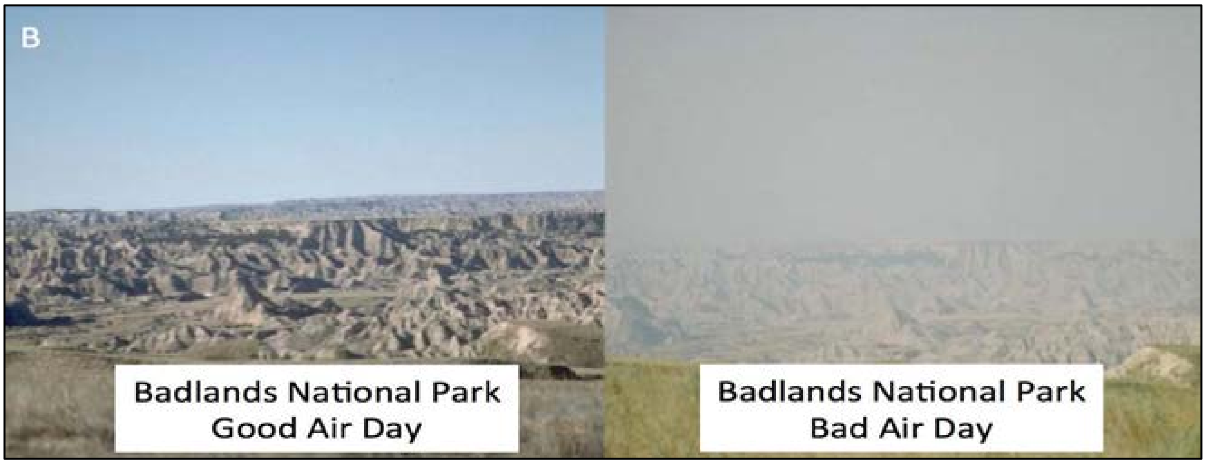


Figure 4.4.3. Photo representation of air quality in Badlands NP for a good air and bad air day. Haze can reduce visibility at Fort Laramie NHS and may be accompanied by an increased risk to human and environmental health. Fires and dust storms can contribute to poor air quality days, such as this one at Badlands NP (Photo by NPS-ARD 2015c; http://www.nature.nps.gov/air/WebCams/index.cfm).

Measure of Visibility: Haze Index

The CAA established a national goal to return visibility to "natural conditions" in Class I areas and the NPS-ARD recommends a visibility benchmark condition for all NPS units, regardless of Class designation, consistent with the Clean Air Act goal. Natural visibility conditions are those estimated to exist in a given area in the absence of human-caused visibility impairment. The Regional Haze Rule (40 CFR § 51–52 1999) calls for improving the worst air quality days and preventing degradation on good air quality days. The haze index (measured in deciviews [dv]) is used to track regional haze. The deciview scale scores pristine conditions as a zero and increases as visibility decreases. Scotts Bluff NM is not a Class I airshed, and therefore not subject to the rule, but the rule provides a good measurement protocol that is relevant to a park for which air quality is an important consideration.

NPS-ARD assesses visibility condition based on the deviation of the estimated current visibility on mid-range days from natural visibility conditions (i.e., those estimated for a given area in the absence of human-caused visibility impairment). Mid-range days are defined as the mean of the visibility observations falling within the range of the 40th through the 60th percentiles and are expressed in terms of a haze index. The visibility condition is calculated as follows:

> *Visibility Condition = estimated current haze index on mid-range days – estimated haze index under natural conditions on mid-range days*

For visibility condition assessments, annual haze index measurements on mid-range visibility days are averaged over a 5-year period at each visibility monitoring site with at least three years of complete annual data and interpolated across all monitoring locations for the contiguous U.S. The maximum value within the Scotts Bluff NM boundary is reported as the visibility condition from this national analysis and compared to NPS-ARD benchmarks (Table 4.4.2).

Table 4.4.2. Air quality condition categories for visibility (NPS-ARD 2015a).

Resource condition		Visibility* (dv)
Warrants significant concern	🔴	> 8
Warrants moderate concern	🟡	2 – 8
Resource in good condition	🟢	< 2

* Estimated 5-year average of visibility on mid-range days minus natural condition of mid-range days.

Visibility is monitored through the Interagency Monitoring of Protected Visual Environments (IMPROVE) Program. In this assessment, we relied we relied primarily on NPS-ARD air quality trends (2004–2013) and conditions (2009–2013; NPS-ARD 2016), with reference to additional studies and data where relevant.

A visibility condition estimate of less than 2 dv above estimated natural conditions indicates that air quality is in *Good Condition*, estimates ranging from 2-8 dv above natural conditions *Warrant Moderate Concern*, and estimates greater than 8 dv above natural conditions *Warrant Significant Concern*. Reference condition ranges reflect the variation in visibility conditions across the monitoring network.

Visibility trends were computed from haze index values on the 20% haziest days and the 20% clearest days, consistent with visibility goals in the Clean Air Act and Regional Haze Rule, which include improving visibility on the haziest days and allowing no deterioration on the clearest days. If the haze index trend on the 20% clearest days is deteriorating, the overall visibility trend is reported as deteriorating. Otherwise, the haze index trend on the 20% haziest days is reported as the overall visibility trend. Visibility trends were calculated from the monitor located at Wind Cave National Park.

Indicator: Ozone

Ozone (O_3) is a colorless gas that naturally occurs high in the atmosphere and protects the earth's surface from harmful ultraviolet rays. However, ozone that occurs close to the ground can be harmful to animal and plant health (McKee 1994, Sokhi 2011). Ground-level ozone is a secondary pollutant that is formed when oxygen reacts with nitrogen oxides (NO_x), volatile organic compounds (VOCs), or carbon monoxide (CO) in the presence of sunlight. On hot, sunny days, the right combination of these compounds can combine to form ozone (Figure 4.4.4).

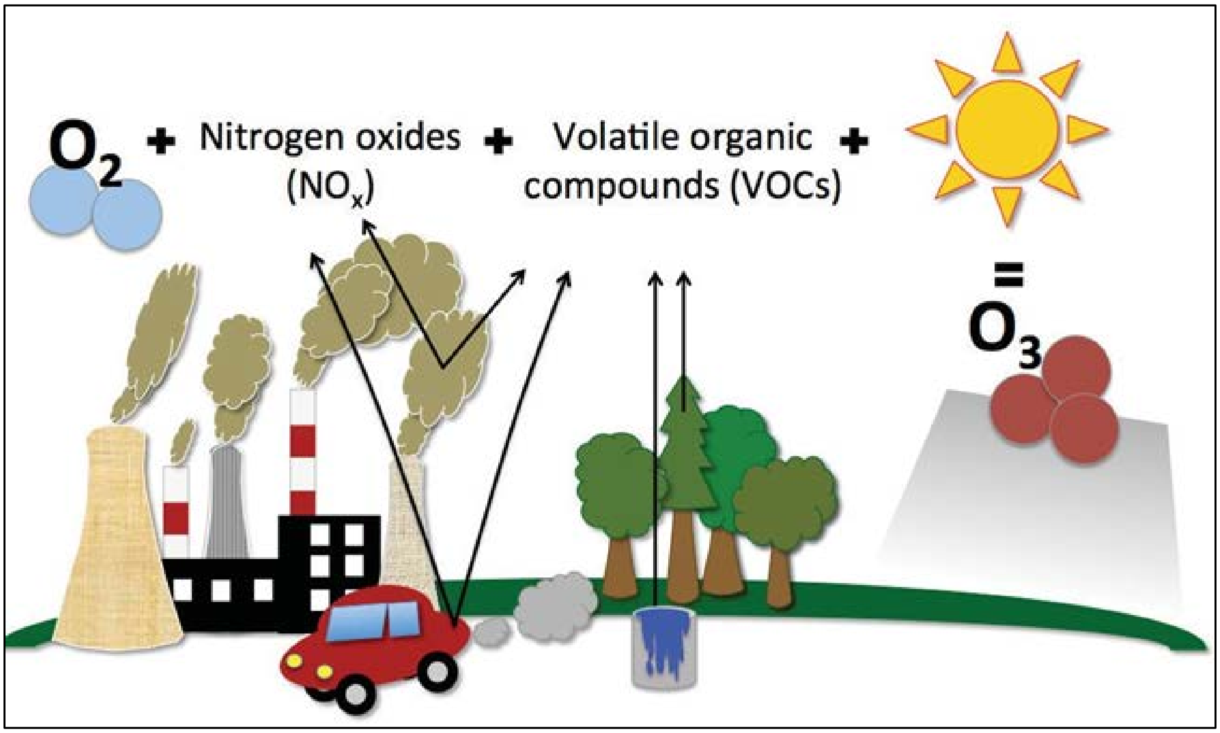


Figure 4.4.4. Graphic illustrating ozone (O_3) production (Dibner 2017). Ozone is formed when oxygen (O_2) combines with nitrogen oxides (NO_x) and volatile organic compounds (VOCs) in the presence of sunlight. Fuel combustion from vehicles, power plants, and industrial operations produces NOx and VOCs. Additional VOCs are produced by anthropogenic sources, such as paints and other solvents, and natural sources, like plants. Ground level ozone can be hazardous to human and environmental health (NPS-ARD 2015b).

While VOCs are produced naturally by some plants and soil microbes (Insam and Seewald 2010), additional VOCs are emitted room chemical solvents and during fuel combustion (EPA 2015b).

Nitrogen oxides are produced by burning fossil fuels, and the largest sources of NO are industrial and vehicle emissions.

Ozone pollution has generally decreased in the United States since 1980 and, to a lesser extent, in the Northern Rockies and Plains region as well (EPA 2014). In South Dakota, vehicle emissions produce the majority of NO_x, followed by biogenics, non-vehicle fuel combustion, and industrial fires (EPA 2015c). At monitoring sites close to South Dakota, there was little change in ozone concentration from 2001–2007 (Figure 4.4.5).

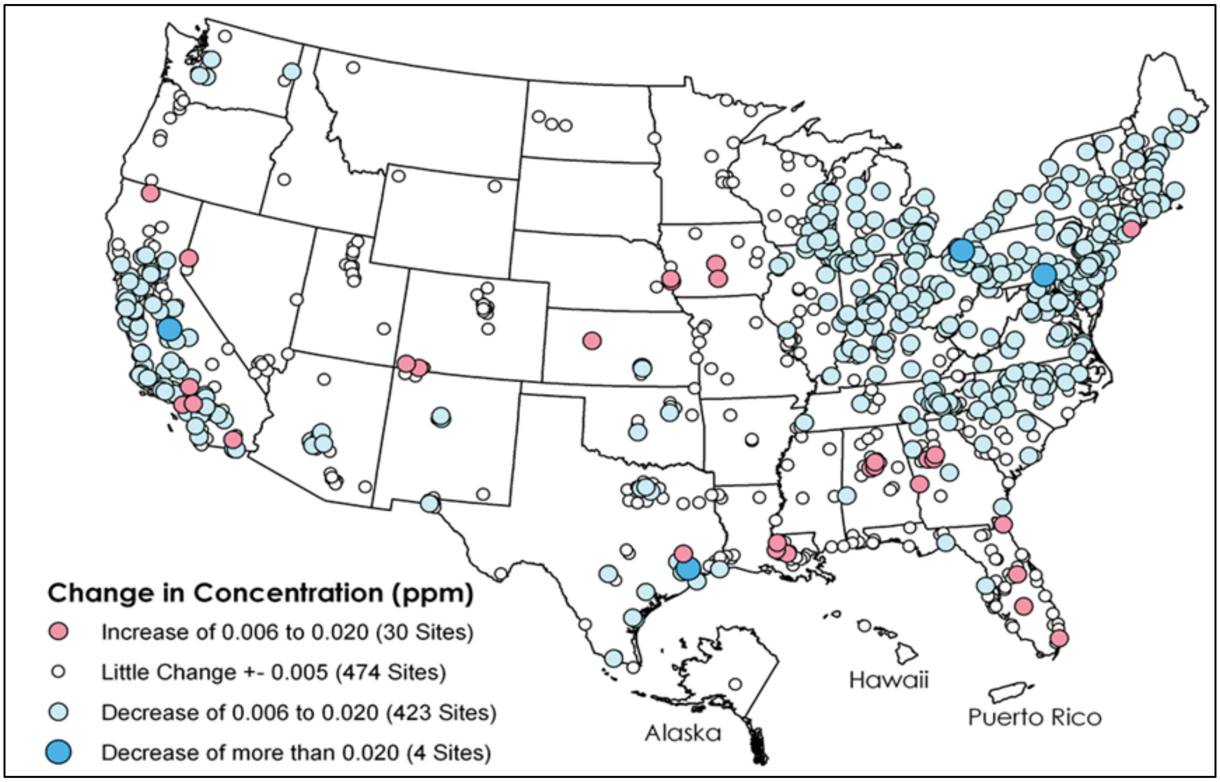


Figure 4.4.5. Change in ozone concentrations from 2001 to 2007 (EPA 2008).

Measure of Ozone: Human Health – Ozone Concentration (4th-Highest Daily Maximum 8-Hour Ozone Concentration in Parts per Billion [ppb])

The primary standard for ground-level ozone is based on human health effects. The status for human health risk from ozone is assessed using the 4th-highest daily maximum 8-hour ozone concentration in parts per billion (ppb). Ozone is monitored across the U.S. through air quality monitoring networks operated by the NPS, EPA, states, and others. Annual ozone concentrations were averaged over a 5-year period at all monitoring sites and interpolated for the contiguous U.S. The ozone condition for human health risk at Scotts Bluff NM was based upon the maximum estimated value within the monument boundary derived from this national analysis.

To assign a condition to the human health measure of ozone, we used the results from the NPS-ARD report on condition and trends for ozone (NPS-ARD 2015b) from 2009–2013. The NPS-ARD rates ozone condition as *Resource in Good Condition* if the ozone concentrations are less than 54 ppb

Warrants Moderate Concern if the ozone concentration is between 55 and 70 ppb, and of *Warrants Significant Concern* if the concentration is greater than or equal to 71 ppb (Table 4.4.3).

Table 4.4.3. Air quality condition categories for human health ozone condition (NPS-ARD 2015a).

Resource condition		Ozone concentration* (ppb)
Warrants significant concern	🔴	≥ 71
Warrants moderate concern	🟡	55 – 70
Resource in good condition	🟢	≤ 54

* Estimated or measured five-year average of annual 4th-highest daily maximum 8-hour.

Condition Adjustment: Ozone

If the NPS unit is located in an area that the EPA designates as "nonattainment" for the 75 ppb ground-level ozone standard, then the ozone condition automatically becomes *Warrants Significant Concern* (NPS-ARD 2015a). We referred to the EPA Air Trends (EPA 2014) reports to identify locations designated as nonattainment for ground-level ozone.

Measure of Ozone: Vegetation Health – W126 Index

Ozone can damage plants (Figure 4.4.6), and some species are particularly sensitive to ozone damage. Ozone-sensitive plant species can be used as bioindicators (Kohut 2007) to assess ozone levels at a park unit. Ozone penetrates leaves through stomata (openings) and oxidizes plant tissue, which alters physiological and biochemical processes. Once the ozone is inside the plant's cellular system, chemical reactions can cause cell injury or even death, but more often reduce resistance to insects and diseases, growth, and reproductive capability.

Figure 4.4.6. Foliar damage caused by high ambient levels of ozone. Photo USDA ARS.

The extent of foliar damage is influenced by several factors, including the sensitivity of the plant to 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 environmental conditions, particularly soil moisture, foster gas exchange and the uptake of ozone by plants (Kohut 2004).

Exposure indices are biologically relevant measures used to quantify plant response to ozone exposure. These measures are better predictors of vegetation response than the metric used for the human health standard. The NPS-ARD assesses vegetation health risk from ozone condition with the W126 index, which preferentially weights the higher ozone concentrations most likely to affect plants and sums all of the weighted concentrations during daylight hours. The highest 3-month period that occurs during the ozone season is reported in parts per million-hours (ppm-hrs).

Ozone is monitored across the U.S. through air quality monitoring networks operated by the NPS, EPA, states, and others. Annual maximum W126 values were averaged over a 5-year period at all monitoring sites with at least 3 years of complete annual data and interpolated for the contiguous U.S. The ozone condition for vegetation health risk at Agate Fossil Beds NM was based upon the maximum value within the monument boundary derived from this national analysis.

To assign a condition for the vegetation health measure of ozone, we used results from the NPS-ARD report on condition and trends for ozone (NPS-ARD 2015b) from 2009–2013.

The W126 condition thresholds are based on information in EPA’s Policy Assessment for the Review of the Ozone National Ambient Air Quality Standards (EPA 2014). Research has found that for a W126 value of ≤ 7 ppm-hrs, tree seedling biomass loss is ≤ 2 % per year in sensitive species. For W126 ≥ 13 ppm-hrs, tree seedling biomass loss is 4–10 % per year in sensitive species. NPS-ARD recommends a W126 of < 7 ppm-hrs to protect most sensitive trees and vegetation. A W126 index in this range was assigned *Resource in Good Condition*, a W126 index of 7-13 *Warrants*

Moderate Concern condition, and an index > 13 *Warrants Significant Concern* (NPS-ARD 2015a; Table 4.4.4).

Table 4.4.4. Air quality condition categories for vegetation health ozone condition (NPS-ARD 2015a).

Resource condition		W126* (ppm-hrs)
Warrants significant concern	🔴	> 13
Warrants moderate concern	🟡	7 – 13
Resource in good condition	🟢	< 7

* Estimated or measured 5-year average of the maximum 3-month 12-hour W126.

Indicator: Particulate Matter

Particulate matter can be detrimental to visibility and human health. There are two particle size classes of concern: PM$_{2.5}$ – fine particles found in smoke and haze, which are 2.5 micrometers in diameter or less; and PM$_{10}$ – coarse particles found in wind-blown dust, which have diameters between 2.5 and 10 micrometers. Both sizes can cause inflammation and irritation of the respiratory system in humans. People can be more susceptible to health effects from air pollution when they are engaged in strenuous recreation. Particulate matter of different sizes can have different consequences for public and ecosystem health (Stözel et al. 2007, EPA 2009, EPA 2016b). The standard for particulate matter is set by the EPA, and is based on human health effects.

Measure of Particulate Matter: PM$_{2.5}$ Concentration

The PM$_{2.5}$ primary standard is 12 micrograms per cubic meter (μg/m^3) annually (3-year average of weighted annual mean) and 35 g/m^3 for 24-hours (3-year average of the 98th percentile of 24-hour concentrations). Fine particulate matter (PM$_{2.5}$) data were collected from 2003–2011 in Sioux County, Nebraska. We evaluated these data over the most recent three years of the sampling period. NPS units that are in EPA designated nonattainment areas for particulate matter are assigned Warrants Significant Concern condition for particulate matter. For NPS units that are outside particulate matter nonattainment areas, EPA AQI breakpoints were used to assign a particulate matter condition based on 3-year average of the 98th percentile of 24-hour PM$_{2.5}$ concentrations (Table 4.4.5).

Table 4.4.5. Air quality condition categories for particulate matter (EPA 2016a).

Resource condition		**98th Percentile 24-hour $PM_{2.5}$ concentration* (µg/m^3)**	**2nd Maximum 24-hour PM_{10} concentration* (µg/m^3)**
Warrants significant concern	🔴	≥ 35.5	≥ 155
Warrants moderate concern	🟡	12.1 – 35.4	55 – 154
Resource in good condition	🟢	≤ 12.0	≤ 54

* Measured three-year average.

Measure of Particulate Matter: PM_{10} Concentration

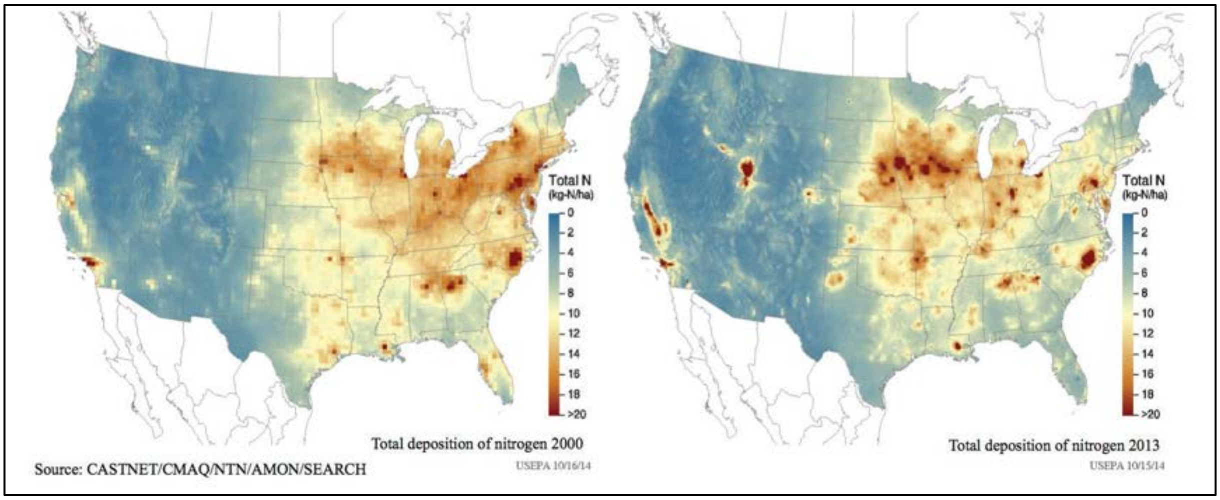
The standard for PM_{10} is 150 µg/m^3 for 24-hours (not to be exceeded more than once per year over 3 years).

We evaluated available data over the most recent three years of the sampling period. For NPS units that are outside particulate matter nonattainment areas, EPA AQI breakpoints were used to assign a particulate matter condition based on 3-year average of 2nd maximum 24-hour PM_{10} concentrations (Table 4.4.5). NPS units that are in EPA designated nonattainment areas for particulate matter are assigned *Warrants Significant Concern* condition for particulate matter.

Indicator: Nitrogen Deposition

Airborne pollutants can be atmospherically deposited to ecosystems through rain and snow (wet deposition) or dust and gases (dry deposition). Nitrogen pollution can harm ecosystems by acidifying or enriching soils and surface waters.

The term “acid rain” includes all precipitation that transports acidifying compounds (primarily sulfuric and nitric acids) out of the atmosphere to the earth’s surface. Fuel combustion, industrial processes, and volcanic eruptions produce S- and N-compounds (EPA 2011) that can alter terrestrial and aquatic ecosystems through both dry and wet deposition (Driscoll et al. 2001). Dry deposition occurs when dust or smoke incorporate S- and N-particles that then settle on the ground, whereas wet deposition occurs when particles combine with water droplets and fall as rain, snow, or other forms of precipitation (EPA 2011). The deposition of S- and N-compounds can acidify water and soil (Likens et al. 1996), potentially reducing biodiversity and increasing ecosystem susceptibility to eutrophication and invasive species (Bouwman et al. 2002). Wet deposition of nitrates has generally decreased in the U.S. during the last 20 years (Du et al. 2014), but total nitrogen deposition has increased in places (Figure 4.4.7) (Kim et al. 2011).



Total deposition of nitrogen 2000

Total deposition of nitrogen 2013

Source: CASTNET/CMAQ/NTN/AMON/SEARCH

Figure 4.4.7. Total nitrogen deposition for the United States for 2000 and 2013. Total wet nitrogen deposition has decreased in some parts of the United States and increased in others. Maps from EPA 2014 http://castnet/cmaq/ntn/amon/search.

Nitrogen, a fertilizer, can disrupt the soil nutrient cycle and change plant communities where it is deposited. Plants in grassland ecosystems are particularly vulnerable to changes caused by nitrogen deposition, as they are often N-limited. In these grasslands, an influx of nitrogen enables exotic invasive grasses to displace native species that are adapted to a low nitrogen environment.

For example, increased deposition of nitrogen has allowed cheatgrass (*Bromus tectorum*), a highly invasive grass that has spread vigorously throughout the northern Great Plains (Ogle and Reiners 2002) the southern Colorado Plateau, Great Basin, and Mojave Desert, weedy annual grasses (e.g., cheatgrass), to outpace and replace native species (Brooks 2003; Schwinning et al. 2005; Chambers et al. 2007; Mazzola et al. 2008; Vasquez et al. 2008; Allen et al. 2009). Water use can change with nitrogen increases, such that plants like big sagebrush have reduced water use efficiency (Inouye 2006).

Measure of Nitrogen Deposition: Wet Deposition of N (kg/ha/yr)

Wet deposition is the most common and simplest way to measure deposition of nitrogen. Dry deposition data for nitrogen is difficult to obtain because dry deposition is not measured directly (Mickler et al. 2000, Freedman 2013). Wet deposition of nitrogen is measured in kilograms per hectare per year (kg/ha/year).

Nitrogen wet deposition is monitored across the United States as part of the National Atmospheric Deposition Program/National Trends Network (NADP/NTN). Annual wet deposition is averaged over a 5-year period at monitoring sites with at least 3 years of annual data and interpolated 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.

To assign a condition for nitrogen, we used the wet deposition results from the NPS-ARD report on condition and trends (NPS-ARD 2015b) from 2009–2013. Total wet deposition of nitrogen levels were calculated from interpolated data (NPS-ARD 2015b), using monitoring sites that were not on site at Agate Fossil Beds NM.

While ecosystems respond to total (wet and dry) deposition, 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. A resulting condition greater than 3 kg/ha/yr is assigned a *Warrants Significant Concern* status (Table 4.4.6). A current nitrogen condition from 1–3 kg/ha/yr is assigned *Warrants Moderate Concern status*. *Resource in Good Condition* was assigned if the current nitrogen condition is less than less than 1 kg/ha/yr.

Table 4.4.6. Air quality condition categories for wet deposition (NPS-ARD 2015a).

Resource condition		**Wet deposition* (kg/ha/yr)**
Warrants significant concern	🔴	> 3
Warrants moderate concern	🟡	1 – 3
Resource in good condition	🟢	< 1

* Estimated or measured 5-year average of nitrogen or sulfur wet deposition.

Condition Adjustments: Nitrogen Deposition

If Agate Fossil Beds NM was at very high risk for nutrient enrichment effects from atmospheric deposition relative to all Inventory & Monitoring parks, the condition for nitrogen deposition was adjusted to the next worse category.

To assess park risk of eutrophication we used a risk assessment conducted by Sullivan et al. (2011a) that combined measures of pollutant exposure, ecosystem sensitivity and park protection to calculate a summary risk. If the park was assigned an ecosystem sensitivity risk of Very High for nutrient enrichment, we moved the condition for nitrogen deposition to the next worse category.

Indicator: Sulfur Deposition

Like nitrogen, sulfur (S) is an acidifying compound that can be transported out of the atmosphere as acid rain. The deposition of S-compounds can acidify water and soil (Likens et al. 1996).

Measure of Sulfur Deposition: Wet Deposition of S (kg/ha/yr)

Wet deposition is the most common and simplest way to measure deposition of sulfur. Dry deposition data of sulfur is difficult to obtain because it can’t be measured directly (Mickler et al.

2000, Freedman 2013). Wet deposition of sulfur is measured in kilograms per hectare per year (kg/ha/yr) (Table 4.4.5).

Sulfur wet deposition is monitored across the United States as part of the NADP/NTN. Wet deposition was calculated by multiplying 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 3 years of annual data. Five-year averages are then interpolated across 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.

To assign a condition for sulfur, we used the wet deposition results from the NPS-ARD report on condition and trends (NPS-ARD 2015b) from 2009–2013. Total wet deposition of sulfur levels were calculated from interpolated data (NPS-ARD 2015b), using monitoring sites that were not on site at Fort Laramie NHS.

NPS-ARD selected a wet sulfur deposition threshold of 1.0 kg/ha/yr (see rationale in the section on nitrogen). A value greater than 3 kg/ha/yr is assigned a *Warrants Significant Concern status*. A value from 1–3 kg/ha/yr is assigned *Warrants Moderate Concern status*, *Resource in Good Condition* if the current sulfur condition is less than less than 1 kg/ha/yr (Table 4.4.5).

Condition Adjustment: Sulfur Deposition

If Scotts Bluff NHS was at a very high risk for acidification, the condition for sulfur deposition was adjusted to the next worse category.

To assess park risk of acidification we used a risk assessment conducted by Sullivan et al. (2011b) that combined measures of pollutant exposure, ecosystem sensitivity and park protection to calculate a summary risk. If the park was assigned a very high risk, we adjusted the condition to the next worse category.

Indicator: Mercury Deposition

Mercury and other toxic pollutants (e.g., pesticides, dioxins, PCBs) accumulate in the food chain and can affect both wildlife and human health. These pollutants enter the atmosphere from contaminated soils, industrial practices, and air pollution (Selin 2009). High levels of mercury and other airborne toxins can accumulate in fat and muscle tissues in animals, increasing in concentration and they move up the food chain. As neurotoxins, these pollutants can cause serious damage to ecosystems and their inhabitants and reduce survival of diverse species from fish to mammals.

While some sources of atmospheric mercury are natural, such as geothermal vents and volcanoes, most sources are anthropogenic; these sources include commercial incineration, mining activities, and coal combustion. These human include by-products of coal-fire combustion, municipal and medical incineration, mining operations, volcanoes, and geothermal vents (NPS-ARD 2015b).

A major contributor of mercury to inland areas is atmospheric deposition. Wet and dry deposition can lead to mercury loadings in surface waters, where mercury may be converted to a bioavailable toxic form of mercury, methylmercury, and bioaccumulate through the food chain.

Measure of Mercury Deposition: Wet Deposition of Hg (µg/m^2/yr) and Methylmercury Risk (ng/L)

Mercury deposition condition was assessed using estimated 3-year average mercury wet deposition (micrograms per meter squared per year [µg/m^2/yr]) and predicted surface water methylmercury concentrations (nanograms per liter [ng/L]). 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 they become biologically available and able to accumulate in food webs (NPS-ARD 2015a). 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, 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 3 years of annual data. Three-year averages are then interpolated across all monitoring locations using an inverse distance weighting method for the contiguous U.S. For individual parks, minimum and maximum values within park boundaries are reported from this national analysis. The maximum value is assigned a rating (Table 4.4.7).

Table 4.4.7. Ratings for mercury deposition (NPS-ARD 2015a).

Rating	Mercury deposition (µg/m^2/yr)
Very high	≥ 12
High	≥ 9 and < 12
Moderate	≥ 6 and < 9
Low	≥ 3 and < 6
Very low	< 3

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 (USGS 2015). The predicted methylmercury concentration at a park is the highest value derived from the hydrologic units that intersect the park. This highest value is then assigned a rating from very low to very high (Table 4.4.8).

Table 4.4.8. Ratings for predicted methylmercury concentration (NPS-ARD 2015a).

Rating	Predicted methylmercury concentration (ng/L)
Very high	≥ 0.12
High	≥ 0.075 and < 0.12
Moderate	≥ 0.053 and < 0.075
Low	≥ 0.038 and < 0.053
Very low	< 0.038

Ratings for mercury wet deposition and predicted methylmercury concentration are then considered concurrently in the mercury status assessment matrix (Table 4.4.9) to identify one of three park-specific mercury/toxics status categories: *Resource in Good Condition*, *Warrants Significant Concern*, or *Warrants Significant Concern*.

Table 4.4.9. Mercury condition assessment matrix (NPS-ARD 2015a).

Predicted methylmercury concentration rating	Mercury wet deposition rating				
	Very low	Low	Moderate	High	Very high
Very low	Good	Good	Good	Moderate	Moderate
Low	Good	Good	Moderate	Moderate	Moderate
Moderate	Good	Moderate	Moderate	Moderate	Significant concern
High	Moderate	Moderate	Moderate	Significant concern	Significant concern
Very high	Moderate	Moderate	Significant concern	Significant concern	Significant concern

Condition Adjustments

The presence of in-park data on either mercury or toxins in food webs may influence the overall rating for mercury condition. An assessment of previous and current studies and availability of fish consumption guidelines serve as the basis for adjusting mercury status. There were no park-specific studies examining contaminant levels that were appropriate for condition adjustment.

Quantifying Air Quality Condition, Confidence, and Trend

To quantify air quality condition and trend, we deferred to the NPS-ARD methods for air quality assessment and used a point system to assign the indicator to a category (NPS-ARD 2015a). This points system is based on the NPS-ARD methods for calculating overall air quality condition: measures that placed the indicator in the *Warrants Significant Concern* category were assigned zero points, *Warrants Moderate Concern* measures were given 50 points, and *Resource in Good Condition* measures were given 100 points. If different measures each placed the indicator in a different condition category, as could be the case for ozone, then the measure with the worst category determined the condition for the indicator (NPS-ARD 2013). We then used the average of these points to assign the indicator to an overall category.

Indicator Confidence

Confidence ratings were based on the type of pollutant, distance to monitor used for interpolated data, time since data collection, and data robustness. We gave a rating of *High* confidence when monitors were on site or nearby, data were collected recently, and the data were collected methodically. We assigned a *Medium* confidence rating when monitors were not nearby, data were not collected recently, or data collection was not repeatable or methodical. We assigned *Low* confidence ratings when there were no good data sources.

Indicator Trend

Potential trend categories were *Improving*, *Unchanging*, or *Deteriorating*. To calculate a trend, we required data that were collected "over a 10-year period at on-site or nearby monitors (within 10 kilometers of the park for ozone, 16 kilometers of the park for wet deposition, and 100 kilometers of the park for visibility)" (NPS-ARD 2013, NPS-ARD 2015a). If there were no data available that met these distance and monitoring durations for a particular indicator, we indicated that trend was Not Available for that indicator.

Overall Air Quality Condition, Trend, and Confidence

To assess overall air quality condition, we used the NPS-ARD method to assign points to each indicator based on condition (NPS-ARD 2015a). We assigned zero points to indicators in *Warrants Significant Concern* category, 50 points to indicators in the *Warrants Moderate Concern* category, and 100 points to indicators in the *Resource in Good Condition* category. The average of the points for each measure was the total score for air quality condition (Table 4.4.10); high scores (67–100) indicated that air quality was in *Good Condition*, medium scores (34–66) indicated that it *Warrants Moderate Concern*, and low scores (0–33) indicated that air quality condition *Warrants Significant Concern*. We applied the EPA non-attainment status adjustments to the overall condition, such that if the NPS unit fell in an area that was in "nonattainment" for ozone or particulate matter, the overall condition would be *Warrants Significant Concern* (NPS-ARD 2015a).

Table 4.4.10. Overall air quality condition categories.

Resource condition		Score
Warrants significant concern	🔴	0 – 33
Warrants moderate concern	🟡	34 – 66
Resource in good condition	🟢	67 – 100

If trend data were available, we calculated overall air quality trends using a points system to assign an overall trend category of *Improving*, *Unchanging*, or *Deteriorating*. Specifically, we subtracted the number of deteriorating trends from improving trends. If the result of this calculation was > 3, the overall trend was *Improving*. If the result was < -3, the overall trend was *Deteriorating*. If the result was between > -2 and < 2, the overall trend was *Unchanging*. If any indicator did not have a trend, then there was no trend for overall condition (NPS-ARD 2015a).

Overall confidence categories were *High*, *Medium*, or *Low* (NPS-ARD 2013). We calculated confidence using a points system similar to overall condition confidence; categories with *High* confidence received 100 points, *Medium* confidence received 50 points, and *Low* confidence received zero points. The overall confidence was *High* if the average of these values was between 67 and 100, *Medium* between 34 and 66, and *Low* between 0 and 33.

4.4.4. Air Quality Conditions, Confidence, and Trends

Visibility

Condition: Warrants Moderate Concern
Confidence: High
Trend: Improving

Condition

The Haze Index for 2009–2013 was 5.1 dv, which placed visibility for Scotts Bluff NM in the *Warrants Moderate Concern* category.

Confidence

Visibility was calculated from data collected at Crescent Lake National Wildlife Refuge, which was close enough to assign a *High* confidence to the visibility data for Scotts Bluff NM.

Trend

Visibility data were collected for at least 10 years at a location close to Scotts Bluff NM, which meant that a trend calculation could be completed. The visibility trend at Scotts Bluff NM was *Improving*.

Ozone

Condition: Warrants Moderate Concern
Confidence: Medium
Trend: Not Available

Condition

Human health condition

The calculated ground-level ozone concentration from 2009–2013 was 63 ppb, which placed the human health measure of ozone pollution at Scotts Bluff NM in the *Warrants Moderate Concern category*.

Vegetation health condition

The W126 value for Scotts Bluff NM was 9.1 ppm-hrs, which placed the vegetation health risk in the Warrants Moderate Concern category. A study of ozone risk to plants concluded that risk of damage was Low at Scotts Bluff NM (Kohut 2004). Ozone-sensitive plants were present (Table 4.4.10), but the observed levels of ozone were unlikely to damage plants (Kohut 2004). The Low rating for risk of foliar damage meant the condition for ozone pollution remained in the *Warrants Moderate Concern* category

Confidence

While previous data collection for ozone levels occurred on site at Scotts Bluff NM, recent data were interpolated from more distant sources (NPS-ARD 2015b) so the confidence was *Medium*.

Trend

There were insufficient data nearby or on-site at Scotts Bluff NM, so a trend for ozone was *Not Available.*

Particulate Matter

●

Condition: Warrants Moderate Concern
Confidence: Medium
Trend: Not Available

Condition

Scotts Bluff NM is located in Scotts Bluff County, Nebraska, that met the 2012 and 2006 $PM_{2.5}$ standards and 1987 PM_{10} standard. For this reason, the county is an EPA-designated "attainment" area for particulate matter.

The measured 3-year average (2007–2009) of the 98th percentile 24-hour $PM_{2.5}$ concentration for Scotts Bluff NM was 17.3µg/m^3, which falls in the *Warrants Moderate Concern* category (EPA 2016c). The PM_{10} concentration was 44.3 µg/m^3 for 2011–2013, which falls in the *Resource in Good Condition* category. The overall particulate matter condition was *Warrants Moderate Concern*.

Confidence

The particulate matter condition was calculated from a $PM_{2.5}$ and PM_{10} monitors located in the towns of Scottsbluff and Terrytown, near the monument, but the most recent data were collected in 2009 for $PM_{2.5}$ and in 1998 for PM_{10}. Confidence was *Medium*.

Trend

Trend was *Not Available*.

Nitrogen Deposition

🔴

Condition: Warrants Significant Concern
Confidence: Medium
Trend: Not Available

Condition

The total N wet deposition level from 2009–2013 was 1.9 kg/ha, placing total N wet deposition pollution at Scotts Bluff NM in the *Warrants Moderate Concern* category.

The Sullivan et al. (2011a, 2011b) studies assessing ecosystem risks from N and S wet deposition assigned overall summary risks to Scotts Bluff for susceptibility to acidification and eutrophication. Scotts Bluff was at moderate risk for acidification (Sullivan et al. 2011b) and nutrient enrichment (Sullivan et al. 2011a) from N deposition, but was ranked high for sensitivity to acidification relative to other Inventory and Monitoring parks (NPS-ARD 2015b). Because of this high ranking relative to other parks, Nitrogen at Scotts Bluff NM was moved to the *Warrants Significant Concern* category (NPS-ARD 2015b).

Confidence

None of the monitoring stations for wet deposition were on site in Scotts Bluff NM or within 16 kilometers (NPS-ARD 2013, NPS-ARD 2015a), so the confidence was *Medium*.

Trend

The closest monitoring site for wet deposition was approximately 85 kilometers southwest in the Pawnee National Grassland. The maximum distance allowed for calculating a trend in wet N or S deposition is 16 kilometers away from a park unit and must include 10 years of data, so we could not calculate trend (NPS-ARD 2013a). Trend was *Not Available*.

Sulfur Deposition

🟢

Condition: Resource in Good Condition
Confidence: Medium
Trend: Not Available

Condition

The total S wet deposition level from 2009– 2013 was 0.6 kg/ha, which placed total S wet deposition pollution at Scotts Bluff NM in the *Resource in Good Condition* category. Sullivan et al. (2011b) assessed overall susceptibility to acidification from S wet deposition based on a combination of pollutant exposure, ecosystem sensitivity, and park protection. Scotts Bluff NM was at a low risk for acidification from S deposition (Sullivan et al. 2011b). Sulfur wet deposition at Scotts Bluff NM remained in the *Resource in Good Condition* category (NPS-ARD 2015b).

Confidence

None of the monitoring stations for wet deposition were on site or within 16 kilometers (NPS-ARD 2013, NPS-ARD 2015b), so the confidence was *Medium*.

Trend

The closest monitoring site for wet deposition was a National Atmospheric Deposition Program (NADP) site approximately 85 kilometers away in the Pawnee National Grassland. The maximum distance allowed for calculating a trend in wet S deposition is 16 kilometers away from a park unit and must include 10 years of data, so we could not calculate trend (NPS-ARD 2013). Trend was *Not Available*.

Mercury Deposition

●

Condition: Warrants Moderate Concern
Confidence: Low
Trend: Not Available

Condition

Given that landscape factors influence the uptake of mercury in the ecosystem, the condition is based on estimated wet mercury deposition and predicted levels of methylmercury in surface waters. The 2012–2014 estimated wet mercury deposition to be low at the park, at 5.7 µg/m^2/yr (K. Taylor, personal communication, 26 May 2016). The predicted methylmercury concentration in park surface waters is high, estimated at 0.1 ng/L (USGS 2015). Wet deposition and predicted methylmercury ratings were combined to determine the *Warrants Moderate Concern* condition.

Confidence

The degree of confidence in the mercury/toxics deposition condition is *Low* because there are no park-specific studies examining contaminant levels.

Trend

Trend was *Not Available*.

Air Quality Overall Condition

Condition

The overall air quality condition was determined by the average of the indicator conditions (Table 4.4.11). We summarized the condition, confidence, and trend for each indicator, and assigned condition points as specified by NPS-ARD (Table 4.4.12; NPS-ARD 2015a). The total score for overall air quality condition was 50 points, which placed Scotts Bluff NM in the *Warrants Moderate Concern category*.

Confidence

Confidence was *High* for Visibility, *Low* for Mercury, and *Medium* for all other indicators. The score for overall confidence was 50 points, which met the criteria for *Medium* confidence in overall air quality.

Trend

Trend was *Not Available*.

Table 4.4.11. Air quality overall condition.

Indicators	**Measures**	**Condition**
Visibility	- Haze index (dv)	🟡⇧
Ozone	- Human health (ppm) - Vegetation health (W126 index)	🟡
Particulate matter	- $PM_{2.5}$ (ppm) - PM_{10} (ppm)	🟡
Nitrogen	- Wet deposition (kg/ha/year)	🔴
Sulfur	- Wet deposition (kg/ha/year)	🟢
Mercury	- Wet deposition ($\mu g/m^2$/year) - Methylmercury risk	🟡
Overall condition for all indicators and measures		🟡

Table 4.4.12. Summary of air quality indicators and measures.

Indicator	Measure	Condition	Confidence	Trend	Condition rational
Visibility	Haze index (dv)	Warrants moderate concern	High	Not available	Visibility from 2009–2013 was 5.1 dv; this value placed visibility in the *Warrants Moderate Concern* category. Data came from nearby monitoring location at CRES1, so confidence was *High* and trend was *Improving*.
Ozone	Human health (ozone concentration)	Warrants moderate concern	Medium	Not available	Ozone from 2009–2013 was 63 ppb; this value placed ozone in the *Warrants Moderate Concern* category. Data were interpolated from monitors not within the necessary radius to calculate a trend; confidence was *Medium* and trend was *Not Available*.
	Vegetation health (W126 measure)	Warrants moderate concern	Medium	Not available	The biologically relevant W126 value was 9.1 ppm-hrs, which placed vegetation health condition in the *Warrants Moderate Concern* category. Risk of foliar damage was *Low*.
Particulate matter	$PM_{2.5}$	Warrants moderate concern	Medium	Not available	$PM_{2.5}$ for 2007-2009 was 17.3 µg/m^3; this valued placed $PM_{2.5}$ in the *Warrants Moderate Concern* category. Data were collected nearby but not recently for *Medium* confidence, and trend was *Not Available*.
	PM_{10}	Resource in good condition	Medium	Not available	PM_{10} for 1996–1998 was 44.3 µg/m^3; this valued placed PM_{10} in the *Resource in Good Condition* category. Data were collected nearby but not recently for *Medium* confidence, and trend was *Not Available*.
Nitrogen deposition	Wet deposition N (kg/ha/yr)	Warrants moderate concern	Medium	Not available	Total wet deposition of N from 2009–2013 was 1.9 kg/ha/yr. This value placed total N wet deposition pollution in the *Warrants Moderate Concern* category, but the risk of acidification was high relative to other parks, so the category was adjusted to *Warrants Significant Concern*. There were no data collected on site or nearby, so confidence was *Medium* and trend was *Not Available*.

Table 4.4.12 (continued). Summary of air quality indicators and measures.

Indicator	**Measure**	**Condition**	**Confidence**	**Trend**	**Condition rational**
Sulfur deposition	Wet deposition S (kg/ha/yr)	Resource in good condition	Medium	Not available	Total wet deposition levels from 2009–2013 was 0.6 kg/ha S. This value placed total S wet deposition in the *Resource in Good Condition* category. Risk of acidification from S was Low, so the category did not need to be adjusted. There were no data collected on site or nearby, so confidence was *Medium* and trend was *Not Available*.
Mercury deposition	Wet deposition (μg/m^2/yr) and methylmercury rating	Warrants moderate concern	Low	Not available	The 2012–2014 estimated wet mercury deposition at the park was 5.7 μg/m^2/yr, which is rated as low. The predicted methylmercury concentration in park surface waters is high, estimated at 0.1 ng/L. Condition was *Warrants Moderate Concern.*

4.4.5. Stressors

Potential local air quality stressors include local industries in the town of Scottsbluff, Western Sugar Cooperative plants in Scottsbluff and Torrington, WY, the Basin Electric Laramie River Station, a coal-fired power plant 100 kilometers northwest of Scotts Bluff NM (US EIA 2015), smoke from fires during the summer months, and oil and gas drills to the south and northwest. Emissions from the power plant and wells likely contribute to impaired visibility and high ozone production in the area (Karion et al. 2013).

Scotts Bluff NM is located just outside of three major oil and gas basins. The Powder River Basin (PRB) is the closest, located to the northeast of Scotts Bluff NM in eastern Wyoming, southwestern South Dakota, and southeastern Montana. The Denver-Julesburg is located to the south of Scotts Bluff NM in northeastern Colorado, and the Williston Basin is located to the north of Scotts Bluff NM in western North Dakota. Each of these basins contains extensive existing oil and gas development. The PRB, the closest basin to the park, has seen extensive oil, gas, and coalbed methane development, as well as extensive surface coal mining. According to data from the Wyoming oil and gas conservation commission, the Powder River Basin contained approximately 40,775 well sites as of 2015, with just over half of these sites in some type of active status (http://wogcc.state.wy.us). Equipment associated with oil and gas development and production, such as drill rigs, fracturing engines, valves, seals, and compressors, emit air pollutants (nitrogen oxides, greenhouse gases, particulate matter, and hydrogen sulfide), and in regions of extensive development, can cause air quality concerns. Air quality modeling indicates that currently oil and gas development to the west may be affecting park air quality to some extent, including potential ozone effects to vegetation (K. Taylor, personal communication, 26 May 2016).

4.4.6. Data Gaps

Most of the available air quality data for Scotts Bluff NM were interpolated from monitors not within the park boundaries, with the exception of the visibility data. The lack of monitoring data at the park unit or nearby limited the level of confidence at which we could assign indicator conditions and overall air quality condition. Additionally, it is preferable not to calculate air quality trends from interpolated data (NPS-ARD 2015a), so it is unclear how conditions other than visibility may have changed at Scotts Bluff NM over time.

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4.4.7. Literature Cited

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4.5. Water Quality

North Platte River at Scotts Bluff NM. Photo © KEN LUND 2005, https://www.flickr.com/photos/kenlund/66306260.

4.5.1. Background and Importance

Surface waters form complex ecosystems that support a vast number of uses. They provide critical wildlife and plant habitat, sources and sinks in water and nutrient cycles, and numerous recreational opportunities. Surface waters are also aesthetic resources and, often, public health resources when they connect to a drinking water supply. Most units of the National Park Service include important water resources. The water quality of streams, rivers, wetlands, ponds, lakes, springs, and other water bodies determines their suitability for these various uses (Boyd 2015). Indicative of the importance of water in park units, NPS identified water quality as a core natural resource (NPS 2009) to include in its nationwide ecosystem monitoring program (Fancy and Bennetts 2012).

The Clean Water Act (33 U.S.C. § 1251 et seq. 2003) provides a general structure for surface water quality regulation the U.S. and the National Park Service places a high priority on improving and protecting water quality in park units (NPS 1999). NPS is dedicated to protecting water quality as a top resource within the Northern Great Plains Network (NGPN) (Wilson et al. 2014). Surface waters are affected by environmental conditions within and beyond their banks, so effective water quality management strategies have an equally broad focus. Public lands and waters under the jurisdiction of NPS are in the unique position of receiving regulatory and managerial priority for water quality protection, which facilitates the protection of surface waters as well as groundwater (NPS 2006).

Regional Context

Most rivers and tributaries in the NGPN feed the Missouri River, which flows into the Mississippi River (Figure 4.5.1). The Missouri River is the longest river in the U.S. (Kammerer 1990) and drains 1.3 million km^2 or upstream land (Seaber et al. 1987). This drainage basin continues to be affected by the construction of thousands of dams, levees, reservoirs, and canals for agricultural, industrial, and infrastructural activities since the 19th century (Buie 1980, Brown et al. 2011).

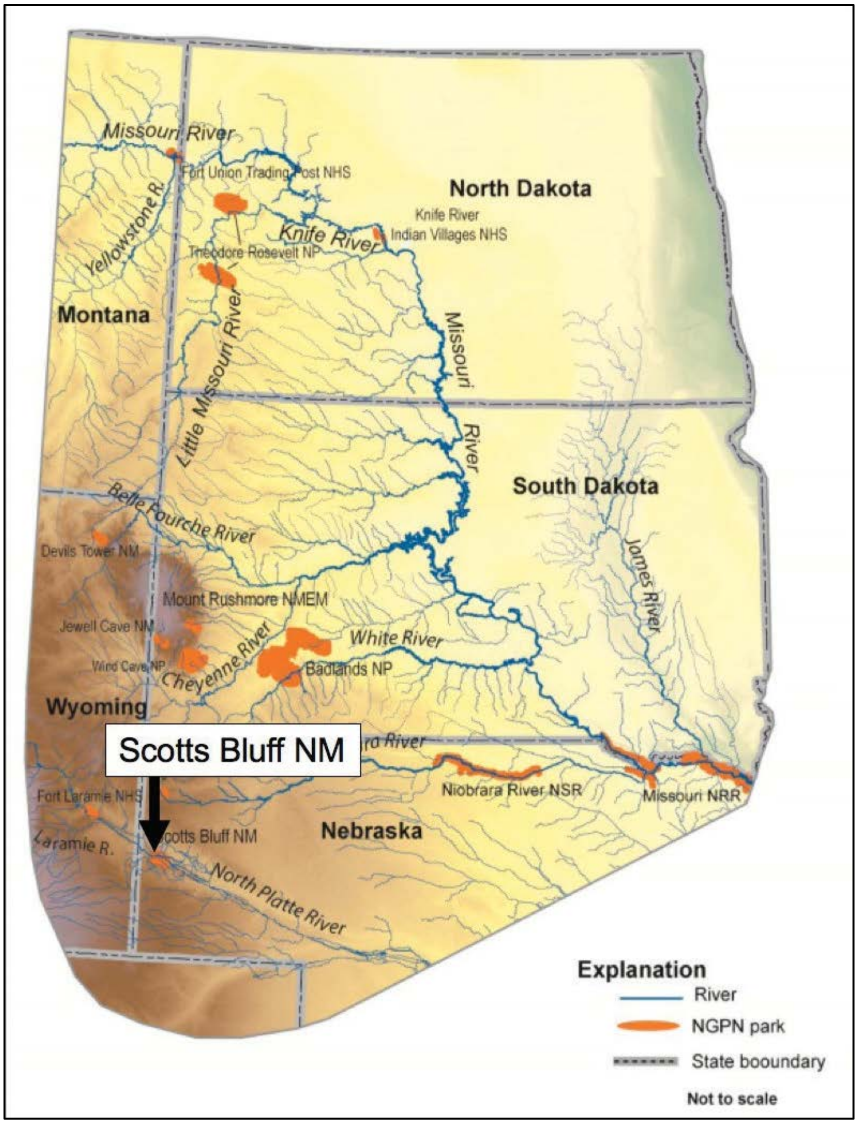

Figure 4.5.1. Tributaries and rivers in NGPN park units (modified from Wilson et al. 2014).

Scotts Bluff NM is located in southwest Nebraska in the North Platte River Drainage (Middle North Platte-Scotts Bluff Watershed) that flows into the Platte River, which eventually flows east into the Missouri River. The Platte River was a guiding natural feature on the western migration of settlers, explorers, and trappers on the Oregon/California/Mormon Trails in the 1800s, and remains an important resource for agriculture (NE DEQ 2015), recreation (NE Game and Parks 2015), and wildlife (Hefley et al. 2015) in the region today. Surface water features at Scotts Bluff NM include several canals, including Central Canal, Gering/Fort Laramie Canal, and Gering Canal (Wilson et al. 2014), and a once formed a natural spring—Scotts Spring—that has been dry since about 2010 (R. Manasek, personal communication, 18 March 2016). Additionally, the 1.25 miles of the North Platte River that border the park unit are the highest-priority waterbody at Scotts Bluff NM (Wilson et al. 2014).

4.5.2. Water Quality Standards

States and tribes must protect or enhance water quality in accordance with the Clean Water Act. State law and tribal codes therefore specify designated uses for every water body or stream segment; uses may include water supply, aquatic life, recreation, aesthetics, and navigation. These designated uses are water quality goals, management objective, and activities that the water body supports. Water bodies are held to regulatory criteria for these designated uses, regardless of whether or not those standards are currently attained (EPA 2014a) or if the water bodies are impaired and, therefore, subject to 303d listing. The U.S. Environmental Protection Agency (EPA) publishes water quality criteria to guide standards set by states and tribes. States adopt or modify the criteria to create more stringent standards, which must then be approved by EPA (40 C.F.R. §131.5).

States set water quality standards at two levels: for human use and use by aquatic life. For each of these levels, standards are calculated for acute and chronic exposure such that pollutants are not expected to pose a significant risk for the designated use. The NGPN has worked with the U.S. Geological Survey (USGS) to identify water resource priorities and key indicators of water quality within the entire network and within each network park. The section of the North Platte River that runs along Scotts Bluff NM is a relatively low priority for NGPN compared to other rivers and tributaries in the NPS network (Wilson et al. 2014), but is designated for recreation, aesthetics, aquatic life, and water supply of agriculture by the state and regulated for those uses (117 Nebraska Administrative Code § 81.1501 2014).

The North Platte River adjacent to the north boundary of Scotts Bluff NM is a Class B Coldwater stream for aquatic life, which means that is does not support naturally reproducing salmonid populations, but supports other coldwater organisms, including various fish, and may support seasonal salmonid migrations. The North Platte River is also designated as Class A for Agriculture, which means that this water supply may be used for general agricultural purposes without treatment (117 Nebraska Administrative Code § 81.1501 2014). The water quality standards are more stringent for the aquatic life use designation than for agricultural water supply, and those are the standards that we considered in this assessment. Canals are subject to regulation by Nebraska DEQ as surface waters, and we used the same criteria for canals as for the North Platte River to protect the uses associated with that section of the river (117 Nebraska Administrative Code § 81.1501 2014).

Some water quality standards vary with season and aquatic life stages, particularly to protect spawning stages of fish species. In Nebraska, water quality standards depend on the stream classification, and surface waters with a Class B Coldwater designation, like the North Platte, are regulated to the following water quality standards for pH, dissolved oxygen (Table 4.5.1), temperature, conductivity, turbidity, and *E. coli* (J. Bender, personal communication, 2 December 2015; 117 Nebraska Administrative Code § 81.1501 2014):

- **pH:** 6.5–9.0
- **Temperature**: ≤ 22°C and, within mixing zones, less than a three-degree difference from the natural background temperature outside of mixing zone.
- **Conductivity:** ≤ 2,000 Siemens/meter from April 1–September 30.

- **Turbidity:** The criteria for turbidity are entirely descriptive and placed in the context of aesthetics. All waters must be free from non-natural sources of pollution that cause cloudiness or haziness.
- ***Escherichia coli (E. coli):*** 30-day geometric mean concentration < 126 colony forming units/100 milliliters.
- **Streamflow:** Water quality standards apply to all waters outside of acute mixing zones (limited areas encompassing point-source discharge) and above a critical low streamflow (117 Nebraska Administrative Code § 81.1501 2014). Streamflow is the amount of water that flows in a river or stream, eventually reaching the ocean.

Table 4.5.1. Dissolved oxygen (DO) criteria by date.

Value calculation	Dates when criterion applies*	Criterion value (mg/L)
One day minimum	April 1–June 30	≥ 5.0
One day minimum	July 1–March 31	≥ 4.0
Seven day mean	April 1–June 30	≥ 6.5
Seven day mean minimum	July 1–March 31	≥ 5.0
30 day mean	July 1–March 31	≥ 6.5

* Seasonal variation protects early life stages of coldwater fish.

Flow changes seasonally with precipitation events, but land use changes can also affect streamflow. Diversions for agriculture, flow regulation for reservoir or hydropower management (Botter et al. 2010), and surface changes that affect runoff (Herb et al. 2008) can alter the total amount of water flowing in a river and affect water quality indicators. While the organisms that inhabit rivers have evolved in seasonally variable streamflow conditions, anthropogenic changes in streamflow can have ecological consequences for aquatic communities (e.g., Poff and Zimmerman 2010).

The flow regime in every river is different, so each river should be compared to itself over time and considered in a regional context. If trends in low and high flows in a river are inconsistent with regional trends, that pattern could indicate a change in land or river use. For trends that are consistent with regional condition, flow rate changes may indicate broader environmental change. There are no set parameters for evaluating the flow status of an individual stream, but there are flow rate limits at which certain water quality values are not valid.

For Coldwater Class B streams in Nebraska, such as the North Platte River, narrative criteria, general criteria, and acute toxicity water quality standards apply to waters flowing above 0.1 cubic feet per second (ft^3/s), while criteria for chronic exposure (> 96 hrs) do not apply below this critical low flow (117 Nebraska Administrative Code § 81.1501 2014); all standards apply above this flow rate.

4.5.3. Methods

Indicators, Measures, and Data Sources

Overall water quality condition depends on the individual conditions of multiple indicators (Figure 4.5.2). The water quality indicators that we considered for this assessment were either regulated by the US EPA, the Nebraska Department of Environmental Quality (117 Nebraska Administrative Code § 81.1501 2014) or identified as key indicators by NPS (Wilson et al. 2014). NPS requires that each network monitor core parameters (DO, pH, specific conductivity, and water temperature) for surface waters within park boundaries. Collecting data for these core parameters is relatively straightforward and can give a general description of water quality, but including other water quality indicators gives a more robust assessment of overall health of the aquatic environment. The NGPN protocol for surface water monitoring incorporates an additional advanced suite of water quality indicators, including aquatic microorganisms (primarily *E. coli* bacteria) and aquatic macroinvertebrates (Wilson et al. 2014). These biological indicators reflect different aspects of water quality and can affect human and environmental health in different ways. Therefore, we considered these biological parameters in our assessment alongside the core parameters and turbidity, a physical aspect of surface water. We considered all indicators and measurements in the context of streamflow, as flow rates determine the applicability of water quality standards.

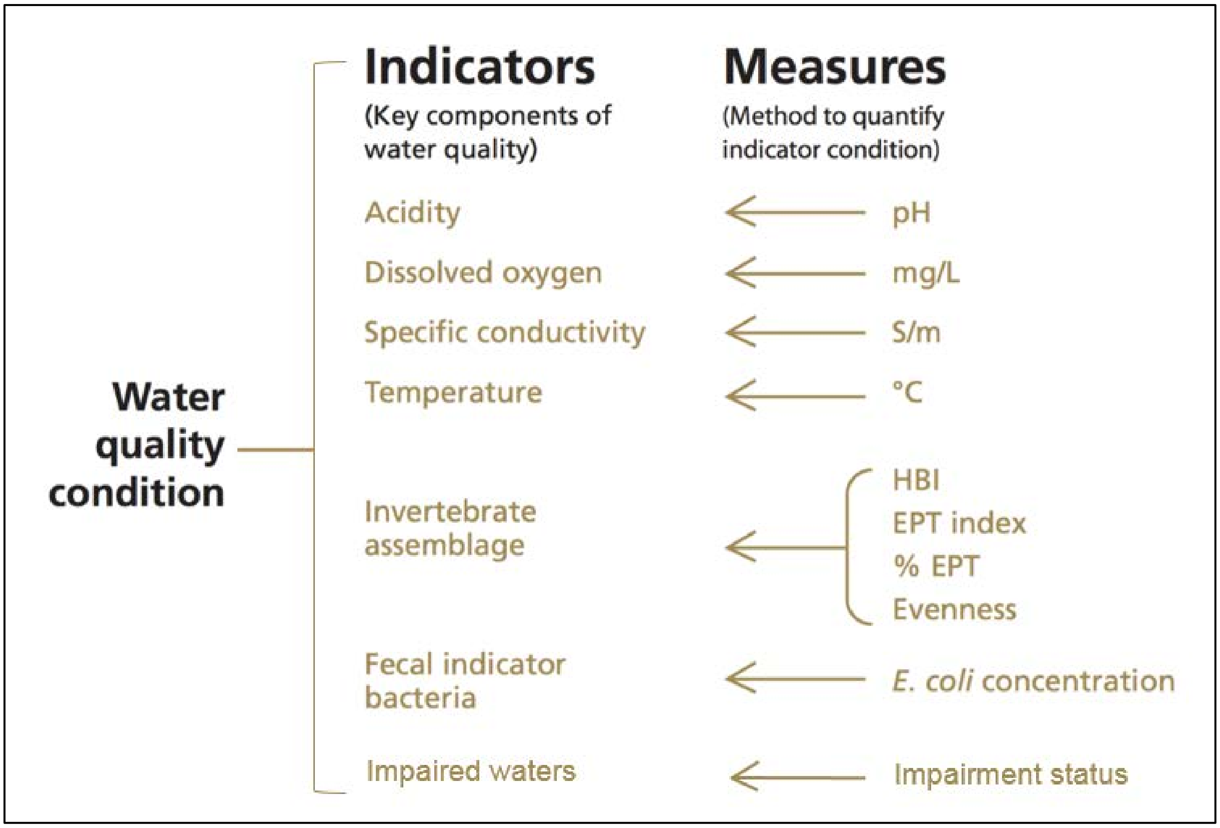

Figure 4.5.2. Schematic of the factors considered in this water quality condition assessment.

As of 2014 no park units within NGPN had sufficient data for a comprehensive surface water quality assessment (Wilson et al. 2014). We have, however, used all available existing data to make as comprehensive an assessment as possible for water quality within Scotts Bluff NM. To assign a condition to each water quality indicator, we used measurements specified by Nebraska Department of Environmental Quality (NEDEQ 2014) where available, EPA, and expert opinion for indicators not regulated federally or by Nebraska DEQ. We assigned to each indicator one of three condition categories based on NPS water quality monitoring protocol (Wilson and Wilson 2014).

Potential water quality condition categories were *Resource in Good Condition*, *Warrants Moderate Concern*, and *Warrants Significant Concern* (Table 4.5.2); condition category was determined by the proportion of samples that were outside the range of allowed values. Ideally, samples would have been collected consistently over time at set monitoring locations, but when long-term data were unavailable, we used multiple samples collected over the length of a water body to assess condition in lieu of time. This approach allowed us to assign a category based on the proportion of those samples that exceeded Nebraska standards for water quality. We then considered all indicator conditions together in an overall water quality condition assessment. For indicators that did not have set standards, we relied on expert opinion and, where possible, adapted the NPS approach to assign a condition.

Table 4.5.2. Water quality condition categories for core parameters (acidity, dissolved oxygen, specific conductance, and temperature), which are determined by the percentage of observations that exceeded state standards (Wilson et al. 2014).

Resource condition		% Exceedance*
Warrants significant concern	🔴	> 25%
Warrants moderate concern	🟡	5 – 25%
Resource in good condition	🟢	0 – 5%

* Percentage of samples above or below their respective state regulatory threshold.

<u>Data Sources</u>

Federal, state, and tribal governments monitor water quality using varying measures and monitoring durations. In this assessment we searched for data that were collected within the boundaries of Scotts Bluff NM, in the North Platte River adjacent to the park unit and, concurrent with DEQ water quality monitoring standards, downstream of the park in the North Platte River. We conferred with experts to identify relevant monitoring data and reports for water quality at Scotts Bluff NM (D. Ihrie, personal communication, 21 December 2015). We identified only one water quality report that sampled water within the boundary of Scotts Bluff NM—an M.S. thesis produced by Rust (2006). We referred primarily to this report in our assessment; there were no water quality monitoring locations on the Platte River within 10 miles downstream of Scotts Bluff NM.

Data that we considered for this assessment were collected 1–2 times between June 2004 and July 2005 from sampling points on the North Platte River, Central Canal, and Gering Canal. Our data sources grouped the Gering/Fort Laramie and Gering Canals as Gering Canal, so we present data for these canals together as Gering Canal. Scott's Spring has been dry since ~2010 and was not included in this assessment (Figure 4.5.3).

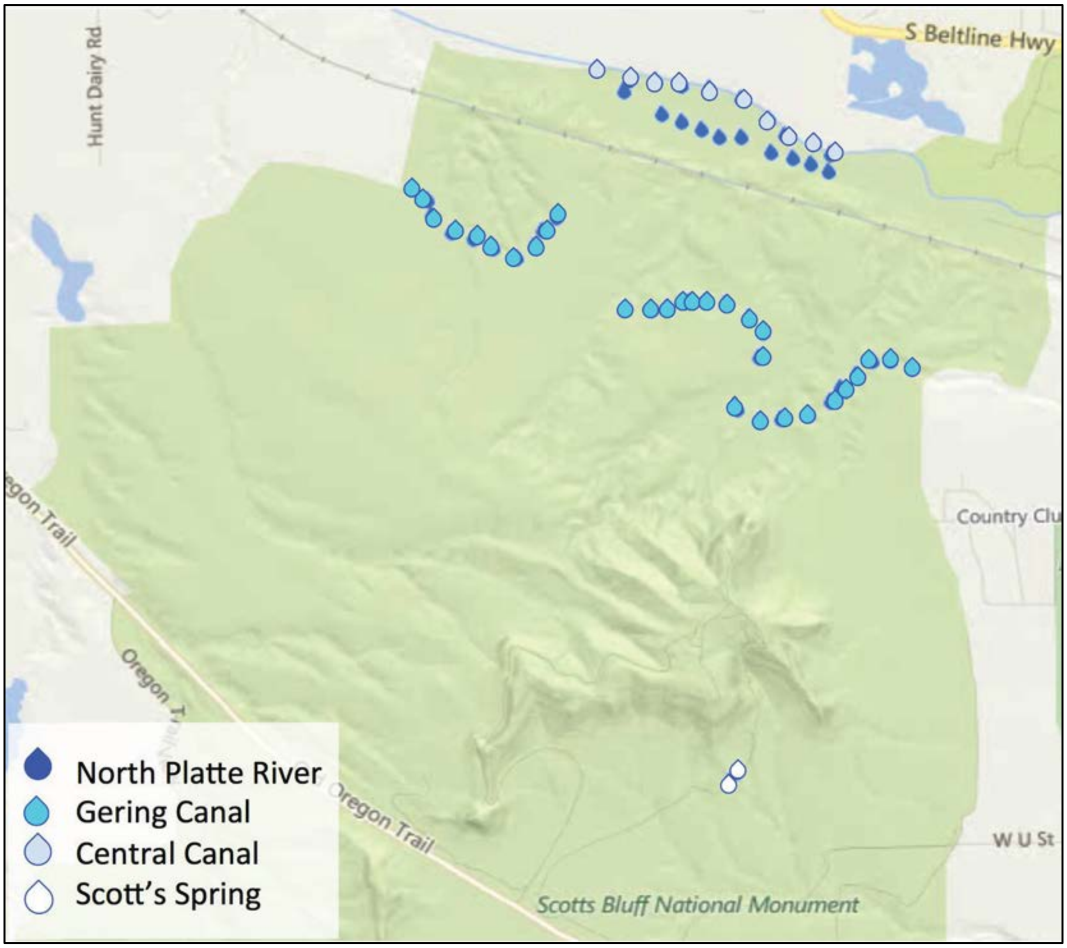

Figure 4.5.3. Water quality sampling locations at Scotts Bluff NM. Scott's Spring had been dry since ~2010 and was not included in this assessment (modified from EPA 2015; data collected by Rust [2006]).

Core Indicator Group

Indicator: Acidity

Most streams are naturally neither very acidic nor alkaline—they are neutral. The organisms that have evolved in these ecosystems are, therefore, adapted to relatively neutral water and many cannot survive in water that is either very acidic or alkaline (Figure 4.5.4). North American streams have become more acidic in the past 100 years from atmospheric deposition of sulfur and nitrogen, and this acidification has had a negative effect on stream ecosystems (Gleick et al. 1993). Some fish and macroinvertebrates are particularly sensitive to changes in pH and have declined in or have been extirpated from low pH streams (e.g., Mulholland et al. 1992, Baldigo and Lawrence 2001).

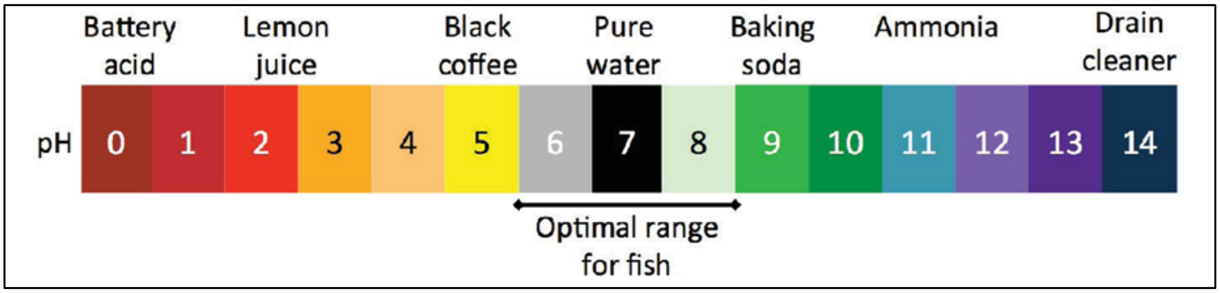

Figure 4.5.4. pH scale. Low and high pH waters are limiting for aquatic life; fish survive best at pH of 5–9.

Measure of Acidity: pH

The pH of a water sample measures the relative amount of free hydrogen ions (H+) and free hydroxyl ions (OH-) in the sample. Acidic water has more H+ and alkaline water has more OH-. The pH indicates the acidity of water on a logarithmic scale of 0 (most acidic) to 14 (most alkaline), where 7.0 is neutral. Standards for pH apply at all streamflow rates.

Indicator: Dissolved Oxygen (DO)

Dissolved oxygen is a critical resource for aerobic aquatic life (Boyd 2015), and low oxygen levels can damage macroinvertebrates and fish (Table 4.5.3) (e.g., Davis 1975, Caraco and Cole 2002). Most fish do best when oxygen concentration is within 50–100% saturation (~5–10 mg/L for a stream at 15°C), and dissolved oxygen tends to be highest in cold waters that receive low nutrient inputs (Boyd 2015). Oxygen solubility decreases as temperature increases (USGS 2014, Boyd 2015), and excessive nutrient inputs allow the explosive growth of algae—algae blooms that can temporarily increase DO. When algae die, however, microbes use oxygen to decompose the organic material; at high algal levels the consequent depletion of oxygen during decay can suffocate other aquatic life (Campbell and Reece 2009). Standards for DO apply at all streamflow rates, though only the 1-day acute criteria are applicable below critical low flow rates.

Table 4.5.3. Dissolved oxygen level ranges and corresponding effects on macroinvertebrate and fish. Dissolved oxygen concentration affects fish survival and health (Boyd 2015).

Dissolved oxygen (mg/L)	Effects
0 – 0.3	Small fish survive short exposure
0.3 – 1.5	Lethal if exposure is prolonged for several hours
1.5 – 5.0	Fish survive, but growth will be slow and fish will be more susceptible to disease
5.0 – saturation	Desirable range
Above saturation	Possible gas bubble trauma if exposure prolonged

Measure of DO: Milligrams Oxygen per Liter Water (mg/L)

Dissolved oxygen is measured as a mass concentration (mass per unit volume)-typically as milligrams per liter (mg/L) water.

Indicator: Specific Conductivity

Specific conductance, or conductivity, is the ability of a solution to conduct electricity. Conductivity increases with the concentration of ions in the water, which come from dissolved salts. Conductivity increases with salt content of water such that pure water has a very low specific conductance and sea water has a high conductance (Miller et al. 1988). Specific conductance is conductivity adjusted for temperature, and is important ecologically because of its relationship to salinity. Aquatic organisms are adapted to a range of salinity and are likely to suffer adverse effects at salt concentrations that are either too high or too low (Boeuf and Payan 2001, Horrigan et al. 2005). Specific conductance is also a water quality indicator for agriculture; highly saline water can damage some crops (e.g., Bartels and Sunkar 2005).

Measure of Specific Conductivity: Siemens per Meter (S/m) or Microsiemens (µS/cm)

Specific conductivity is calculated from the conductance between two electrodes over a set distance. The unit for conductance at 25 °C is a siemens (Miller et al. 1988).

Indicator: Temperature

Fish, macroinvertebrates, microorganisms, and aquatic plants are limited to specific ranges of temperature. Temperature affects the solubility of salts and dissolved oxygen concentration (Boyd 2015), chemical toxicity in fish (Cairns et al. 1975), and various biochemical processes such as metabolic rate in fish (Gillooly 2001). Temperature fluctuates seasonally, and varies with the size and depth of a water body, its physical structure, the clarity of the water (Paaijmans et al. 2008), and flow rates or circulation rates. Standards for temperature apply at all streamflow rates.

Measure of Temperature: Degrees (°C or °F)

Temperature is measured in degrees Celsius (°C) or degrees Fahrenheit (°F). We present temperatures in °C to stay consistent with regulatory guidelines. The conversion between Celsius and Fahrenheit is approximately 0 °F = -17.8 °C, and the conversion formula is: T(°C)= (T(°F) – 32)/1.8.

Physical Indicators

Indicator: Turbidity

Turbidity is the cloudiness or clarity of water; low turbidity waters are relatively clear, while waters with high turbidity are opaque. Light scatters when it hits fine particles in water, such as silt, clay, and organic particles, and high scatter causes opacity. Turbidity can affect plant growth, macroinvertebrate productivity, and fish communities (Lloyd 1987). Sources of particulate matter that cause turbidity can be natural, such as from soil erosion during flood events, or anthropogenically induced, such as from wastewater discharge from urban areas (Petit et al. 2013).

Measure of Turbidity: Descriptive Aesthetic Condition

Turbidity is measured in a variety of units, but the nephelometric turbidity unit (NTU) has been adopted by most state and federal regulatory situations. Turbidity is the amount of light reflected by particles in a water sample. Relatively high concentrations of suspended particles in turbid samples have high light reflection and, therefore, high NTU measurements. Nebraska does not specify an NTU standard value, but rather, gives an aesthetic guideline that waters must be free from non-natural sources of pollution that cause cloudiness or haziness. Similar to our approach with quantitative measures, we assigned the turbidity condition based on the proportion of turbidity observations within park boundaries that violated these standards.

Biological Indicators

Indicator: Invertebrate Assemblage

Aquatic macroinvertebrates are small organisms that live in the sediment or on rocks at the bottom of lakes, rivers, and streams. They are visible to the naked eye and spend at least part of their lives in water. The composition of aquatic invertebrate communities can indicate long-term water quality condition that may not be reflected in periodic or short-term chemical and physical samples. Aquatic invertebrates experience and respond to a variety of water conditions in their environment for the duration of their lives—spanning weeks to many years (e.g., Martıñez 1998, Tronstad 2015)—thus providing a comprehensive picture of overall water quality. Some invertebrate taxa are more sensitive to changes in water quality than other taxa, so measuring the proportion of those taxa in a stream is one way to measure water quality, but differences in stream channel shape, depth, and substrate, and natural water conditions can also account for differences in invertebrate presence and abundance. Therefore, comparing several measures indicative of invertebrate community health is ideal.

Measure of Invertebrate Assemblage: Hilsenhoff Biotic Index (HBI)

Some aquatic invertebrates are more sensitive to environmental conditions than others. The Hilsenhoff Biotic Index (HBI) is an overall tolerance index for a community that combines the estimated tolerance of individual species with their local abundance (Hilsenhoff 1987, 1988). This biotic index is calculated from the total number of individuals (N) in a sample where n is the number of individuals of taxonomic group *i* and *a* is the tolerance of that group:

$$HBI = \frac{\sum n_i a_i}{N}$$

Tolerance to pollution ranges from 0 for highly sensitive species, to 10 for highly tolerant species (Hilsenhoff 1987). We assigned a condition value to the HBI based on the overall community tolerance (Hilsenhoff 1988). Values from 0–4.50 indicated Resource in Good Condition, values from 4.51–6.50 indicted that water quality Warrants Moderate Concern, and values from 6.51–10.00 indicted that water quality Warrants Significant Concern (Table 4.5.4).

Table 4.5.4. Water quality condition categories for Hilsenhoff Biotic Index (HBI) scores (Hilsenhoff 1988).

Resource condition		HBI score
Warrants significant concern	🔴	6.51 – 10.00
Warrants moderate concern	🟡	4.51 – 6.50
Resource in good condition	🟢	0 – 4.50

Measure of Invertebrate Assemblage: EPT Index

Three orders of macroinvertebrates— Ephemeroptera, Plecoptera, and Trichoptera—are particularly sensitive to pollution and are unlikely to occur in polluted waters when more tolerant groups are present. The presence of very few EPT species in a sample can indicate poor water quality, though EPT indices must be compared to EPT criteria that are specific to the region where data were collected.

An EPT index is simply the total number (richness) of distinct species within each of the EPT orders. For example, a sample that contained three species belonging to Ephemeroptera, three species in Plecoptera, and four Trichoptera would have an EPT index of 10. We assigned condition to this measure based on background data for EPT numbers in the ecoregion (25f—Scotts Bluff and Wildcat Hills) that included Scotts Bluff NM (Bazata 2011, 2013) and adapted the condition categories to fit conservatively into the three condition scheme we used for our assessment. We assigned the condition *Warrants Significant Concern* to values below the 25th percentile (of samples collected from a variety of streams sampled in the region [Bazata 2011]), *Warrants Moderate Concern* to values from the 25th to the 75th percentile of all streams, and *Resource in Good Condition* to values above the 75th percentile of streams (Table 4.5.5).

Table 4.5.5. Water quality condition categories for the Ephemeroptera, Plecoptera, and Trichoptera (EPT) index (adapted from Hargett 2011).

Resource condition		EPT index
Warrants significant concern	🔴	< 7
Warrants moderate concern	🟡	7 – 13
Resource in good condition	🟢	> 13

Measure of Invertebrate Assemblage Proportion or Percentage of EPT Taxa

Though EPT index is a good general measurement of water quality, the proportion of EPT to non-EPT taxa can improve on this measure. Taxa that are tolerant to pollution and EPT are all likely to be present in high-quality water bodies, but the proportion of EPT to more tolerant taxa declines as water quality declines (e.g., Tronstad 2013, 2015). Condition ranges were not available for % EPT for Nebraska, so we referred to reference conditions assigned to the upstream region in southeast Wyoming (Hargett 2011 p. 62) and assigned condition based on these ranges (Table 4.5.6).

Table 4.5.6. Water quality condition categories for proportion of Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa (Hargett 2011).

Resource condition		Proportion EPT taxa
Warrants significant concern	🔴	< 0.38
Warrants moderate concern	🟡	0.38 – 0.68
Resource in good condition	🟢	> 0.68

Measures of Invertebrate Assemblage: Taxa Evenness

Evenness is a diversity index that describes the similarity in number of members that belong to different groups in a community (Figure 4.5.5). Values for evenness may fall between 0 and 1. If all groups have a similar number of members, the community is very even, with an evenness value close to 1. Communities that have high evenness can remain more functional in stressful conditions than uneven communities (Wittebolle et al. 2009). A stream macroinvertebrate community may comprise many taxa, but even a very rich community can be in poor condition if there are few individuals belonging to sensitive taxa while there are many individuals from more hardy taxa. Evenness is likely to vary naturally among streams with different natural characteristics, so we referenced the literature and expert opinion to assign condition levels (L. Tronstad, personal communication, 27 January 2016). We used a quantile approach to assign condition to evenness scores. Values that were below the median (of a random distribution) were assigned the condition *Warrants Significant Concern*, values from the median up to the 75th percentile were classified as *Warrants Moderate Concern*, and values above the 75th percentile were assigned a *Resource in Good Condition* (Table 4.5.7).

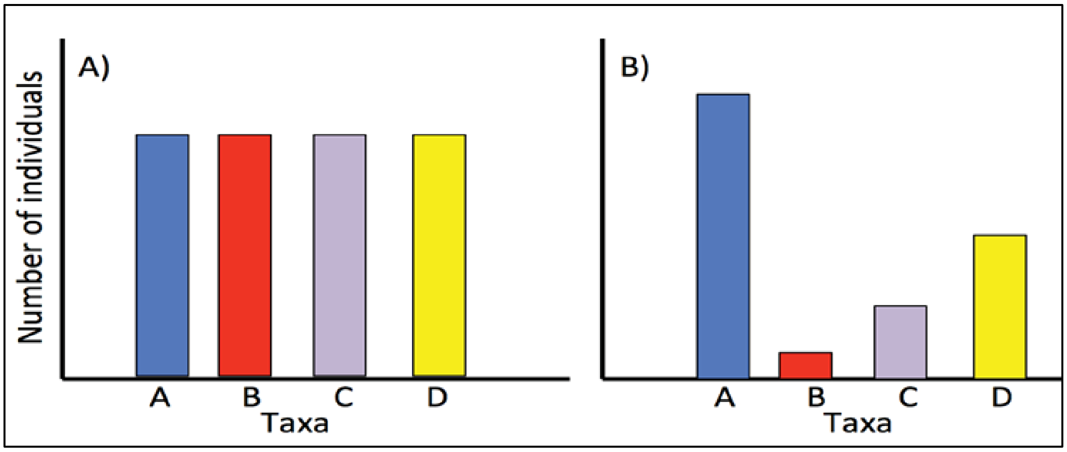

Figure 4.5.5. Illustration for describing taxa evenness. Taxa evenness is high if individuals are A) distributed similarly among taxa, and low if B) distributed unequally among taxa.

Table 4.5.7. Water quality condition categories for evenness.

Resource condition		Evenness score
Warrants significant concern	🔴	0 ≤ x ≤ 0.5
Warrants moderate concern	🟡	0.50 < x ≤ 0.75
Resource in good condition	🟢	0.75 < x ≤ 1

Indicator: Fecal Indicator Bacteria (Fecal Coliform)

Fecal coliform bacteria live in intestines of warm-blooded animals and are common biological contaminants of surface waters. Not all coliform bacteria are harmful, but the presence of some coliform bacteria can indicate the presence of pathogenic organisms (Gallagher and Spino 1968). Sampling for these bacteria is useful for assessing safety of drinking water and recreational water use

(Geldreich 1970), as well as wildlands water quality (Bohn and Buckhouse 1985). Escherichia coli is a well-known fecal coliform that has been associated with illness following food contamination. Fecal coliform standards and testing in Nebraska surface waters (117 Nebraska Administrative Code § 81.1501 2014) are concerned primarily with *E. coli*.

Measure of Fecal Indicator Bacteria (Fecal Coliform): Escherichia coli (E. coli) Concentration

Concentration of *E. coli* (number of bacteria per unit volume) is regulated within single samples and within a 30-day period and must not exceed 126 colony-forming units (cfu)/100 mL (117 Nebraska Administrative Code § 81.1501 2014). We used the geometric mean of at least five samples within 30 to calculate this value. In single samples, the concentration of this bacterium is also regulated to standards reflective of the amount that waterbodies are used for recreation (117 Nebraska Administrative Code § 81.1501 2014). If we did not have the requisite samples to apply a 30-day mean, we used the most conservative of the single sample standards to evaluate *E. coli* condition (Table 4.5.8). These standards do not apply to drinking water; fecal coliform must be absent from drinking water (0/100mL).

Table 4.5.8. Water quality condition categories for *Escherichia coli (E. coli).*

Resource condition		***E. coli*** **concentration (cfu/100 milliliters)**
Warrants significant concern	🔴	126 ≤ x
Warrants moderate concern	🟡	100 < x < 126
Resource in good condition	🟢	0 < x ≤ 100

Indicator: Impaired Waters

Impaired waters are waters that do not meet the water quality criteria for their designated beneficial uses. Impairment may be due to pathogens, nutrients, and/or sediment in the water.

Measure of Impaired Waters: Impairment Status

States develop Total Maximum Daily Loads (TMDL) for regulated pollutants in their water bodies and EPA approves these criteria. If waters do not meet these standards, states must submit a list of impaired waters to the EPA under section 303(d) of the Clean Water Act. Impaired waters then receive priority depending on their designated use and the severity of the impairment. All Impaired waters are degraded and received the condition, *Warrants Significant Concern*. This condition supersedes those given by all other indicators. For unimpaired waters, other indicators determine water quality condition.

Quantifying Water Quality Condition, Confidence, and Trend

Indicator Condition

If any waters within the park were impaired waters, under section 303(d) of the Clean Water Act, the overall condition was Warrants Significant Concern. If waters were not Impaired, we followed NPS methods for water quality assessment where applicable (Wilson and Wilson 2014). For measurements beyond the scope of NPS guidelines, we created condition categories based on expert opinion and the scientific literature. We used a point system to assign each indicator to a category. This point system is based on the NPS methods that were developed to calculate overall air quality condition (NPS-ARD 2015), a methodical and rigorous assessment approach that can be applied to other resources as well. In this approach, we assigned zero points to the condition *Warrants Significant Concern*, 50 points to *Warrants Moderate Concern*, and100 points to *Resource in Good Condition*. If results from different locations throughout the park (e.g., North Platte River vs. Gering Canal) indicated different conditions, we used a weighted average by number of sampling points to calculate a summary measure across all surface waters within the park unit. If two or more measures placed the indicator in different condition categories, the measure with the worst category determined the condition for the indicator (NPS-ARD 2015).

Indicator Trend

Potential trend categories were *Improving, Unchanging,* or *Deteriorating*. To calculate a trend estimate, we sought data that were collected continuously for two years (Wilson and Wilson 2014). Data from ongoing NPS monitoring efforts will not be available until 2017, but we endeavored to identify a trend if other monitoring data were available. If there were no data available that met these monitoring requirements for a particular indicator, we indicated that trend was *Not Available* for that indicator.

Indicator Confidence

Confidence ratings were based on monitoring location, monitoring frequency, and time since data collection. We gave a rating of *High* confidence when monitors or sampling efforts were on site, data were collected recently, and the data were collected methodically. We assigned a *Medium* confidence rating when monitors and sampling efforts were located downstream, data were not collected recently, or data collection was not repeatable or methodical. We assigned *Low* confidence ratings when there were no good data sources to support the condition.

Overall Water Quality Condition, Confidence, and Trend

We used the general approach for combining indicator conditions, trends, and confidence described in Chapter 3 (Methods 3.2.2) to calculate overall resource condition, trend, and confidence (Table 4.5.9).

Table 4.5.9. Summary of water quality indicators and measures.

Indicator	Measure	Condition	Confidence	Trend	Condition rational
Acidity	pH	Resource in good condition	Medium	Not available	Acidity was within state standards during sampling period. Monitoring was not repeated at several sites and all data were collected 10 years prior to this assessment, so confidence was *Medium* and trend was *Not Available*.
Dissolved Oxygen (DO)	mg/L	Resource in good condition	Medium	Not available	D.O. was within state standards during sampling period. Monitoring was not repeated at several sites and all data were collected 10 years prior to this assessment, so confidence was *Medium* and trend was *Not Available*.
Conductivity	S/m	Resource in good condition	Medium	Not available	Conductivity was within state standards during sampling period. Monitoring was not repeated at several sites, all data were collected 10 years prior to this assessment, and unclear if results were adjusted for temperature, so confidence was *Medium* and trend was *Not Available*.
Temperature	°Celsius	Warrants moderate concern	Medium	Not available	Temperature was within state standards during sampling period. Monitoring was not repeated at several sites and all data were collected 10 years prior to this assessment, so confidence was *Medium* and trend was *Not Available*.
Turbidity	Qualitative aesthetic assessment	Resource in good condition	Low	Not available	Turbidity was recently (2014) rated satisfactory in one water body adjacent to the park unit, but was not assessed in surface waters within the park unit. Confidence was *Low* and trend was *Not Available*.
Invertebrate assemblage	• HBI • EPT index • % EPT	Warrants moderate concern	Medium	Not available	The average of conditions indicated by all measures was 66, which warranted Moderate Concern. Monitoring was not repeated at several sites and all data were collected 10 years prior to this assessment, so confidence was *Medium* and trend was *Not Available*.

Table 4.5.9 (continued). Summary of water quality indicators and measures.

Indicator	Measure	Condition	Confidence	Trend	Condition rational
Fecal indicator bacteria	*Escherichia coli* (*E. coli*) count	Warrants significant concern	Medium	Not available	Coliform counts of *E. coli* exceeded state standards in multiple sampling sites during sampling period. Monitoring was not repeated at several sites and all data were collected 10 years prior to this assessment, so confidence was *Medium* and trend was *Not Available.*
Impaired waters	Impairment status	Warrants significant concern	High	Unchanging	The North Platte River, the predominant water feature running through the park, was an Impaired Water for pathogens, nutrients, and sediment. The river has been Impaired since 1998. Confidence was *High* and trend was *Unchanging*.

4.5.4. Water Quality Conditions, Confidence, and Trends

We assessed condition of water quality indicators for all available data and assigned an overall condition to water quality at Scotts Bluff NM. Rust (2006) sampled core indicators (DO, conductance, pH, and temperature) thirty times in the North Platte, Gering Canal, and Central Canals, and sampled invertebrate community three times in these water bodies. Samples of other parameters were inconsistent, collected between two and eight times at each water body. Core water quality indicators were sampled once at 30 locations along the Gering Canal, and three times at 10 locations between May 2004 and July 2005. The sampling scheme was the same for the North Platte River. We evaluated each water body separately and assigned indicator condition based on the worst observed condition.

Acidity

●

Condition: Resource in Good Condition
Confidence: Medium
Trend: Not Available

Condition

To assign a condition for acidity we used data summarized by Rust (2006) and the EPA STORET database, via My WATERS Mapper (EPA 2015). All 90 samples collected from the North Platte River, Gering Canal, and Central Canal were within the acceptable range for pH (6.5–9.0) for Nebraska. These data placed acidity for Scotts Bluff NM in the *Resource in Good Condition* category.

Confidence

Acidity was calculated from pH data collected on site at Scotts Bluff NM and some sampling was repeated over two years at several water bodies. Other water bodies were not subject to repeat sampling, and all data were collected more than 10 years prior to this assessment. Because the sampling schedule was inconsistent and data were not collected recently, the confidence was *Medium*.

Trend

Acidity was calculated from pH data collected once or twice in a year, so data were insufficient to identify a trend. Trend was *Not Available*.

Dissolved Oxygen (DO)

🟢

Condition: Resource in Good Condition
Confidence: Medium
Trend: Not Available

Condition

To assign a condition to dissolved oxygen (DO), we used data summarized by Rust (2006) and the EPA STORET database (EPA 2015). All 90 samples collected from the North Platte River, Gering Canal, and Central Canals were above the acceptable minimum DO for a single sample (5.0 mg/L) for Nebraska. These values placed DO for Scotts Bluff NM in the *Resource in Good Condition* category.

Confidence

Dissolved oxygen condition was calculated from data collected on site at Scotts Bluff NM and some sampling was repeated over two years at several water bodies. Other water bodies were not subject to repeat sampling, and all data were collected more than 10 years prior to this assessment. Because the sampling schedule was inconsistent and data were not collected recently, the confidence was *Medium*.

Trend

Dissolved oxygen was calculated from data collected once or twice in a year, so data were insufficient to identify a trend. Trend was *Not Available*.

Conductivity

🟢

Condition: Resource in Good Condition
Confidence: Medium
Trend: Not Available

Condition

To assign a condition to conductivity, we used data summarized by Rust (2006) and the EPA STORET database (EPA 2015). All 90 samples collected from the North Platte River, Gering Canal, and Central Canal were below the acceptable maximum conductivity for a single sample (< 2,000 S/m) for Nebraska. These values placed conductivity for Scotts Bluff NM in the *Resource in Good Condition* category.

Confidence

Conductivity condition was calculated from data collected on site at Scotts Bluff NM, but samples were collected only once at each point along length of water bodies and were collected more than 10 years prior to this assessment. Additionally, Rust (2006) did not specify if data were adjusted for temperature, which would give specific conductance—a standard approach to measuring conductivity, so that uncertainty adds to overall uncertainty. The confidence for conductivity was *Medium*.

Trend

Conductivity was calculated from data collected once or twice in a year, so data were insufficient to identify a trend. Trend was *Not Available*.

Temperature

🟡

Condition: Warrants Moderate Concern
Confidence: Medium
Trend: Not Available

Condition

To assign a condition to temperature we used data summarized by Rust (2006) and the EPA STORET database (EPA 2015). All 30 samples along Gering Canal were below the maximum allowed temperature (22°C), but 20 samples (67% of samples) from Central Canal were above the allowed temperature maximum, which indicated a condition of *Warrants Significant Concern*, and five samples (17%) from the North Platte River were above the maximum temperature, which indicated a condition of *Warrants Moderate Concern*. The weighted average score was 59, which placed temperature for Scotts Bluff NM in the *Warrants Moderate Concern* category.

Confidence

Temperature condition was calculated from data collected on site at Scotts Bluff NM and some sampling was repeated over two years at several water bodies. Other water bodies were not subject to repeat sampling, and all data were collected more than 10 years prior to this assessment. Because the sampling schedule was inconsistent and data were not collected recently, the confidence for temperature was *Medium*.

Trend

Temperature was calculated from data collected once or twice in a year, so data were insufficient to identify a trend. Trend was *Not Available*.

Turbidity

●

Condition: Resource in Good Condition
Confidence: Low
Trend: Not Available

Condition

To assign a condition to turbidity, we reviewed the most recent Nebraska Water Quality Integrated Report (NE DEQ 2014) and searched for records of aesthetic impairment of surface waters considered in this assessment. Nebraska DEQ evaluated aesthetics of the North Platte River and found the aesthetics were satisfactory, so turbidity was in *Resource in Good Condition*. We also compared turbidity measurements that Rust (2006) collected for all surface waters in Scotts Bluff NM with her North Platte data. Surface water turbidity values were similar to North Platte Values, but Gering Canal had much higher turbidity—up to five times as high as values observed in North Platte. While high turbidity can negatively affect aquatic life, the effects of turbidity on aquatic life are highly variable and background conditions can be more indicative of larger ecosystem condition than stream-specific conditions (e.g., Lloyd et al. 1987). We did not have access to data on background condition for normal turbidity conditions within Scotts Bluff NM, so we did not change the indicator condition based on these data.

Confidence

We assigned turbidity condition based on Nebraska DEQ assessment of surface water aesthetics, which included only the North Platte River. Similar assessments did not exist for other surface waters in Scotts Bluff NM, and numeric data were more than 10 years old. Because aesthetic assessments were unavailable for most water bodies and background data on turbidity were unavailable, the confidence for temperature was *Low*.

Trend

Turbidity data were insufficient to identify a trend. Trend was *Not Available*.

Invertebrate Assemblage

●

Condition: Warrants Moderate Concern
Confidence: Medium
Trend: Not Available

Condition

We used data collected by Rust (2006) to assign a condition to invertebrate assemblage. To calculate overall indicator condition from the three available measures, we used the average condition indicated by each measure. No data were available on taxa evenness, so we excluded it from our analyses.

Hilsenhoff Biotic Index (HBI)

Values of HBI indicated *Resource in Good Condition* in all surface waters surveyed at Scotts Bluff NM. EPT Index. Values of EPT index indicated *Significant Concern* in each of the water bodies except Central Canal, where results indicated *Moderate Concern*. The weighted average measure across all surface waters was 16.1, which indicated *Significant Concern*.

Percentage (%) of EPT

Percentages of EPT observed in Scotts Bluff surface waters indicated *Resource in Good Condition* in all surface waters. The average of conditions indicated by all measures was 66, which placed the condition of macroinvertebrate assemblage at Scotts Bluff NM in the category, *Warrants Moderate Concern.*

Confidence

Macroinvertebrate data were collected on site at Scotts Bluff NM and some sampling was repeated over two years at several water bodies. Other water bodies were not subject to repeated sampling, and all data were collected more than 10 years prior to this assessment. Because the sampling schedule was inconsistent and data were not collected recently, the confidence for temperature was *Medium*.

Trend

Macroinvertebrate measures were calculated from data collected once or twice in a year, so data were insufficient to identify a trend. Trend was *Not Available*.

Fecal Indicator Bacteria (Fecal Coliform)

●

Condition: Warrants Significant Concern
Confidence: Medium
Trend: Not Available

Condition

To assign a condition to fecal coliform bacteria, we used data summarized by Rust (2006) and the EPA STORET database (EPA 2015). More than 25% of coliform count samples in all surveyed surface waters, exceeded the maximum allowed coliform count (126cfu/100mL). These exceedances placed the fecal bacteria indicator for Scotts Bluff NM in the *Warrants Significant Concern* category.

Confidence

Fecal indicator bacteria condition was calculated from data collected on site at Scotts Bluff NM and some sampling was repeated over two years at several water bodies. Other water bodies were not subject to repeated sampling, and all data were collected more than 10 years prior to this assessment. Fecal indicators can be highly variable with stream turbidity and flow, so confidence would improve with a comparison between those variables, as well as with repeated and more recent sampling. Confidence for fecal indicator bacteria was *Medium*.

Trend

Fecal coliform data were collected once or twice, at most, in one year across all surface waters, so data were insufficient to identify a trend. Trend was *Not Available*.

Impaired Waters

Condition: Warrants Significant Concern
Confidence: High
Trend: Unchanging

Condition

To assign a condition to fecal coliform bacteria, we used reports available through the EPA STORET database (EPA 2016). The North Platte River was impaired at each two-year reporting data from 1998 to the time of this assessment. This impairment status received the condition, *Warrants Significant Concern.*

Confidence

Monitoring of Impaired waters, including the North Platte, occurs at least every two years and the status is submitted to the EPA. Reporting has been consistent for the North Platte and TMDL was developed for one pathogen, *E. coli*, in 2012. Confidence for impairment status was *High*.

Trend

Reporting for Impairment of the North Platte River occurred every two years from 1998 to the time of this assessment, in 2016. Trend was *Unchanging*.

Water Quality Overall Condition

Condition

Overall water quality condition was determined by the impairment status, which placed water quality at Scotts Bluff NM in the *Warrants Significant Concern* category (Table 4.5.10).

Confidence

Confidence was *High* for impaired waters, which was the overriding indicator because the North Platte River was impaired. Confidence in overall water quality was likewise *High*.

Trend

Trend data for the overriding indicator, impaired waters, was *Unchanging*, so overall trend for water quality was *Unchanging*.

Table 4.5.10. Water quality overall condition.

Indicators	Measures	Condition
Acidity	pH	🟢
Dissolved oxygen	mg/L	🟢
Temperature	°C	🟡
Turbidity	NTUs	🟢
Invertebrate assemblage	• HBI • EPT index • % EPT • Evenness	🟡
Fecal indicator bacteria	*E. coli* concentration	🔴
Impaired waters	Impairment status	🔴↔
Overall condition for all indicators and measures		🔴↔

4.5.5. Stressors

The North Platte River has been altered since settlers first followed the water along the Oregon Trail. The segment of the North Platte River that flows past Scotts Bluff NM was impaired for several designated uses due to high levels of *E. coli* and hazard index compounds (EPA 2014b). This section of the river has been impaired, for these uses and several others, since 2002 (EPA 2016). In other locations, elevated *E. coli* is most commonly associated with runoff from agriculture and urban development (e.g., Doran and Linn 1979). While EPA has not specified likely causes for impairment to the river, runoff from agriculture and urban development may contribute to impairment. Additionally, the recent development of the Bakken shale oil poses a significant industrial threat to water supply competitive demand and water quality, in the general region (P. Penoyer, personal communication, 7 July 2016).

4.5.6. Data Gaps

Water quality data for core indicators and invertebrates at Scotts Bluff NM were limited to samples collected between 2004 and 2005, with no more than three samples collected from any one location during that time (Rust 2006). The numerical turbidity data collected during this sampling period were difficult to interpret without knowing background conditions. More recent aesthetic evaluations of turbidity levels were available from Nebraska DEQ, but were limited to the North Platte River.

Regular sampling at locations within the park would improve assessment efforts to understand the spatial and temporal dimensions of water quality condition at Scotts Bluff NM. A variety of potential sampling schemes would provide NPS with sufficient data to evaluate trends in water quality over time (Wilson et al. 2014), although the best one for Scotts Bluff will depend on the specific objectives of NPS management.

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4.6. Geology

4.6.1. Background and Importance

Geological resources underlie and affect many other resources within National Park System units. Their characteristics and qualities, such as general rock type, mineral content, grain size, porosity and permeability, and friability (ability for rock to be reduced to smaller pieces) determine the location and stability of other park resources. Topography, slope stability, surface- and groundwater flow patterns, soil types, vegetation, and human use patterns are all affected by underlying geology.

In the northern Great Plains area, most of the bedrock is composed of soft Upper Cretaceous and Tertiary sedimentary strata. Many of these rocks are rich in swelling clays, which can make them lead to slope instability and ground heaving. Modern river valleys in this region hold thick fluvial gravel deposits that overlie the sedimentary bedrock. In many areas these river gravels have shaped the history of human habitation, as buildings were historically placed near the river channels (Graham 2009a).

Geologic hazards in the northern Great Plains area are mostly related to mass wasting activity, as the soft, clay-rich bedrock is often prone to slumps, slides, and rockfalls. While events such as these are natural, various land uses and human activities such as road and trail building can affect the magnitude and rate of mass wasting activities. For this reason and because of the potential danger to visitors, NPS places a high priority on managing key locations within a park to minimize uncharacteristic or dangerous mass wasting events.

The Great Plains region has not been seismically active for millions of years and earthquakes are uncommon in the area, although small earthquakes have occurred in the northern Laramie Range in Wyoming approximately 145 kilometers (90 miles) northwest of Scotts Bluff NM, and also near Guernsey, WY, approximately 97 kilometers (60 miles) to the northwest (Case 2002).

Regional Context

Surface and subsurface strata of the Great Plains physiographic province represent many different paleo-environments spanning millions of years. While older rocks are present in the subsurface, the oldest rocks exposed within Scotts Bluff National Monument are those of the Orella Member of the Brule Formation, a subdivision of the widespread White River Group of Eocene–Oligocene age (~36–30 million years ago) (Evanoff 2014).

The strata of the White River Group stretch for hundreds of miles across the region, with thicknesses ranging from a few meters to over 275 meters (~900 feet) (Larson and Evanoff 1998). They are mainly composed of wind-deposited and reworked volcanoclastics (volcanically derived sediment such as ash) and are the remnants of a blanketing deposit that covered the region from at least the eastern side of the Wind River Range in central Wyoming to western Nebraska and South Dakota (Prothero and Emry 2004).

These White River strata of the northern Great Plains are an important sequence of rocks, in that they hold the best-preserved record of a climactic transition in the terrestrial rock record (Prothero 1994). This transition, termed the Eocene–Oligocene climate transition (EOT), records gradual changes from generally warmer and wetter to cooler and drier conditions. During this time the change in environmental conditions reduced forest cover and correspondingly increased open grasslands, as reflected in fossil soils (Prothero 1994). Because differential erosion across the region has removed some parts of the White River Group strata and left others in place, outcrops across the area preserve different segments of the EOT (Prothero and Emry 2004). The section of the White River Group in Scotts Bluff National Monument does not preserve the Eocene–Oligocene boundary itself, instead recording the aftermath of the climatic transition during the early Oligocene (Benton et al. 2015). The fossil record for this time supports this gradual ecosystem transition, with the appearance of several rodents and artiodactyls (even-toed ungulates) with high-crowned teeth that were well suited for the tough vegetation of the new grasslands, after the loss of the brontotheres (an extinct order of large mammals in the same order as horses and rhinos) with their low-crowned teeth (Prothero 1994).

The youngest strata that crop out in Scotts Bluff National Monument are the beds of the lower Gering Formation and the overlying undifferentiated Monroe Creek-Harrison formations of the Arikaree Group, which overlies White River Group strata (Evanoff 2014). The Arikaree Group here is late Oligocene in age (~28.5–26 million years ago; Tedford et al. 2004). Common fossils in these beds include oreodonts (small artiodactyls), camels, rodents, and early canids, all well adapted to arid grassland life (Prothero 1994).

4.6.2. Geology Standards

No federal or state regulations exist to protect geological resources. Paleontological resources on federal lands are protected under several laws and rulings, including the National Environmental Policy Act of 1969 (P.L. 91–190; 31 Stat. 852, 42 U.S.C. 4321–4327); the Federal Land Policy and Management Act of 1976 (P.L. 94–579; 90 Stat. 2743, U.S.C. 1701-1782); and most recently the Omnibus Public Land Management Act of 2009 (PL 111–11, Title IV, Subtitle D—Paleontological Resources Protection). These Federal guidelines were put in place to protect fossil resources from destruction by various types of human activities, including theft and ground disturbance during construction.

4.6.3. Methods

Indicators and Measures

Overall geological resource condition in Scotts Bluff National Monument depends on the condition of a single indicator, weathering/erosion; we consider weathering and erosion together because they are two sides of the same coin, working in tandem to break down and remove geologic material. Preservation of paleontological resources is also an issue of concern at Scotts Bluff NM (Graham 2009b), and it is discussed in detail in the section on Paleontological Resources in this NRCA.

Indicator: Weathering/Erosion

Weathering and erosion are important geologic resource issues within Scotts Bluff National Monument (Graham 2009b). Weathering is defined as the breaking down of minerals within a rock by chemical and/or mechanical means, while erosion is the movement of that weathered material away from its place of origin (Press and Siever 2001). Weathering and erosion, in tandem, describe the loss of geologic material from a particular location, and are best considered together. In Scotts Bluff NM, weathering and erosion act together to affect geologic resources. Weathering and erosion are wearing away the top of Scotts Bluff, and they also result in rockslides of the main strata that form the bluff. Both of these actions are degrading the geologic resource on which the park unit is based.

Weathering and erosion impact the condition of geologic resources in Scotts Bluff National Monument due to the nature of the strata that compose the Bluff and the surrounding rock. Strata that crop out within the Monument include two rock units: the Orella member of the Brule Formation, White River Group (Oligocene), which forms the slopes of Scotts Bluff itself as well the badlands topography around the Bluff; and the upper cliff-forming Oligocene-Miocene Arikaree Group. Both of these rock units consist of several different sedimentary rock types including mudstone, siltstone, and sandstone, and both have large components of volcanic ash including reworked and primary ash deposits (Graham 2009b).

The strata of the Arikaree Group, the source of the majority of the rockslides within Scotts Bluff NM, are divided into two units: the lower Gering Formation and the upper Monroe Creek-Harrison Formations (undivided). The beds of the Gering Formation are poorly cemented sandstones that are easily weathered (Evanoff 2014). In particular, an ash bed that underlies a massive sandstone bed in the upper part of the cliff provides a weak point for weathering to start. This allows undercutting of the overlying bed, which eventually fails and falls. Once a rockslide occurs, the remaining part of the upper cliff becomes more stable for a time until it is once again undercut enough to fail. This cycle has been estimated to take place over approximately 20 years (Graham 2009b).

While weathering and erosion are natural processes, human activities can change the rate at which these processes occur. The bluff at Scotts Bluff is a major feature of the park unit that is used heavily by visitors who hike up and on the bluff. Rockslides on the bluff (see following “Mass Wasting Events” section) pose some risks to visitors, and in the past, management efforts have attempted to control some rockslides occurring within Scotts Bluff NM

Mass Wasting Events

Mass wasting, the geologic process of sediment, rock, and soil moving downslope, is another important geologic resource issue within Scotts Bluff National Monument. Mass wasting is a natural process that occurs as a result of water, ice, and/or wind acting on loosely consolidated strata, which then fails under the pull of gravity. Mass wasting can also be exacerbated by human activities such as road or trail building. Because Scotts Bluff NM is based around the strata of the bluff, mass wasting of these strata results in loss of an important park resource.

Within Scotts Bluff NM, rockslides have had a large impact on park resources and visitor access to these resources, and consequently there are some quantitative data on the amount of debris produced by rockslides in Scotts Bluff NM over the past 40 years. In 1989 an environmental assessment was performed that looked at the stability of the cliffs along the Summit Road, and workers from the Federal Highways Administration used shotcrete (concrete molded by compressed air) to stabilize the area around the tunnels in 1991 (Graham 2009b). Similar projects on other slide-prone areas may be necessary in the future to help preserve park resources and keep roads and trails open and safe.

Measurements used to quantify the amount of debris have been inconsistent—some amounts are listed as a volume of rock debris, others are listed as the mass of rock debris, and others do not have an amount of rock debris listed. As a result, these data cannot be used to make quantitative assessments of the amount of rockslide debris production. If NPS were to use historical mass wasting events to guide management decisions in the future managers could consider the size and frequency of rockslides together.

Descriptions of rockslides that have occurred along the roads and trails of Scotts Bluff National Monument, along with accounts of park personnel in reports and regional news stories, show that significant rockslides have occurred over the past 40 years and have impacted both the Saddle Rock Trail and the Summit Road (e.g., Graham 2009b; NPS 2015; Meyers 2015; Table 4.6.1). These observations demonstrate that rockslides are a major issue of concern for Scotts Bluff NM.

Table 4.6.1. Documented rockslide events in Scotts Bluff NM (Data from Graham 2009b; Meyers 2015; NPS 2015, 2016.)

Year slide occurred	Area of slide	Additional information on slide
1974	Saddle Rock Trail	–
1976–1985	Summit Road	10 major rockslides over this time period
2000	Summit Road	3,000 tons of debris
October 2000	Saddle Rock Trail	–
May 2015	Saddle Rock Trail	1,000 cubic yards of debris
December 2015	Saddle Rock Trail	30,000 tons of debris

In 1974, a rockslide occurred in the vicinity of the Saddle Rock Trail, and between 1976 and 1985 ten major rockslides occurred along the Summit Road (Graham 2009b). In 1989, an environmental assessment of the Summit Road found that road construction had exposed a vertical cliff of a portion of the Arikaree Group, which made it more likely to slide (NPS 1989). In October of 2000 another major rockslide event occurred along the Saddle Rock Trail above the tunnel that resulted in the trail being closed for several months. After this event an environmental assessment was completed, and the NPS then blasted large amounts of unstable rock and debris in an attempt to keep the trail open (Graham 2009b).

A second rockslide in 2000 deposited approximately 3,000 tons of rock on the Summit Road (Graham 2009b). In May of 2015, a large rockslide occurred along a lower part of the Saddle Rock Trail, bringing an estimated 1,000 cubic yards of debris onto the trail (Meyers 2015). On December 15, 2015, a second major rockslide occurred along the Saddle Rock Trail. This rockslide brought down an estimated 30,000 tons of rock onto the trail (NPS 2015) undercut a portion of the upper trail. As a result, the Saddle Rock Trail is closed to visitors until the situation can be assessed (NPS 2015).

Significant rockslides have impacted roads and trails within Scotts Bluff National Monument numerous times over the past 42 years, and are likely to occur in the future.

To assign a condition to this indicator, we used weathering and erosion measurements at the summit of Scotts Bluff. As the single indicator, the condition of weathering/erosion was also the overall geological resource condition.

Measure of Weathering/Erosion: Amount of Weathering/Erosion (millimeters/year of Bedrock)

Weathering caused by the actions of water and ice is slowly breaking down the rock that forms the highest part of Scotts Bluff. This weathered material is then removed from that surface by erosion via wind and water. Until recently, geologists have not had a good way to measure background rates of weathering and erosion over short timespans such as years or decades because rates are often on the order of fractions of a millimeter per year (Burbank 2002). As a result, we often do not have a good understanding of how quickly exposed bedrock weathers and erodes on human timescales. Recent advances in the use of cosmogenic nuclides (nuclides created by the interaction of cosmic rays with materials on Earth's surface) for measuring weathering and erosion rates have helped our understanding of these rates, but these tests have not been done at Scotts Bluff NM (Granger and Riebe 2014). We can, however, get a general picture of weathering and erosion rates by comparing current position of geologic material to a historic reference point.

In 1933 a metal survey marker was emplaced in the rock at the top of Scotts Bluff. Over the past 83 years, erosion of weathered bedrock from around the marker has left the marker exposed. As a result, we can directly measure the amount of weathering and erosion that has occurred at the summit of Scotts Bluff over the past 83 years (Graham 2009b). This measurement can also provide a general estimate of the rate of weathering and erosion of the cliff-forming strata of the Arikaree Group where rockslides occur. Natural weathering and erosion most likely account for the change in position of the marker relative to the ground, although inquisitive visitors hiking around the area of the marker could have slightly affected these rates as well. We identified significant weathering and erosion as being the loss of more than 0.2 millimeters/year of bedrock, based on general background rates of the weathering and erosion of exposed bedrock in alpine and desert settings given by Burbank (2002) of 0.005–0.020 millimeters/year. We identified weathering and erosion rates consistent with natural conditions as being consistent with this background rate of 0.005–0.020 millimeters/year.

If weathering and erosion of the summit of Scotts Bluff was significantly outside the range of natural historic variation (> 0.2 millimeters/year) we assigned the condition *Warrants Significant Concern*. If weathering and erosion of the summit of Scotts Bluff was moderately outside the range of historical variation (0.02–0.2 millimeters/year), we assigned the condition *Warrants Moderate Concern*. We gave the highest level of condition, *Resource in Good Condition*, if weathering and erosion were consistent with expected natural conditions (0.005–0.02 millimeters/year) (Table 4.6.2).

Table 4.6.2. Geologic resource condition categories for amount of erosion.

Resource condition		Erosion rate
Warrants significant concern	🔴	Weathering and erosion of the summit of Scotts Bluff significantly outside range of natural variation (> 0.2 mm/yr)
Warrants moderate concern	🟡	Weathering and erosion of the summit of Scotts Bluff is moderately outside range of natural variation (0.02 – 0.2 mm/yr)
Resource in good condition	🟢	Weathering and erosion is consistent with expected natural conditions (0.005 – 0.02 mm/yr).

<u>Data Sources</u>

Much of the information summarized here was presented in a Geologic Resources Inventory Report prepared for the National Park Service (Graham 2009b). Other sources of information include scientific papers and books that we identify throughout this assessment. No fieldwork was performed for this summary.

Although some quantitative data were available on weathering and erosion at Scotts Bluff National Monument, they were not of sufficient quality and consistency to be used to assess both measures of the indicator. Instead, we referred to quantitative data on the amount of weathering and erosion of the summit of Scotts Bluff as well as qualitative information on the occurrences and sizes of rockslides from park reports and popular accounts to assess indicator quality.

Quantifying Geologic Condition, Confidence, and Trend

Indicator Condition

To quantify geologic condition and trend, we used quantitative data and scientific literature. For measurements beyond the scope of NPS guidelines, we created condition categories based on expert opinion and the scientific literature. We used a point system to assign each indicator to a category. This point system is based on the NPS methods that were developed to calculate overall air quality condition (NPS-ARD 2015), a methodical and rigorous assessment approach that can be applied to other resources as well. In this approach, we assigned zero points to the condition *Warrants Significant Concern*, 50 points to *Warrants Moderate Concern*, and 100 points to *Resource in Good Condition*. The average of all measures determined the condition category of the indicator; scores from 0–33 fell in the *Warrants Significant Concern* category, scores from 34–66 were in the *Warrants Moderate Concern* category, and scores from 67–100 indicated *Resource in Good Condition.*

Indicator Trend

Potential trend categories were *Improving, Unchanging*, or *Deteriorating*. Because of the long timescales of many geologic processes as well as the complex interactions between geology and other natural processes such as precipitation, it is often difficult or impossible to see true trends in the condition of a geologic resource. To calculate a trend estimate for indicators, we sought quantitative or qualitative data that were collected at least sporadically for as long as the park unit has formally existed; in the case of Scotts Bluff NM this time period is 87 years (Graham 2009b). If there were no data available that met these monitoring requirements for a particular indicator, we indicated that trend was *Not Available* for that indicator.

Indicator Confidence

Confidence ratings were based on availability and type of data collected about the indicator. We gave a rating of *High* confidence when quantitative data were collected on site or nearby under similar conditions or in similar strata, quantitative data were collected recently, and quantitative data were collected methodically. We assigned a *Medium* confidence rating when quantitative data were not collected nearby, quantitative data were not collected recently, quantitative data collection was not repeatable or methodical, or data were qualitative only. *Low* confidence ratings were assigned when there were few good data sources to support the condition.

Overall Geologic Condition, Confidence, and Trend

We used the general approach for combining indicator conditions, trends, and confidence described in Chapter 3 (Methods 3.2.2) to calculate overall resource condition, trend, and confidence (Table 4.6.3).

Table 4.6.3. Summary of geologic resource indictors and measures.

Indicator	Measure	Condition	Confidence	Trend	Condition rational
Weathering/ erosion	Amount of weathering and erosion on Scotts Bluff	Warrants significant concern	Medium	Not available	Weathering and erosion of the rocks exposed at the summit of Scotts Bluff is very high. This assessment places weathering and erosion in the *Warrants Significant Concern* category. Rockslides have caused significant issues with and closures of the Summit Road and the Saddle Rock Trail in the past, and continue to do so currently. These assessments place rockslides in the *Warrants Significant Concern* category.

4.6.4. Geologic Conditions, Confidence, and Trends

Quantitative measurements of weathering and erosion were our primary data for assigning a condition to geological resources at Scotts Bluff National Monument. We drew from formal reports to assess the condition of the resource.

<u>Weathering/Erosion</u>

🔴

Condition: Warrants Significant Concern
Confidence: Medium
Trend: Not Available

Condition

Because of the type of rock that crops out at Scotts Bluff National Monument, weathering and erosion are major factors in the condition of geologic resource. We used one measure of weathering/erosion to assess its condition: the amount of weathering and erosion occurring at the summit of Scotts Bluff.

In 1933, surveyors placed a metal survey post into the solid rock at the summit of Scotts Bluff, flush with the surface. Today, 83 years later, approximately 300 millimeters of this post has become exposed due to weathering and erosion. This demonstrates a rate of weathering and erosion of approximately 0.36 millimeters/year. Based on our classification of significant weathering and erosion as a loss of more than 0.2 millimeters/year, we assigned a condition of *Warrants Significant Concern* for the measure of the amount of weathering/erosion of the top of Scotts Bluff and awarded 0 points to the measure. The condition of the indicator, weathering/erosion, was also *Warrants Significant Concern.*

Confidence

There were quantitative data available on the rate of weathering and erosion of the summit of Scotts Bluff, but the reference conditions were not site-specific; these rates were general weathering and erosion rates for exposed bedrock in alpine and desert environments. We therefore gave this measure a confidence rating of *Medium*. The overall confidence for the indicator of weathering and erosion is *Medium*.

Trend

Sufficient long-term data were not available for the amount of erosion and weathering of the top of Scotts Bluff to assess any trends in these measures. As a result, trend was *Not Available* for the indicator.

Geologic Resource Overall Condition

Condition

The overall geologic resources condition was determined by the condition of the single indicator, weathering/erosion (Table 4.6.4). Weathering/erosion was given a condition of *Warrants Significant Concern*, which placed the overall geologic resource condition for Scotts Bluff NM in the category *Warrants Significant Concern.*

Confidence

Confidence was *Medium* for the single indicator of weathering/erosion, so overall confidence was *Medium* for geologic resources.

Trend

Trend data were *Not Available* for the single indicator of weathering/erosion, so overall trend for geologic resources was *Not Available*.

Table 4.6.4. Geological resources overall condition.

Indicators	Measures	Condition
Weathering and erosion	Amount of weathering and erosion	🔴
Overall condition for all indicators and measures		🔴

4.6.5. Stressors

We identified one potential stressor for geologic resources at Scotts Bluff National Monument: potential damage to resources caused by visitors who may wander off trails and unintentionally cause erosion.

4.6.6. Data Gaps

We recognize one data gap for geologic resources at Scotts Bluff NM: the method of measuring the amount of debris produced in rockslides. Future efforts could quantify the impact of rockslides through consistent measurement methodology, such as estimating cubic yards of debris.

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4.7. Paleontological Resources

4.7.1. Background and Importance

The principal mission of the National Park Service is the preservation, protection, and stewardship of natural and historic resources. Fossils and the natural geologic processes that form, preserve, and expose them are included in this mission (NPS 2016). Paleontological resources are non-renewable, and they hold the keys to understanding the complex history of life on Earth. They are known from 260 NPS units, and they are the main resource showcased in 13 of those parks (NPS 2016).

Paleontological resources are non-renewable, and they hold the keys to understanding the complex history of life on Earth. Paleontological resources are defined in the Paleontological Resources Preservation Act (2009) as “any fossilized remains, traces, or imprints of organisms, preserved in or on the earth’s crust, that are of paleontological interest and that provide information about the history of life on Earth …” excluding archaeological and cultural resources. The distribution of paleontological resources is directly related to the distribution of sedimentary geologic units exposed on the ground surface, and this relationship allows prediction of fossil potential on a landscape-wide scale.

In the northern Great Plains area, most of the fossiliferous bedrock deposits represent two general time periods and environments: the Late Cretaceous Western Interior Seaway, with remains of invertebrates such as ammonites and vertebrates such as bony fish, sharks, and marine reptiles; and the Tertiary terrestrial deposits of Oligocene and Miocene age that record the spread of grasslands across the region and the rise of large grazing mammals.

<u>Regional Context</u>

Surface and subsurface strata of the Great Plains physiographic province represent many different paleo-environments spanning millions of years. While older rocks are present in the subsurface, the oldest rocks exposed within Scotts Bluff National Monument are those of the Orella Member of the Brule Formation, a subdivision of the widespread White River Group of late Eocene–early Oligocene age (~36–30 million years ago) (Evanoff 2014).

The strata of the White River Group stretch for hundreds of miles across the region, with thicknesses ranging from a few meters to over 275 meters (~900 feet) (Larson and Evanoff 1998). They are mainly composed of wind-deposited and reworked volcanoclastics (volcanically-derived sediment such as ash) and are the remnants of a blanketing deposit that covered the region from at least the eastern side of the Wind River Range in central Wyoming to western Nebraska and South Dakota (Prothero and Emry 2004).

These White River strata of the northern Great Plains are an important sequence of rocks, in that they hold the best-preserved record of a climactic transition in the terrestrial rock record (Prothero 1994). This transition, termed the Eocene–Oligocene climate transition (EOT), records gradual changes from generally warmer and wetter to cooler and drier conditions. During this time the change in environmental conditions reduced forest cover and correspondingly increased open grasslands, as reflected in fossil soils (Prothero 1994).

Because differential erosion across the region has removed some parts of the White River Group strata and left others in place, outcrops across the area preserve different segments of the EOT (Prothero and Emry 2004). The section of the White River Group in Scotts Bluff National Monument does not preserve the Eocene–Oligocene boundary itself, instead recording the aftermath of the transition during the Oligocene (Benton et al. 2015). The fossil record for this time supports this gradual ecosystem transition, with the appearance of several rodents and artiodactyls (even-toed ungulates) with high-crowned teeth that were well suited for the tough vegetation of the new grasslands, and the loss of the brontotheres (an extinct order of large mammals in the same order as horses and rhinos) with their low-crowned teeth (Prothero 1994).

Although Scotts Bluff National Monument was not established specifically to protect fossil resources, many vertebrate fossils are known and have been collected from the monument (Graham 2009). Most fossils have been collected from the Orella Member of the Brule Formation, White River Group, which is exposed in badlands within the Monument (Evanoff, 2014). Taxa from this rock unit include numerous tortoises, oreodonts and other artiodactyls, nimravids, canids, and lagomorphs (Foss and Naylor 2002; Wang 1994; Korth 1988).

The youngest strata that crop out in Scotts Bluff National Monument are the beds of the lower Gering Formation and the overlying undifferentiated Monroe Creek-Harrison formations of the Arikaree Group, which overlies White River Group strata (Evanoff 2014). The Arikaree Group here is late Oligocene to Miocene in age (~28.5–26 million years ago; Tedford et al. 2004). Vertebrate fossils are rare in the Arikaree Group in Scotts Bluff NM, but artiodactyls and beavers are known from the Monroe Creek Formation within the Monument, and large artiodactyl tracks have been found in the Gering Formation (Swinehart and Loope 1987; Loope 1986). Common fossils in these beds elsewhere include oreodonts, camels, rodents, and early canids, all well adapted to arid grassland life (Prothero 1994).

4.7.2. Standards for Paleontological Resources

Paleontological resources on federal lands are protected under several laws and rulings, including the National Environmental Policy Act of 1969 (P.L. 91– 190, 31 Stat. 852, 42 U.S.C. 4321–4327); the

Federal Land Policy and Management Act of 1976 (P.L. 94–579, 90 Stat. 2743, 43 U.S.C. 1701-1782); and most recently the Omnibus Public Land Management Act of 2009 (PL 111–11, Title IV, Subtitle D—Paleontological Resources Protection). These Federal guidelines were put in place to protect fossil resources from destruction by various types of human activities, including theft and ground-disturbance during construction.

4.7.3. Methods

Indicators and Measures

Overall paleontological resource condition at Scotts Bluff National Monument depends on the condition of a single indicator, fossil loss.

Indicator: Fossil Loss

As non-renewable resources, the loss of fossils from National Park Service units is a very important resource issue. Fossils can be lost through natural processes as well as from human impacts. Weathering, defined as the breaking down of minerals within a rock (or a fossil) by chemical and/or mechanical means, and erosion—the movement of weathered material away from its place of origin—are natural processes that can negatively impact fossil resources (Press and Siever 2001; Benton et al. 2015). Poaching of fossils from park units by people also results in the loss of fossil resources.

To assign a condition to this indicator, we used qualitative information about fossil loss, including weathering and erosion of rock and its contained fossils, as well the amount of poaching of fossils that has been documented within the park.

Measure of Fossil Loss: Weathering and Erosion that Impacts Fossils (millimeters/year)

The amount of weathering and erosion that impacts the condition of paleontological resources in Scotts Bluff National Monument is a direct result of nature of the strata that contain the fossils. Strata that crop out within the Monument include two rock units: the Orella member of the Brule Formation, White River Group (Oligocene), which forms the slopes of Scotts Bluff itself as well the badlands topography around the Bluff, and the upper cliff-forming Oligocene-Miocene Arikaree Group. Both of these rock units consist of several different sedimentary rock types including mudstone, siltstone, and sandstone, and both have large components of volcanic ash including reworked and primary ash deposits (Evanoff 2014). The vast majority of the vertebrate fossils known from within Scotts Bluff NM are found in the badlands of the Brule Formation (Benton 2015).

Until recently, geologists have not had a good way to measure background rates of weathering and erosion over short timespans such as years or decades because rates are often on the order of fractions of a millimeter per year (Burbank 2002). As a result, we often do not have a good understanding of how quickly exposed bedrock weathers and erodes on human timescales. Recent advances in the use of cosmogenic nuclides (nuclides created by the interaction of cosmic rays with materials on Earth's surface) for measuring weathering and erosion rates have helped our understanding of these rates, but these tests have not been done at Scotts Bluff NM (Granger and Riebe 2014).

In Badlands National Park, recent work has focused on erosion rates that specifically impact fossil resources. Between 2011 and 2013, measurements of weathering and erosion of fossil-bearing strata were collected using a combination of direct measurements of the amount of material removed, digital imaging, and measurements of the amount of rainfall received on the strata. These measurements allow assessments of the actual amount of impact that weathering and erosion are having on fossil-bearing strata. These strata – the Scenic Member of the Brule Formation of the White River Group at Badlands NP – are lithologically similar enough to the fossil-bearing Orella Member of the Brule Formation at Scotts Bluff NM for this data to be used here.

If weathering and erosion has been occurring at a rate that negatively impacts fossil resources, we assigned the condition *Warrants Significant Concern*. If weathering and erosion was moderate, and fossil resources were only moderately impacted, we assigned the condition *Warrants Moderate Concern*. If there was no weathering or erosion OR any weathering and erosion was at a low level, we assigned the highest level of condition, *Resource in Good Condition* (Table 4.7.1).

Table 4.7.1. Paleontological resources condition categories for amount of erosion.

Resource condition		Impact of weathering/erosion
Warrants significant concern	🔴	Weathering and erosion is occurring at a rate that negatively impacts fossil resources
Warrants moderate concern	🟡	Weathering and erosion is moderate and somewhat impacts fossil resources
Resource in good condition	🟢	No weathering or erosion has occurred OR any weathering and erosion is at a low level

Measure of Fossil Loss: Occurrence of Fossil Poaching and Vandalism

Poaching and vandalism of fossils from Federal lands is an important cause of the loss of paleontological resources. Fossils are objects of interest and are unique and often coveted. The increasing economic value of fossils, spurred by the sale of a *Tyrannosaurus rex* fossil for more than $8 million in 1997, puts paleontological resources on public lands at risk for permanent loss (Eveleth 2013; Beat and Hanna 2009).

Fossil poaching can take many forms. For example, the casual park visitor may pick up a piece of fossilized bone during a hike along a park trail, believing that taking one fossil will not cause a problem. Multiplied by a million visitors per year, however, this activity can have a major impact on the resource. Poaching is also done by hobby collectors unaware of the legalities, as well as commercial collectors who specifically target areas within park units that are known to be fossil-rich and rarely patrolled (Benton et al. 2015).

In addition to the direct loss of fossils, fossil poaching also results in the loss of important contextual data. Even if a poached fossil is recovered, the geologic, taphonomic (what happens between the death of an organism and its discovery as a fossil), and paleoecological data that had been associated with the fossil before it was illegally removed can never be recovered (Beat and Hanna 2009).

The Paleontological Resources Preservation Act (2009) provides the National Park Service with mandates for protection of Federal fossil resources, and it clarifies the criminal penalties for fossil poaching (Benton et al 2015). Even with strengthened laws, however, fossil poaching and vandalism are still major issues for paleontological resources. From 2004 to 2014 nearly 900 individual law enforcement reports of fossil vandalism or poaching were documented in National Park System units (Santucci 2014).

One difficulty in prosecuting fossil poachers is the fact that unless they are "caught in the act," it is difficult if not impossible to prove that a fossil has been poached. Recent work utilizing rare Earth element signatures in fossils, however, is showing promise as a method to demonstrate the provenance of fossils. This information can then potentially be used to prove the origin of a poached fossil (Cerruti et al. 2014). Because fossils and their contextual data are non-renewable resources, any amount of poaching impacts the resource in a negative way. We therefore classified significant fossil poaching as any formal or informal reports of poaching.

If fossil poaching occurrences were known, we assigned the condition *Warrants Significant Concern*. Because there is no amount of fossil poaching that is acceptable, we did not include a condition of *Warrants Moderate Concern* in our assessment. We gave the highest level of condition, *Resource in Good Condition*, if there was no fossil poaching known (Table 4.7.2).

Table 4.7.2. Paleontological resources condition categories for fossil poaching occurrences.

Resource condition		Fossil poaching status
Warrants significant concern	🔴	Fossil poaching occurrences are known
Warrants moderate concern	🟡	–
Resource in good condition	🟢	No fossil poaching occurrences are known

Data Sources

Some of the information summarized here was presented in a Geologic Resources Inventory Report prepared for the National Park Service (Graham 2009). Other sources of information include scientific papers and books that we identify throughout this assessment. Especially useful was a recently published book on the White River Badlands geology and paleontology (Benton et al. 2015).

Quantifying Paleontological Resource Condition, Confidence, and Trend

Indicator Condition

To quantify paleontological resource condition and trend, we used quantitative and qualitative data, expert opinion, and reports of prior impacts to the resource, as described above. For measurements beyond the scope of NPS guidelines, we created condition categories based on expert opinion and the scientific literature. We used a point system to assign each indicator to a category. This point system is based on the NPS methods that were developed to calculate overall air quality condition (NPS-ARD 2015), a methodical and rigorous assessment approach that can be applied to other resources as well. In this approach, we assigned zero points to the condition *Warrants Significant Concern*, 50 points to *Warrants Moderate Concern*, and 100 points to *Resource in Good Condition.* The average of all measures determined the condition category of the indicator; scores from 0–33 fell in the *Warrants Significant Concern* category, scores from 34–66 were in the *Warrants Moderate Concern* category, and scores from 67–100 indicated *Resource in Good Condition*.

Indicator Trend

Potential trend categories were *Improving, Unchanging,* or *Deteriorating*. Because of the long timescales that are involved in many geologic processes as well as the complex interactions between geology and other natural processes such as precipitation, it is often difficult or impossible to see true trends in the condition of a geologic resource. To calculate a trend estimate for indicators, we sought quantitative or qualitative data that were collected at least sporadically for as long as the park unit has formally existed; in the case of Scotts Bluff NM this time period is 87 years (Graham 2009b). If there were no data available that met these monitoring requirements for a particular indicator, we indicated that trend was *Not Available* for that indicator.

Indicator Confidence

Confidence ratings were based on availability and type of data collected about the indicator. We gave a rating of *High* confidence when quantitative data were collected on site or nearby under similar conditions or in similar strata, quantitative data were collected recently, and quantitative data were collected methodically. We assigned a *Medium* confidence rating when quantitative data were not collected nearby, quantitative data were not collected recently, quantitative data collection was not repeatable or methodical, or data were qualitative only. *Low* confidence ratings were assigned when there were no good data sources to support the condition.

Overall Paleontological Resource Condition, Confidence, and Trend

We used the general approach for combining indicator conditions, trends, and confidence described in Chapter 3 (Methods 3.2.2) to calculate overall resource condition, trend, and confidence (Table 4.7.3).

Table 4.7.3. Summary of paleontological resource indicators and measures.

Indicator	Measure	Condition	Confidence	Trend	Condition rational
Fossil loss	Amount of weathering and erosion	Not available	Low	Not available	Measured rates of weathering and erosion in Badlands NP are high and can expose fossils from bedrock and cause serious damage in a relatively short amount of time. No similar data exists for Scotts Bluff NM, so the condition for weathering and erosion that can impact fossil resources is *Not Available*.
	Fossil poaching and vandalism	Warrants significant concern	High	Not available	Reports of fossil poaching and vandalism in Scotts Bluff have occurred and are somewhat common. This assessment places fossil poaching and vandalism in the *Warrants Significant Concern* category

4.7.4. Paleontological Resource Conditions, Confidence, and Trends

<u>Fossil Loss</u>

🔴

Condition: Warrants Significant Concern
Confidence: Medium
Trend: Not Available

Condition

Because fossils are non-renewable resources, any factors that impact them is important to the assessment of the resource condition. We used two measures of fossil loss to assess its condition: 1) the amount of erosion occurring to the fossil-bearing strata and thus potentially impacting fossils, and 2) the occurrence of fossil poaching and vandalism within the park unit.

In Badlands NP, six sites within the Scenic Member of the Brule Formation were monitored for rates of weathering and erosion of fossil-bearing strata from 2010 to 2013. These data, collected over 18 months, give an average erosion rate of 9.7 millimeters/year. North-facing slopes had higher rates, with an average of 11.9 millimeters/year, while south-facing slopes had erosion rates of 7.9 millimeters/year (Stetler 2014). In addition, this study looked specifically at the rates that fossil bone degrades once it becomes exposed to the elements and found that, in some instances, fossils were completely destroyed within a single season (Stetler 2014).

Although we can use these estimates for the amount of weathering and erosion that has historically impacted the fossil-bearing strata at Scotts Bluff NM, no studies of weathering and erosion have been done in these rocks. Estimates have been made of erosion rates between 6-25 millimeters/year in these badlands, and these rates are high enough to impact fossil resources based on the study as Badlands NP (R. Manasek, personal communication, 30 June 2016).

However, as we had no quantitative data determine whether weathering and erosion are occurring at a rate that would result in damage to fossil resources, condition for the amount of weathering and erosion was *Not Available*.

Fossil poaching and vandalism occurrence was the second measure used to assess the condition of fossil loss. Paleontological inventories of National Grasslands in Nebraska and South Dakota have shown that more than a quarter of almost 300 fossil localities in those areas showed signs of poaching (Miller, 2003). At Scotts Bluff National Monument, fossil poaching incidents are somewhat common, and are estimated to occur at a rate of two reported incidents per year (R. Manasek, personal communication, 30 June 2016). A 2002 paleontological survey of the badlands of Scotts Buff NM discovered evidence of illegal fossil collecting, and park staff have caught poachers in the act of illegal collection (Foss and Naylor 2002; Graham 2009). In its recent Fossil Management Plan, Scotts Bluff NM includes plans for the monument's law enforcement ranger to patrol the badlands frequently in order to deter fossil poaching (R. Manasek, personal communication, 30 June 2016).

Even with the measures that are being taken to stop or mitigate fossil poaching and vandalism within Scotts Bluff NM, reports of fossil poaching still occur. Based on our classification of significant fossil poaching or vandalism as any formal or informal reports of poaching or vandalism, we assigned a condition of *Warrants Significant Concern* for the measure of fossil poaching and vandalism occurrences and awarded the measure 0 points. The average of both measures determined the condition category of the indicator.

Confidence

There were no quantitative data available on the rates of weathering and erosion of the fossil-bearing strata at Scotts Bluff NM, and therefore we gave this measure a confidence rating of *Low*. There was quantitative data available on fossil poaching and vandalism occurrences. We were able to evaluate the impact of fossil poaching and vandalism on paleontological resources using this data, thus achieving a *High* confidence in this measure. The overall confidence for the indicator of fossil loss was *Medium*.

Trend

Trend was *Not Available* for either measure, so trend was *Not Available* for the indicator off fossil loss.

Paleontological Resource Overall Condition

Condition

The overall paleontological resources condition was determined by the condition of the single indicator, fossil loss (Table 4.7.4). Fossil loss was given a condition of *Warrants Significant Concern*, which placed the overall paleontological resource condition for Scotts Bluff NM in the category *Warrants Significant Concern.*

Confidence

Confidence was *Medium* for the single indicator of fossil loss, so overall confidence was *Medium* for paleontological resources.

Trend

Trend data were *Not Available* for the single indicator of fossil loss, so overall trend for paleontological resources was *Not Available*.

Table 4.7.4. Paleontological resources overall condition.

Indicators	Measures	Condition
Fossil loss	• Amount of weathering and erosion • Fossil poaching and vandalism	🔴
Overall condition for all indicators and measures		🔴

4.7.5. Stressors

We identified two potential stressors to paleontological resources at Scotts Bluff NM: the timing and amount of precipitation events, and the lack of a permanent paleontologist. As demonstrated by the 2014 study that looked at the effects of weathering and erosion on fossil-bearing strata, single heavy precipitation events can have a large impact on short-term weathering and erosion (Stetler 2014). It has been predicted that climate change may result in an increase in the numbers of these extreme precipitation events for Badlands NP, and this assessment can likely be extended to Scotts Bluff NM. An increase in these extreme precipitation events would in turn increase the impact of weathering and erosion on fossil resources (Amberg et al. 2012). Because fossils are an important resource at Scotts Bluff NM, it would greatly benefit the park to have a professional paleontologist on-site. While current resource management staff members are caring for the resource to a great extent, there are challenges that would be best met by a trained paleontologist.

4.7.6. Data Gaps

We identified one data gap for paleontological resources. The lack of data on rates of weathering and erosion of the fossil-bearing strata at Scotts Bluff NM is a major gap, as this information would allow better assessment of the vulnerability of fossils to degradation due to weathering and erosion. A study similar to one that was started at Badlands NP in 2010 (Stetler et al. 2014) that looked at the rates of weathering and erosion on fossil-bearing strata would yield very useful data on this topic.

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4.8. Vegetation

The majority of the text in this chapter was written by Isabel W. Ashton and Christopher J. Davis for the 2011-2015 Summary Report, Plant Community Composition and Structure Monitoring for Scotts Bluff National Monument. The authors of the Scotts Bluff NM NRCA have reorganized several subsections of the Ashton and Davis (2016) report to follow the structure used for the other natural resource sections in this assessment. For this section, the Vegetation condition assessment, the term "we" refers to Ashton, Davis, and their team. Text included by the NRCA authors is denoted by italicized text.

Saw-sepal penstamon (*Penstamon glaber*) at Scotts Bluff NM. Photo by NPS/GANT.

4.8.1. Background and Importance

During the last century, much of the prairie within the Northern Great Plains has been plowed for cropland, planted with non-natives to maximize livestock production, or otherwise developed, making it one of the most threatened ecosystems in the United States. Within Nebraska, greater than 77% of the area of native mixed grass prairie has been lost since European settlement (Samson and

Knopf 1994). The National Park Service (NPS) plays an important role in preserving and restoring some of the last pieces of intact prairies within its boundaries. The stewardship goal of the NPS is to "preserve ecological integrity and cultural and historical authenticity" (NPS 2012); however, resource managers struggle with the grim reality that there have been fundamental changes in the disturbance regimes, such as climate, fire, and grazing by large, native herbivores, that have historically maintained prairies and there is the continual pressure of exotic invasive species. Long-term monitoring in national parks is essential to sound management of prairie landscapes because it can provide information on environmental quality and condition, benchmarks of ecological integrity, and early warning of declines in ecosystem health.

Scotts Bluff National Monument (SCBL), established in 1919 to protect and preserve two iconic bluffs and the associated heritage of western expansion, covers 3,003 acres and is dominated by mixed-grass prairie with smaller areas of juniper woodlands, badlands, and riparian forests. Vegetation monitoring began at SCBL in 1997 by the Heartland Inventory & Monitoring Program (James 2010) and the Northern Great Plains Fire Ecology Program (NGPFire; Wienk et al. 2011). In 2010, SCBL was incorporated into the Northern Great Plains Inventory & Monitoring Network (NGPN). At that time, vegetation monitoring protocols and plot locations were shifted to better represent the entire park and to coordinate efforts with NGPFire (Symstad et al. 2012b). A total of 34 plots were established by NGPFire and NGPN in SCBL and the combined sampling efforts began in 2011 (Ashton et al. 2011). In 2014, an additional 20 plots were established in the riparian forest to assess forest condition. In this report, we use the data from 2011-2015 to assess the current condition of park vegetation and the data from 1998-2015 are used to look at longer-term trends.

Using 18 years of plant community monitoring data in SCBL, we explore the following questions:

1. What is the current status of plant community composition and structure of SCBL grasslands (species richness, exotic plant cover, and diversity) and how has this changed from 1998-2015?
2. How do trends in grassland condition correlate with climate and fire history?
3. Was the SCBL golf course restoration effective at creating a grassland community dominated by native species?
4. What is the composition and structure of the riparian corridor at SCBL?

4.8.2. Methods

Three different methods and protocols have been used to monitor long-term vegetation plots at SCBL since 1997: the NGPN monitoring protocol (Symstad et al. 2012b, a), the Fire Monitoring Handbook (NPS 2003), and the Heartland Vegetation Monitoring Protocol (James et al. 2009). Below we briefly describe all three methods, but focus on the NGPN monitoring protocol, which is the current standard and was used to collect most of the data in this report. For more detail on any of the methods, please see the protocol publications (cited above).

The NGPN and NGPFire implemented a survey to monitor plant community structure and composition in SCBL using a spatially balanced probability design (Generalized Random Tessellation Stratified [GRTS]; Stevens and Olsen 2003, 2004). Using a GRTS design, NGPN selected 20 randomly located sites within the upland grasslands of SCBL to become Plant Community Monitoring plots (PCM plots; Figure 4.8.1). The NGPN visits 8 PCM plots every year using a rotating sampling scheme where 4 sites were visited in the previous year and 4 sites are new visits. After 5 years (2011-2015), most of the PCM plots were visited at least twice during the last two weeks of May. When a PCM plot fell within an active burn unit, NGPFire added additional visits based on a 1, 2, 5, and 10 year sampling schedule. NGPFire also established and monitored a number of new sites focused in active burn units (Fire FPCM plots) using the same GRTS sampling schema. From 2011-2015, 14 FPCM plots were established. Finally, using the same set of random sites, NGPN selected 20 additional PCM plots that fell within the riparian forest along the North Platte River. These were monitored in 2014 to assess forest condition. A total of 34 plots were established by NGPFire and NGPN in 2011-2015.

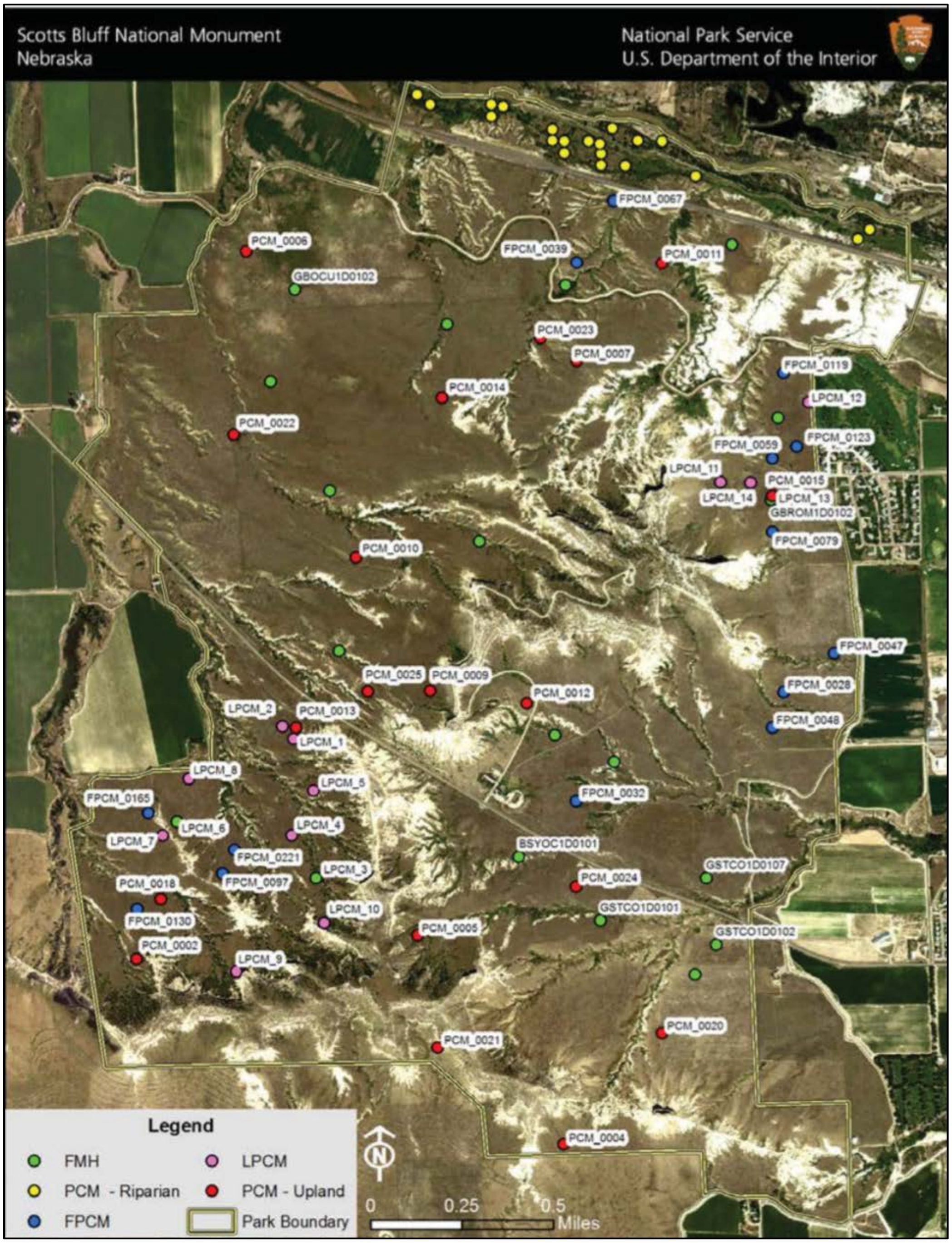

Figure 4.8.1. Map of Scotts Bluff National Monument (SCBL) plant community monitoring plots, 1997-2015. Twenty PCM plots (red) were established by the Northern Great Plains Inventory & Monitoring Program (NGPN) and 14 (blue) FPCM plots were established by the Fire Effects Program (NGPFire) between 2011 and 2015. Eleven LPCM plots were established by the Heartland Monitoring Network (pink) representing restored and native mixed-grass prairie. In 2014, 20 plots were established by the NGPN to monitor riparian forest condition (yellow). An additional 19 FMH plots (green) were monitored from 1997-2011 by NGPFire.

At each of the grassland sites we visited, we recorded plant species cover and frequency in a rectangular, 50 meter x 20 meter (0.1 hectare), permanent plot (Figure 4.8.2). Data on ground cover and herb-layer (≤ 2 meter) height and plant cover were collected on two 50 meter transects (the long sides of the plot) using a point-intercept method (Figure 4.8.3). At 100 locations along the transects (every 0.5 meter) a pole was dropped to the ground and all species that touched the pole were recorded, along with ground cover, and the height of the canopy (Figure 4.8.3). Using this method, absolute canopy cover can be greater than 100% (particularly in wet years and productive sites) because we record multiple layers of plants. Species richness data from the point-intercept method were supplemented in the 16 PCM plots with species presence data collected in five sets of nested square quadrats (0.01 meter^2, 0.1 meter^2, 1 meter^2, and 10 meter^2) located systematically along each transect (Figure 4.8.2).

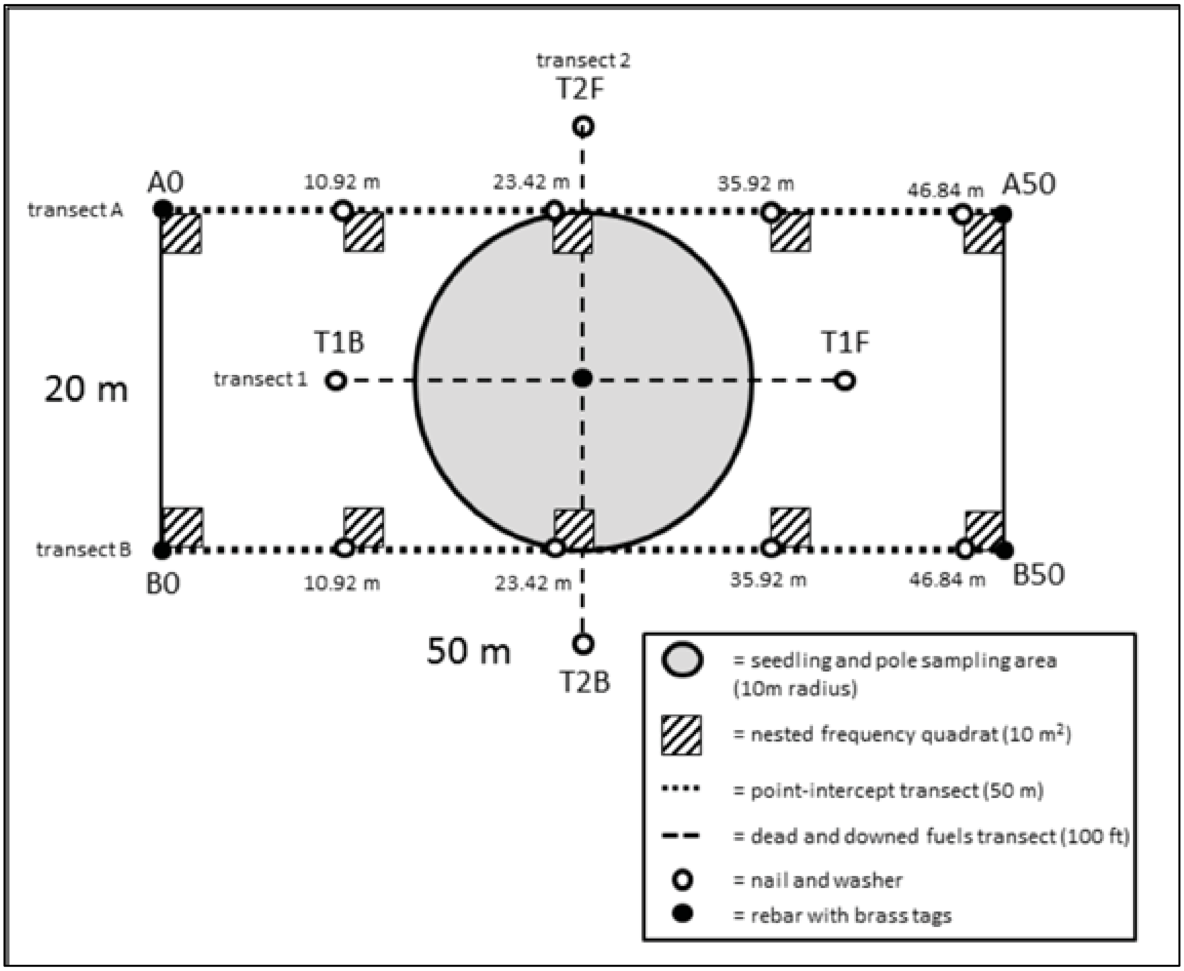

Figure 4.8.2. Long-term monitoring plot layout used for sampling vegetation in Agate Fossil Beds National Monument (Ashton and Davis 2016).

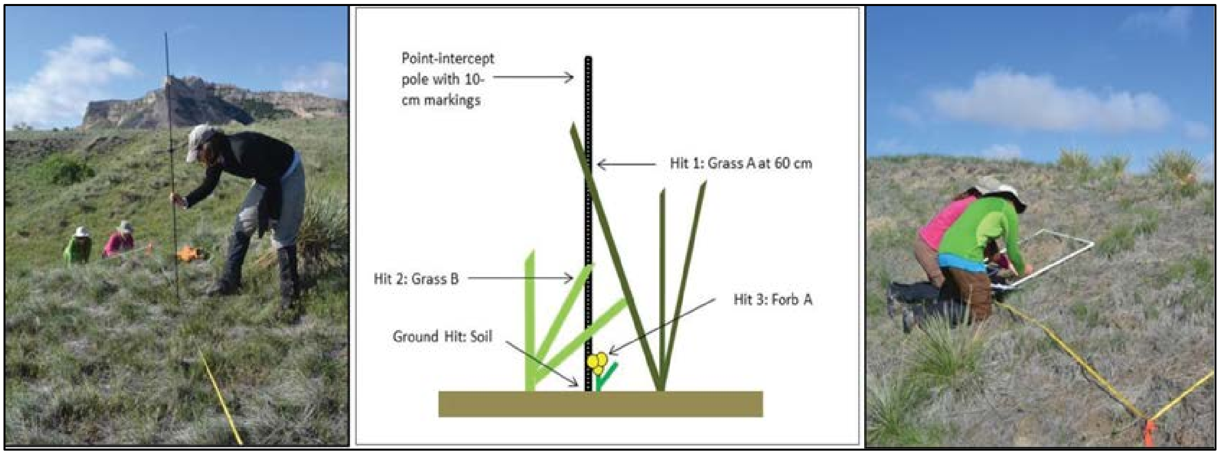

Figure 4.8.3. The Northern Great Plains Inventory & Monitoring vegetation crew used point-intercept (left and center panel) and quadrats (right panel) to document plant diversity and abundance.

When woody species were also present, tree regeneration and tall shrub density data were collected within a 10 meter radius subplot centered in the larger 50 meter x 20 meter plot (Figure 4.8.2). Trees with diameter at breast height (DBH) > 15 centimeter, located within the entire 0.1 hectare plot, were mapped and tagged. For each tree, the species, DBH, status, and condition (e.g., leaf-discoloration, insect-damaged, etc.) were recorded. This occurred at only 2 PCM plots in SCBL from 2011-2015.

NGPN completed a survey of riparian forests in SCBL in the last week of August 2014 using a set of 20 forested sites. In this case, seedlings and poles were measured as described above, but larger trees (DBH > 15 centimeter) were not tagged and only measured within the 10 meter radius subplot. Dead and downed woody fuel load data were collected at these forested plots on two perpendicular, 100 feet (30.49 meter) transects with midpoints at the center of the plot (Figure 4.8.2), following Brown's Line methods (Brown 1974, Brown et al. 1982). These data were not reported because grasses dominated the fuel layer.

At all PCM plots, but not the FPCM plots, we also surveyed the area for common disturbances and target species of interest to the park. Common disturbances included such things as prairie dog towns, rodent mounds, animal trails, and fire. For all plots, the type and severity of the disturbances were recorded. We also surveyed the area for exotic species that have the potential to spread into the park and cause significant ecological impacts (Table 4.8.1). These species were chosen in collaboration with the Midwest Invasive Plant Network, the Exotic Plant Management Team, park managers, and local weed experts. For each target species that was present at a site, an abundance class was given on a scale from 1-5 where 1 = one individual, 2 = few individuals, 3 = cover of 1-5%, 4 = cover of 5-25%, and 5 = cover > 25% of the plot. The information gathered from this procedure is critical for early detection and rapid response to such threats.

Table 4.8.1. Exotic species surveyed for at Scotts Bluff National Monument as part of the early detection and rapid response program within the Northern Great Plains Network.

Species name	Common name	Habitat
Alliaria petiolate	Garlic mustard	Riparian
Polygonum cuspidatum; P. sachalinense; P. x bohemicum	Knotweeds	Riparian
Pueraria montana var. lobate	Kudzu	Riparian
Iris pseudacorus	Yellow iris	Riparian
Ailanthus altissima	Tree of heaven	Riparian
Lepidium latifolium	Perennial pepperweed	Riparian
Arundo donax	Giant reed	Riparian
Rhamnus cathartica	Common buckthorn	Riparian
Heracleum mantegazzianum	Giant hogweed	Riparian
Centaurea solstitalis	Yellow star thistle	Upland
Hieracium aurantiacum; H. caespitosum	Orange and meadow hawkweed	Upland
Isatis tinctoria	Dyer’s woad	Upland
Taeniatherum caput-medusae	Medusahead	Upland
Chondrilla juncea	Rush skeletonweed	Upland
Gypsophila paniculata	Baby’s breath	Upland
Centaurea virgate; C. diffusa	Knapweeds	Upland
Linaria dalmatica; L. vulgaris	Toadflax	Upland
Euphorbia myrsinites; E. cyparissias	Myrtle spurge	Upland
Dipsacus fullonum; D. laciniatus	Common teasel	Upland
Salvia aethiopis	Mediterranean sage	Upland
Ventenata dubia	African wiregrass	Upland

Other Monitoring Plots (1997-2015)

In 1997, NGPFire began monitoring plots within SCBL to evaluate the effectiveness of prescribed burns. Starting in 1998, data collection followed the NPS National Fire Ecology Program protocols (NPS 2003): in grassland plots vegetation cover and height data were collected using a point-intercept method, with 100 points evenly distributed along a single 30 meter transect. In forested sites, plots are 0.1 hectare (20 x 50 meter) in size and point-intercept data were collected along the two 50 meter sides. For each live tree with a DBH > 15 centimeter located within the 0.1 hectare plot, the species and DBH were recorded. The densities of smaller trees (2.54 centimeter ≤ DBH ≤ 15 centimeter) were measured within a subset of the plot area. NGPFire plot locations were located randomly within major vegetation types within areas planned for prescribed burning (burn units) in the near future.

The plots were then sampled 1, 2, 5, and 10 years after a prescribed burn. The data were not collected using these protocols in 1997 and 2010, so these years were excluded from analyses. Hereafter, we refer to these plots as Fire Monitoring Handbook (FMH) plots. These FMH plots are being retired after the10 year visit (e.g. the rebar will be removed) and replaced with the FPCM plots described above.

The Heartland Inventory & Monitoring Program also established a number of plots in 1997. Plant frequency was measured using circular subplots as described in the Heartland Networks' vegetation monitoring protocol (James et al. 2009). The data and a summary of results from these plots are described in detail by James (2010). In 2009, 2013 and 2014, a subset of these plots (called Legacy Plant Community Monitoring Plots, LPCMs) was revisited by NGPN and point-intercept data was also collected using the methods described above. These plots were chosen to revisit because they were established to evaluate the effectiveness of a restoration project. In 1989, Scotts Bluff NM began a restoration project in a former golf course with a goal of restoring native prairie –these areas were planted with native grasses and forbs in 1997 (Huddle et al. 2001), two plots were established within the restored area (LPCM_13 and 14) and two plots were established nearby in native prairie (LPCM_11 and 12). In this report, we present the point-intercept from the 3 survey years, but do not report frequency.

Data Management and Analysis

We used FFI (FEAT/FIREMON Integrated; http://frames.gov/ffi/) as the primary software environment for managing our sampling data. FFI is used by a variety of agencies (e.g., NPS, USDA Forest Service, U.S. Fish and Wildlife Service), has a national-level support system, and generally conforms to the Natural Resource Database Template standards established by the Inventory and Monitoring Program. Species scientific names, codes, and common names are from the USDA Plants Database (USDA-NRCS 2015). However, nomenclature follows the Integrated Taxonomic Information System (ITIS) (http://www.itis.gov). In the few cases where ITIS recognizes a new name that was not in the USDA PLANTS database, the new name was used, and a unique plant code was assigned. This report uses common names after the first occurrence in the text, but scientific names can be found in Appendix A.

After data for the sites were entered, 100% of records were verified to the original data sheet to minimize transcription errors. A further 10% of records were reviewed a second time. After all data were entered and verified, automated queries were used to check for errors in the data. When errors were caught by the crew or the automated queries, changes were made to the original datasheets and/or the FFI database as needed. Summaries were produced using the FFI reporting and query tools and statistical summaries, and graphics were generated using R software (version 3.2.2).

Plant life forms (e.g., shrub, forb) were based on definitions from the USDA Plants Database (USDA-NRCS 2015). The conservation status ranks of plant species in Nebraska is determined by the Nebraska Natural Heritage Program (NENHP). For the purpose of this report, a species was considered rare if its conservation status rank was S1, S2, or S3. See Table 4.8.2 for a detailed definition of each conservation status rank. Plant life forms (e.g., shrub, forb) were based on definitions from the USDA Plants Database (USDA-NRCS 2015). The conservation status ranks of plant species in Nebraska is determined by the Nebraska Natural Heritage Program (NENHP). For the purpose of this report, a species was considered rare if its conservation status rank was S1, S2, or S3. See Table 4.8.2 for a detailed definition of each conservation status rank.

Table 4.8.2. Definitions of state and global species conservation status ranks. Adapted from NatureServe status assessment table (http://www.natureserve.org/conservation-tools/conservation-status-assessment).

Status rank	Category	Definition
S1/G1	Critically imperiled	Due to extreme rarity (5 or fewer occurrences) or other factor(s) making it especially vulnerable to extirpation
S2/G2	Imperiled	Due to rarity resulting from a very restricted range, very few populations (often 20 or fewer), steep declines, or other factors making it very vulnerable to extirpation
S3/G3	Vulnerable	Due to a restricted range, relatively few populations (often 80 or fewer), recent widespread declines, or other factors making it vulnerable to extirpation
S4/G4	Apparently secure	Uncommon but not rare; some cause for concern due to declines or other factors
S5/G5	Secure	Common, widespread and abundant
S#S#	Range rank	Used to indicate uncertainty about the status of the species or community
G#G#	(e.g. S2S3)	Ranges cannot skip for more than one rank

* S = state ranks, G = global ranks.

We measured diversity at the plots in two ways: species richness and Pielou's Index of Evenness. Species richness is simply a count of the species recorded in an area. Peilou's Index of Evenness, J', measures how even abundances are across taxa and ranges between zero and one; values near zero indicate dominance by a single species and values near one indicate nearly equal abundance of all species present. Plant richness was calculated for each plot using the total number of species intersected along the transects. Average height was calculated as the average height per plot using all species intersected on the transects. Climate data from the Scottsbluff, Nebraska W.B. Heilig Field Airport weather station (GHCND:USW00024028) were downloaded from NOAA's online database (NOAA 2015). Fire history maps were compiled for the park and cross-referenced with plot locations. For each time data were collected at a plot (i.e., plot visit), we determined the number of years since the plot had burned and the number of fires recorded for that plot. For plots where no burns were recorded, we calculated the difference between the year of data collection and the oldest fire recorded in the park. This is likely an underestimate of the true time since it burned because fires were infrequent prior to the 1980s.

Reporting on Natural Resource Condition

Results were summarized in a Natural Resource Condition Table based on the templates from the State of the Park report series (http://www1.nrintra.nps.gov/im/stateoftheparks/index.cfm). The goal is to improve park priority setting and to synthesize and communicate complex park condition information to the public in a clear and simple way. By focusing on specific indicators, such as exotic species cover, it will also be possible and straightforward to revisit the metric in subsequent years.

We chose a set of indicators and specific measures that can describe the condition of vegetation in the Northern Great Plains and the status of exotic plant invasions. The measures include: absolute herb-layer canopy cover, native species richness, evenness, relative cover of exotic species, and annual brome cover. Reference values were based on descriptions of historic condition and variation, past studies, and/or management targets. Current park condition was compared to a reference value, and status was scored as *Good Condition, Warrants Moderate Concern*, or *Warrants Significant Concern* based on this comparison. *Good condition* was applied to values that fell within the range of the reference value, and *Significant Concern* was applied to conditions that fell outside the bounds of the reference value. In some cases, reference conditions can be determined only after we have accumulated more years of data. When this is the case, we refer to these as "To be determined", or TBD, and estimate condition based on our professional judgment.

Indicators and Measures

Indicators and measures of Vegetation condition Scotts Bluff NM. Summaries of indicators came directly from Ashton and Davis (2016) unless italicized; text in italics was added by NRCA authors.

Indicator: Upland Plant Community Structure and Composition

The vegetation structure and composition of the Northern Great Plains have changed since Scotts Bluff NM was first established. Much of the prairie has been converted to agriculture or developed for residential and industrial use. Many of the natural processes that helped shape the landscape, such as grazing by bison, are now gone (Ricketts et al. 1999). Understanding the composition and structure of upland species within park will help with efforts to protect the remnants of native prairie that are present.

Measure of Upland Plant Community Structure and Composition: Native Species Richness

Species richness is simply a count of the species recorded in an area. Plant richness was calculated for each plot using the total number of species intersected along the transects.

Measure of Upland Plant Community Structure and Composition: Native Evenness

Peilou's Index of Evenness, J', measures how even abundances are across taxa. It ranges between 0 and 1; values near 0 indicate dominance by a single species and values near 1 indicate nearly equal abundance of all species present.

Evenness is a diversity index that describes the similarity in number of members that belong to different groups in a community (Figure 4.8.4). Values for evenness may fall between 0 and 1. If all groups have a similar number of members, the community is very even, with an evenness value close to 1. Communities that have high evenness can remain more functional in environmentally stressful conditions than uneven communities (Wittebolle et al. 2009).

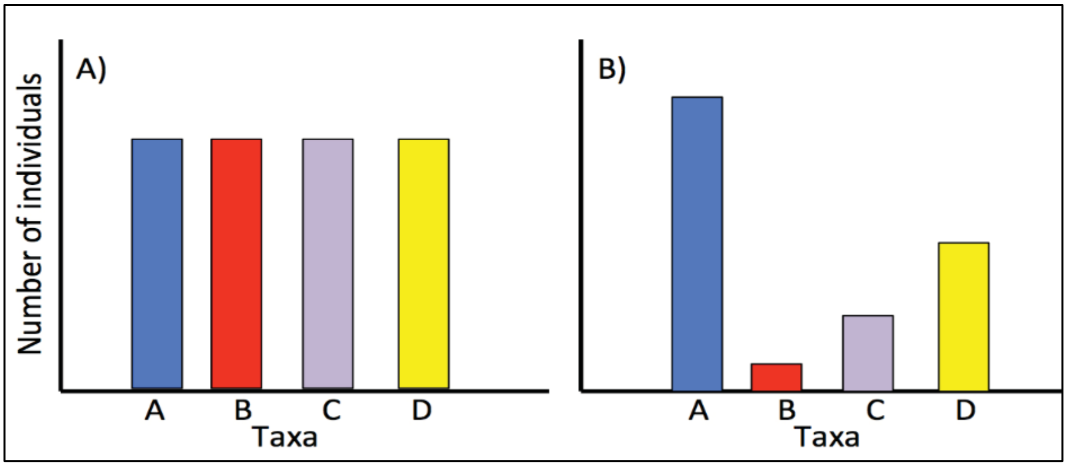

Figure 4.8.4. Illustration for describing evenness. Taxa evenness is high if individuals are A) distributed similarly among taxa, and low if B) distributed unequally among taxa.

Indicator: Exotic Plant Early Detection and Management

A major threat to native plant communities is the spread of exotic (non-native) plants (McKinney and Lockwood 1999). Environmental conditions can affect how well natives compete with invasive species (Nernberg and Dale 1997), as can the local and regional abundance of particular invasive species (Carboni et al. 2016). Additionally, the characteristics of the existing native plant community can determine how likely it is to be invaded (Thuiller et al. 2010). Identifying and managing the exotic species that are present at Scotts Bluff NM is important for protecting the native prairie within in the park.

Measure of Exotic Plant Early Detection and Management: Relative Cover of Exotic Species

Relative cover of exotic species is the proportion or percentage of a surveyed area that is made up of exotic species. Calculating the absolute cover of a plant species (all of the area covered by a species) is both impractical and unnecessary, but researchers can calculate the proportion of the park that is covered by a species by sampling plots and transects that area representative of the ecosystems within the park.

Measure of Exotic Plant Early Detection and Management: Annual Brome Cover

There is evidence from other regions that annual bromes can affect persistence of native species (D’Antonio and Vitousek 2003). In the Northern Great Plains Parks, there is a negative correlation between the cover of annual bromes and native species richness (Figure 4.8.10) (F1, 551 = 36.5, P < 0.0001).

Indicator: Upland Riparian Community Structure and Composition

Riparian zones exist where rivers or streams meet land. The vegetation in these areas may be particularly diverse (Naiman and Decamps 1997) and lush, and can be a striking difference from upland ecosystems in drier regions like the Northern Great Plains.

Riparian ecosystem community composition and structure are largely determined by the flow patterns of the streams that they border (Johnson 1998), where plants are subject to seasonal changes and annual variation in flow.

Measure of Upland Riparian Community Structure and Composition: Plains Cottonwood Stand Seral Stage

Since the mid to late 1880's, riparian forests have expanded along the North Platte as a result of the construction of dams and the resulting changes in water flow (Johnson 1994). Willows and cottonwoods have thrived because low flows in June allow for sufficient recruitment and lower peak flows and reduced ice scour reduce tree mortality.

Seral stage is an intermediate stage of ecological succession; vegetation communities in disturbed areas are at a seral stage.

Measure of Upland Riparian Community Structure and Composition: Percent of 20 Riparian Plots with Native Deciduous Seedlings

The percent of seedlings in the riparian zone indicates successful recruitment since reproduction. This demographic measure can be incorporated into quantitative population analyses in the future.

Quantifying Overall Vegetation Quality Condition, Confidence, and Trend

The NRCA authors used the general approach for combining indicator conditions, trends, and confidence described in Chapter 3 (Methods 3.2.2) to calculate overall resource condition, trend, and based on the results presented by Ashton and Davis.

4.8.3. Results and Discussion (In other NRCA sections: Vegetation Quality Conditions, Confidence, and Trends)

Status & Trends in Community Composition and Structure of SCBL Prairies

There are 515 plant species on the SCBL species list and we found 250 of these in monitoring plots from 1998-2015 at SCBL (Appendix A). Graminoids, which includes grasses, sedges, and rushes, accounted for most of the vegetative cover at SCBL, but forbs, shrubs and subshrubs (defined as low-growing shrubs usually shorter than 0.5m) were also present (Figure 4.8.5). We found 40 exotic plant species at SCBL, all of which were forbs or graminoids. Exotic graminoids were particularly abundant (Figure 4.8.5). The shrubs and subshrubs were all native species.

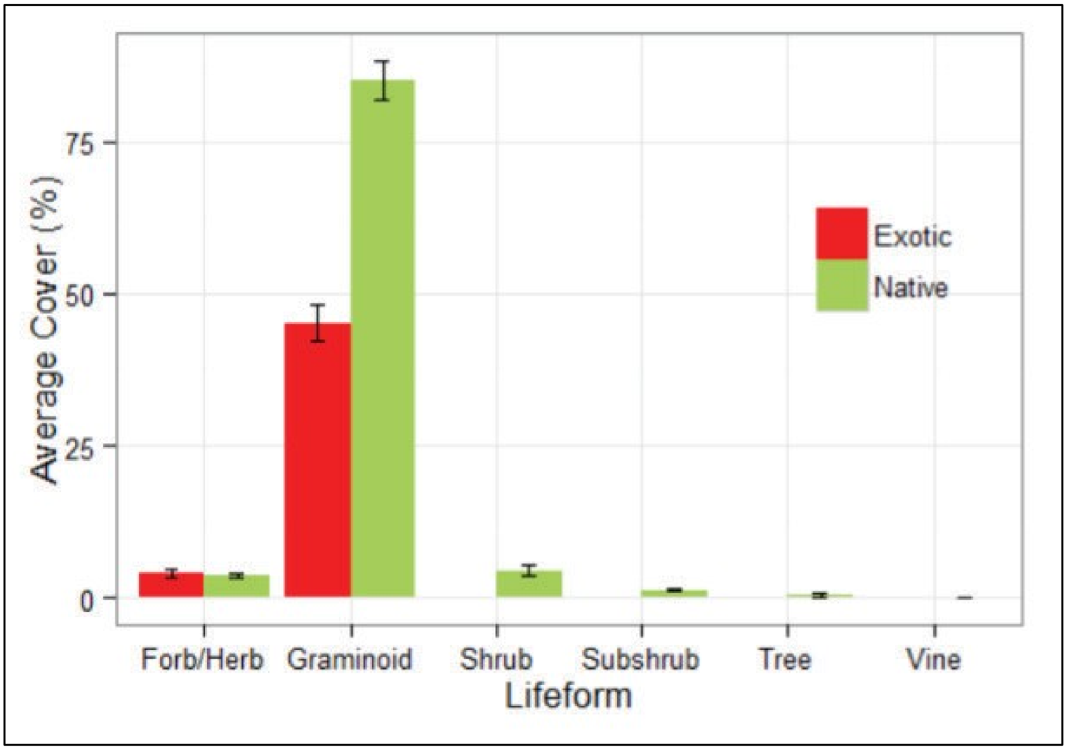

Figure 4.8.5. Average cover by lifeform of native (green) and exotic (red) plants recorded in monitoring plots in Scotts Bluff National Monument (1998-2015). Absolute cover can be greater than 100% because the point-intercept methods records layers of overlapping vegetation (figure from Ashton and Davis 2016).

Western wheatgrass (*Pascopyrum smithii*), needle and thread (*Heterostipa comata*), and threadleaf sedge (*Carex filifolia*) were the most abundant native graminoids and averaged between 15 and 30% absolute cover (Figure 4.8.6). Cheatgrass (*Bromus tectorum*) and Japanese brome (*B. japonicus*) were the most pervasive exotics at SCBL. Cheatgrass and Japanese brome are both Eurasian, annual grasses that have been a part of the NGP landscape for more than a century, but their invasion in the region has accelerated since 1950 (Schachner et al. 2008). The presence of annual bromes in mixed grass prairie is associated with decreased productivity and altered nutrient cycling (Ogle et al. 2003). There is strong evidence from regions further west that cheatgrass alters fire regimes and the persistence of native species (D’Antonio and Vitousek 2003). Our data suggest that the cover of annual bromes has been increasing over time (R2 = 0.19, F1, 121 = 36.5 P < 0.001) (Figure 4.8.7). From 1998 to 2015, the average relative cover of annual bromes was 27.5 ± 1.8% (mean ± standard error), but the average for the last 5 years was 37.2 ± 2.3%. While there are many other exotic plants within SCBL, they contribute relatively little to cover. The average cover of exotic cover is annual bromes. Clearly, reducing the cover of annual bromes presents a major challenge for the park, as it has been for the past 15 years. We are currently studying the temporal and spatial abundance of annual bromes in greater depth with a goal of using data to help guide management actions.

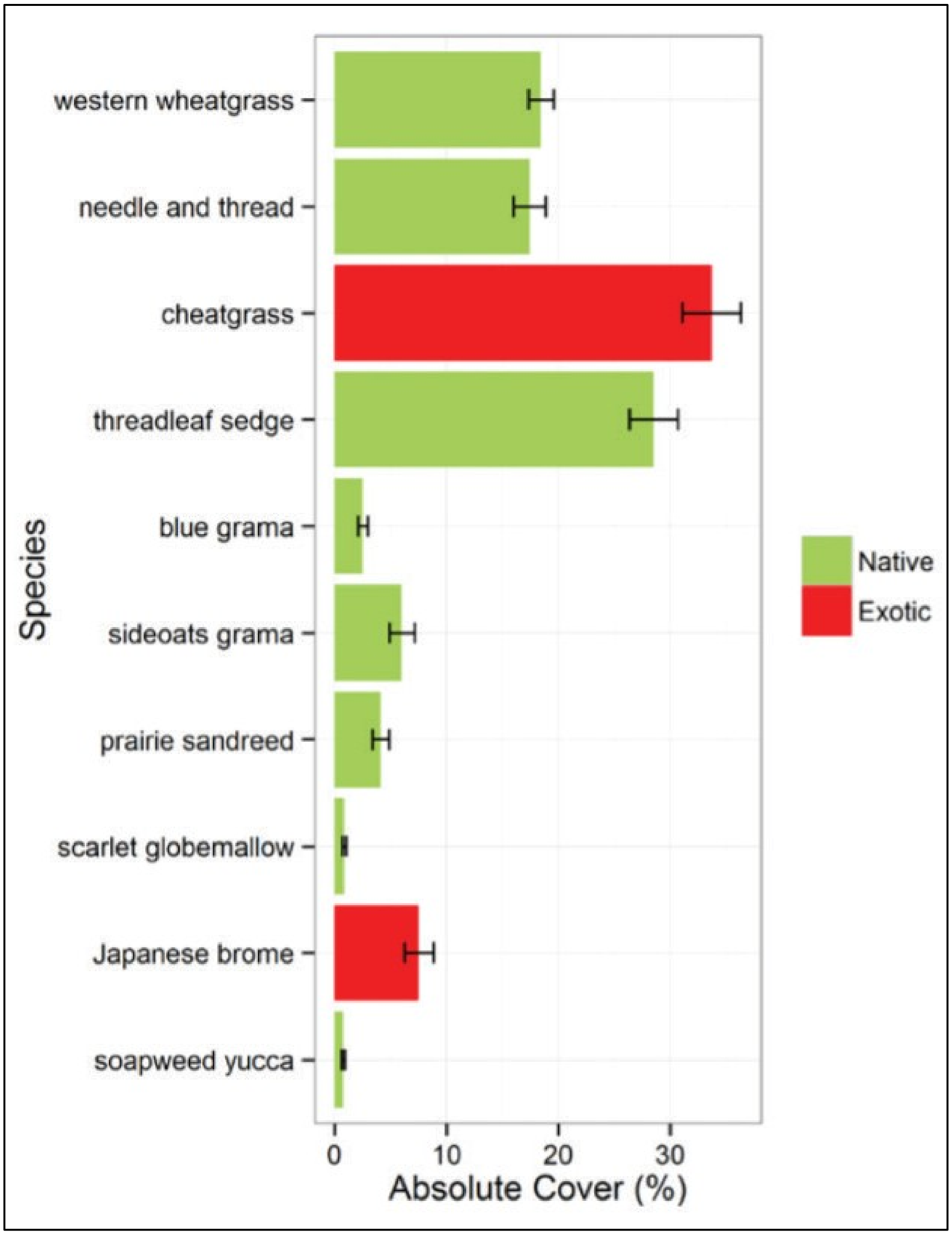

Figure 4.8.6. The average absolute cover of the 10 most common native (green) and exotic (red) plants recorded at Scotts Bluff National Monument in 1998-2015. Bars represent means ± one standard error (figure from Ashton and Davis 2016).

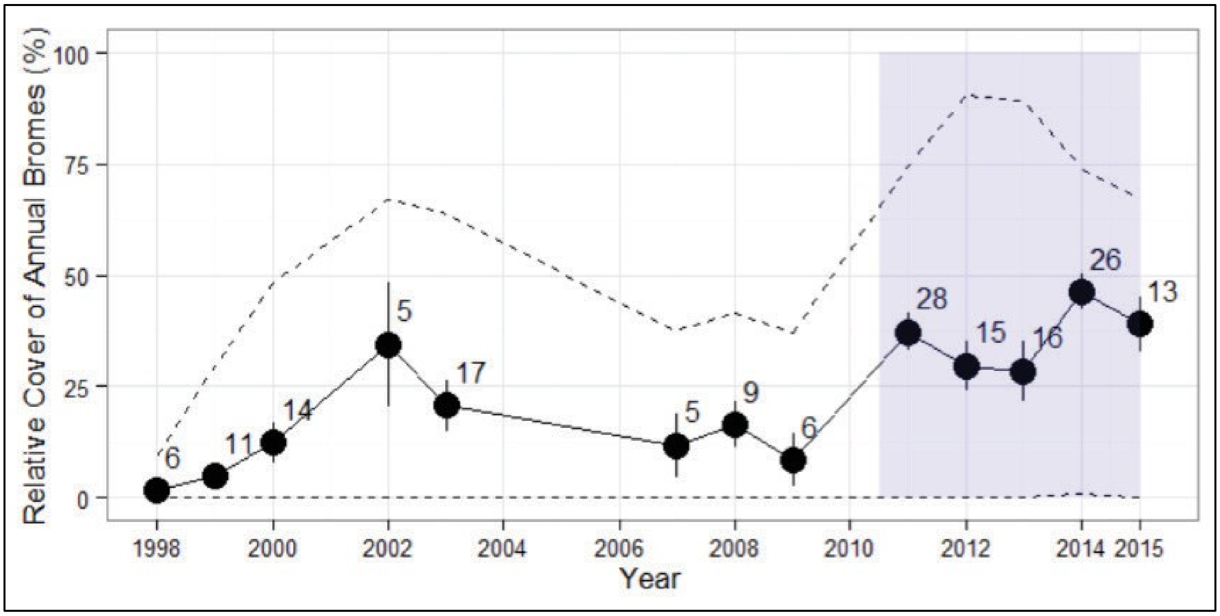

Figure 4.8.7. Trends in the relative cover of annual bromes in Scotts Bluff National Monument from 1998-2015. Points represent mean ± one standard errors and sample size is to the right of the point. Years with fewer than 3 monitoring plots were excluded from the graph. The shaded area highlights the period from 2011-2015 when sampling methods were consistent and distribution of plots was more even and consistent across years. The dashed line represents the maximum and minimum cover values for each year (figure from Ashton and Davis 2016).

Species Richness, Diversity, and Evenness

One of the ways for the NPS to measure effectiveness of actions to achieve its mission of 'preserving ecological integrity' is to examine trends in native plant diversity and evenness within park unit boundaries. Average species richness has been measured by point-intercept since 1998 and in 1 meter^2 and 10 meter^2 quadrats since 2011 (Table 4.8.3).

Table 4.8.3. Average plant species richness in monitoring plots at Scotts Bluff National Monument from 1998 to 2015. Values represent means ± one standard error.

Richness category	**Point-intercept (1998-2015; n=58)**	**1 m^2 quadrats (2011-2015; n=38)**	**10 m^2 quadrats (2011-2015; n=38)**
Species richness	11.0 ± 0.6	6.3 ± 0.3	10.0 ± 0.6
Native species richness	8.6 ±0.6	4.6 ± 0.3	7.7 ± 0.6
Exotic species richness	2.7 ± 0.2	1.6 ± 0.1	2.4 ± 0.2
Graminoid species richness	6.9 ± 0.3	3.7 ± 0.2	4.7 ± 0.2
Forb species richness	3.2 ± 0.2	2.3 ± 0.2	4.4 ± 0.4

While there was some variation across the park, the plots we visited in SCBL tended to have a low diversity of native plants compared to other mixed-grass prairies. Species richness in the mixed-grass prairie is determined by numerous factors including fire regime, grazing, prairie (Symstad and Jonas 2011). In SCBL, there is also a mixed history of past land-use practices that have affected current species richness. While it is difficult to define a reference condition for species richness, both space and time, the natural range of variation over long-time periods may be a good starting point (Symstad and Jonas 2014). Long-term records of species diversity in mixed-grass prairie from a relatively undisturbed site in Kansas varied between 3 and 15 species per square meter over the course of 30 years (Symstad and Jonas 2014). Compared to this, SCBL is within the natural range (5 species) but is on the low end of the range, and some sites, such as PCM_0006, 0015, and 0022 [in the northwest (0006, 0022) and northeast (0015) portions of the park; Figure 4.8.1], fall below this reference condition. In two of these plots, past and current land use can explain the degraded state: site 0006 falls within an active prairie dog town and historic feed lot, and 0015 is within the footprint of a former golf course. One of the most diverse plots, SCBL_FPCM_0039 in the north-central part of the park (Figure 4.8.1), has a mix of native shrub and grassland habitat (Figure 4.8.8).

Figure 4.8.8. A photograph of long-term monitoring plot SCBL_FPCM_0039 which has a large diversity of native plant species.

We did not find any trends in species richness or evenness (Figure 4.8.9). Native species richness in 1meter^2 quadrats was consistent from 2011 to 2015 and ranged from a low in 2012 of 4.3 ± 0.7 (a drought year) to a high of 5.2 ± 0.6 in 2014 (a wet year). In the longer record from point-intercept data (1998-2015; Figure 4.8.9: top) annual average native richness ranged between 5 and 12 species. Annual average evenness ranged from 0.58 to 0.81 during this time period, indicating the plots were not strongly dominated by a single species (Figure 4.8.9: bottom). There is a great deal of variation in species richness and evenness among sites within the park (dashed lines in Figure 4.8.9 represent the maximum and minimum values) which makes long-term trends in these metrics difficult to detect.

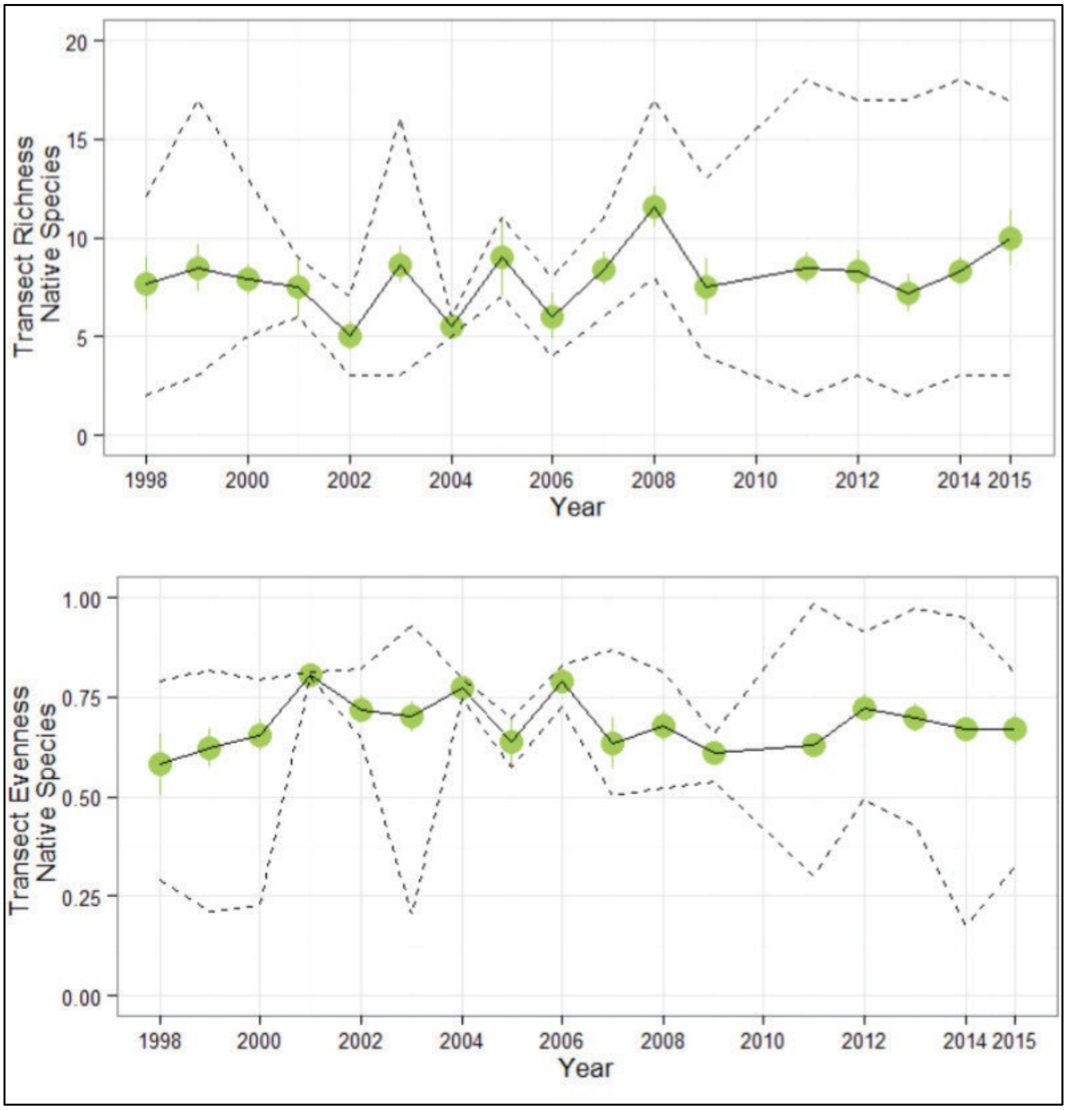

Figure 4.8.9. Trends in native species richness and evenness in Scotts Bluff National Monument, 1998-2015. Data are means ± one standard error. The dashed line indicates the maximum and minimum values for each year (figure from Ashton and Davis 2016).

There is evidence from other regions that annual bromes can affect persistence of native species (D'Antonio and Vitousek 2003). In SCBL, there is a negative correlation between the cover of annual bromes and native species richness (Figure 4.8.10) ($F_{1,\,162} = 19.3$, $P < 0.0001$). If the high cover of annual bromes in SCBL persists or increases, we expect there will be a corresponding decline in native species richness over time.

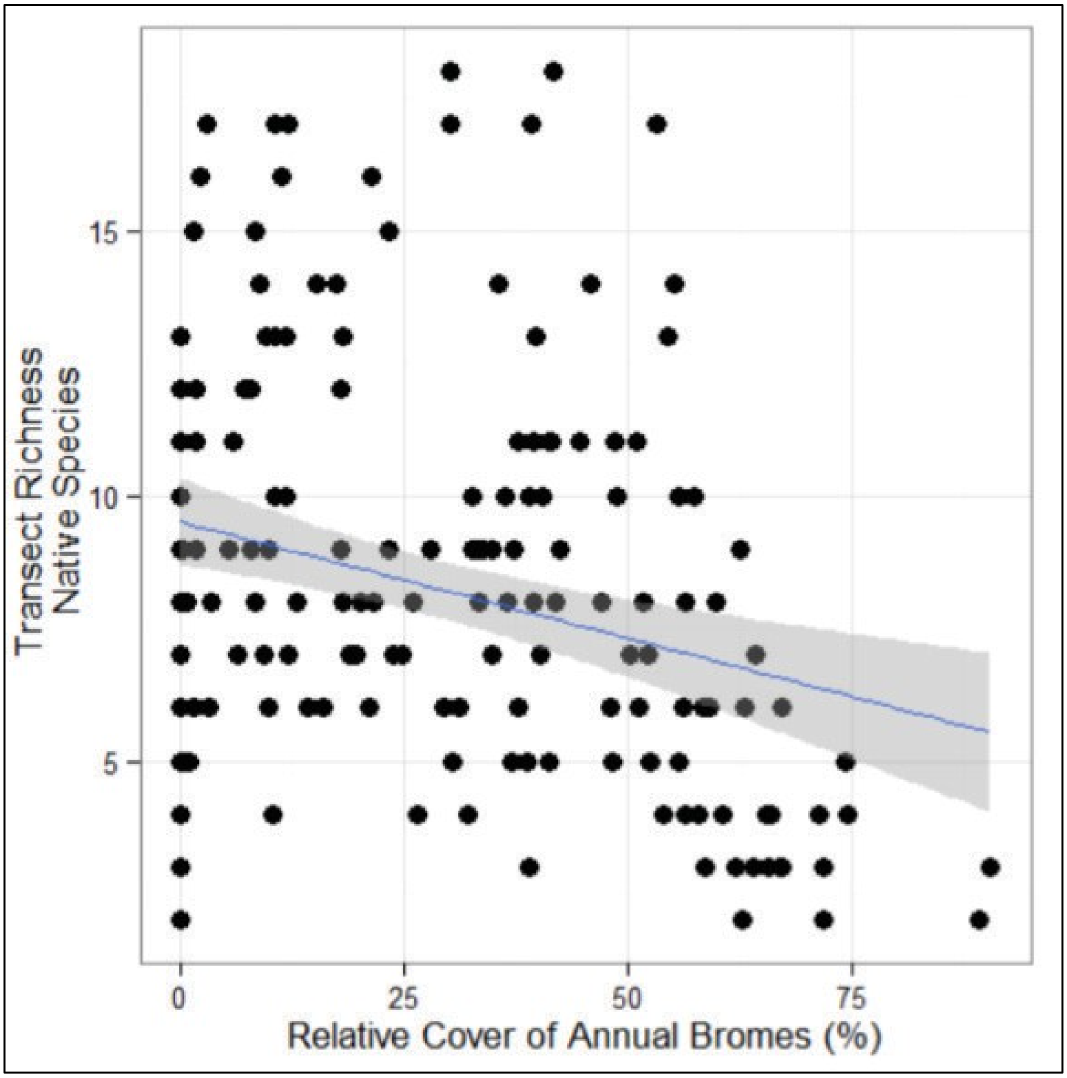

Figure 4.8.10. The relationship between native species richness and the relative cover of annual bromes in long-term monitoring plots at Scotts Bluff National Monument, 1998-2015 (figure from Ashton and Davis 2016).

Disturbance from grazing, prairie dogs, fire, and humans affects plant community structure and composition in mixed-grass prairie. We estimated the approximate area affected by natural and human disturbances at each site we visited in 2011-2015 by surveying the area for ~5 minutes at the end of the plot visit. The most common disturbance was from rodents (e.g. pocket gophers) and prairie dogs, but there was also evidence of deer trails and grazing. We found no correlation between native richness or exotic cover and total disturbance or small or large animal disturbance.

The Influence of Climate and Fire on Plant Community Structure and Diversity

Climate

The Northern Great Plains has a continental climate, with hot summers and very cold winters. The 30-year normal temperatures at a nearby weather station, Scottsbluff W. B. Heilig Field airport, ranged from average minimum monthly temperatures in December of 12.5 °F to maximum monthly

July temperatures of 89.8 °F (based on 1981-2010). The 30-year normal annual precipitation totals 15.79 inches. Annual precipitation at SCBL in 1998-2015 was variable and ranged between 6.9 and 22.9 inches, in 2012 and 2015, respectively. There were dry years in the early 2000s, 2006-2008, and in 2012-2013 (Figure 4.8.11). The last two years have been much wetter than average. The native vegetation is adapted to this variation, and productivity responds strongly to decreases in spring and summer precipitation (Yang et al. 1998, Smart et al. 2007). Species richness and diversity in regional grasslands are also sensitive to temperature and precipitation fluctuation, but the response is complex and less predictable (Jonas et al. 2015).

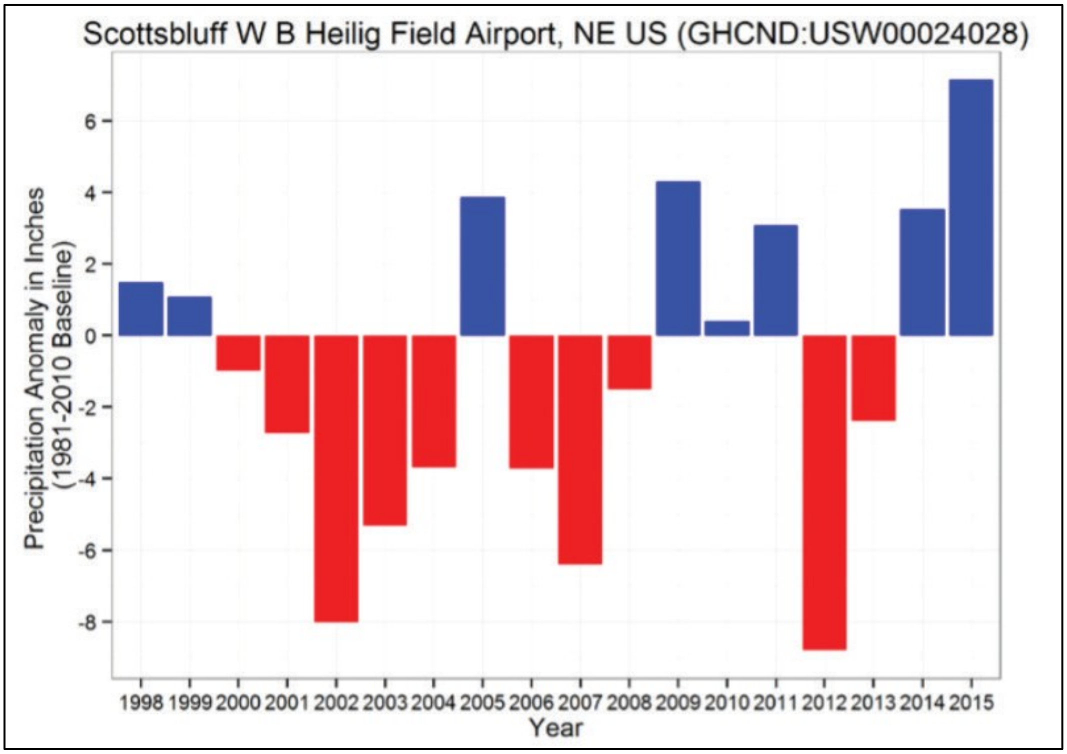

Figure 4.8.11. The total annual precipitation anomaly from 1998-2015 for Scotts Bluff National Monument. Positive values (blue) represent years wetter than and negative values (red) years drier than the 1981-2010 average. The anomaly is measured in inches and based on data from a nearby weather station (figure from Ashton and Davis 2016).

At SCBL, the average height of plants increased with increasing precipitation (R2 = 0.23, P = 0.05), but did not respond to temperature. There was a marginally significant trend for native species richness to increase in years with more precipitation (R2 = 0.17, P = 0.09), but richness did not correlate with temperature. The relative cover of annual bromes did not correlate with total annual precipitation or temperature. Because of the large variation in annual temperature and precipitation patterns at SCBL, a longer time series of vegetation data is needed to elucidate trends and correlations with climate.

Fire History

Historically, fire was a common disturbance in Northern Great Plains grasslands, with natural fire return intervals of 9-12 years (Guyette et al. 2015). Natural fires have been suppressed for most of the last century, but the use of prescribed burning in Northern Great Plains parks to mitigate the effects of the absence of natural fires has increased over time since its start at Wind Cave NP in 1973 (Wienk et al. 2011). As of 2015, there is a mosaic of recently burned and unburned areas at SCBL (Figure 4.8.12).

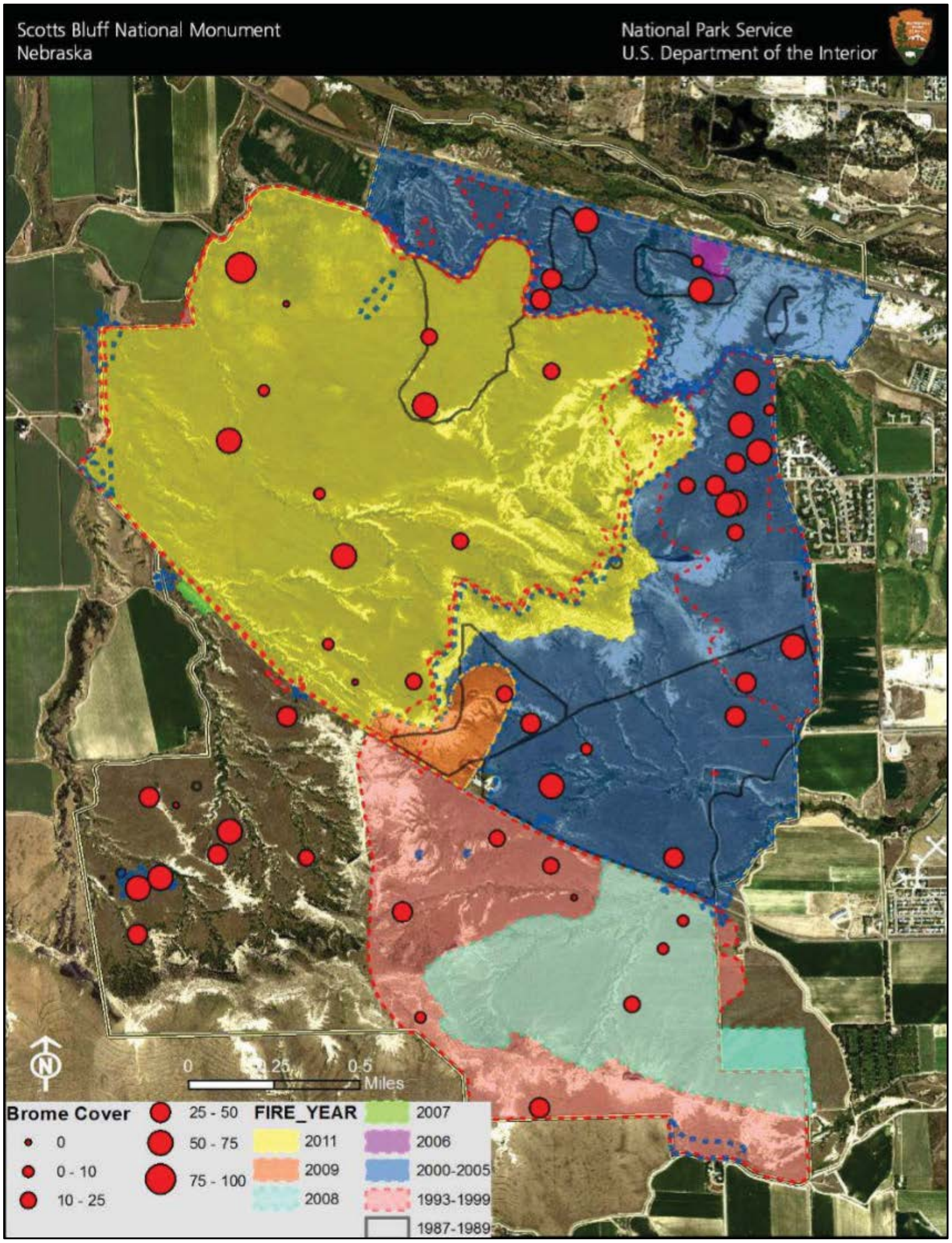

Figure 4.8.12. Map of recent fire history at Scotts Bluff National Monument (figure from Ashton and Davis 2016).

The effects of specific prescribed burns on vegetation and fuel loads and more details about fires at SCBL can be found in past NGPFire annual reports (see http://www.nps.gov/ngpfire/docs.htm). Here, we were interested in determining the relationship between fire history and vegetation. We compared two vegetation metrics, native species richness and relative cover of annual bromes, with the length of time between the data collection at a plot and the most recent fire at that plot (years since fire). For example, a site that burned in the spring and then was visited in the summer would be 0 years since fire. We excluded plots that had not burned from this analysis, because we do not have confidence in the historical fire record (pre-1980s).

We found a positive relationship between native richness and years since fire (Figure 4.8.13; F1, 136 = 6.3, P = 0.0135). There was a lower number of native species in sites that burned more recently. This suggests that prescribed fire may reduce native species richness in the short term, but it over time mixed-grass prairie recovers. We found no significant relationship between annual brome and years since fire (Figure 4.8.13) (F1, 136 = 0.9, P = 0.3325). This implies that in the short-term, prescribed burns are not effective at reducing brome. However, unburned plots concentrated in the southwest portion of the park had a higher cover of annual bromes than sites that burned more recently (Figure 4.8.12). Burning this unit of the park may assist in increasing native richness and reducing annual brome cover. The increasing trend in annual brome abundance across the park (Figure 4.8.7) despite fairly frequent prescribed burns suggests that burning alone may not be sufficient. The best approach to reducing annual brome abundance in SCBL will likely include burning, targeted herbicides, and seeding of native species. Ongoing research on this topic and an upcoming adaptive management initiative for annual brome control in NGPN parks should provide more data and guidance to help with these management decisions.

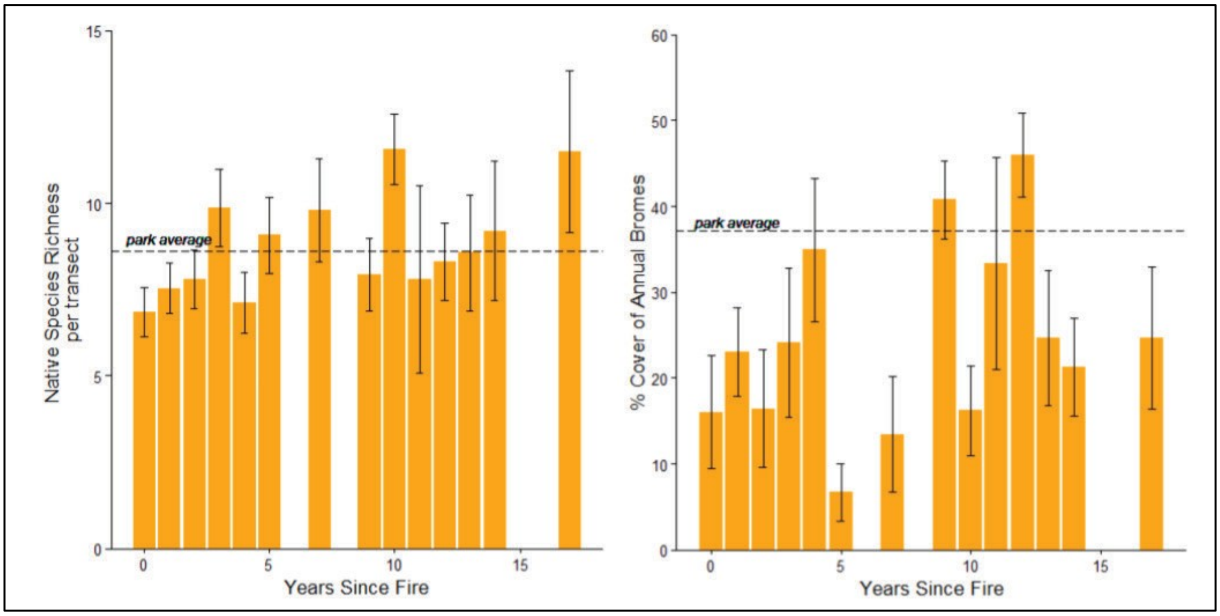

Figure 4.8.13. Native species richness and percent cover of annual bromes across plots with different fire histories (figure from Ashton and Davis 2016).

<u>Rare Plants</u>

While repeating rare plant surveys and locating rare species is not the focus of NGPN plant community monitoring, we identified 35 rare plant species in SCBL monitoring plots from 1998 to 2015. Of these species, the critically imperiled species slender wheatgrass (*Elymus trachycaulus* S1) (Figure 4.8.14) was the most abundant with an average cover of 1.52%. Other critically imperiled species were observed in low frequencies and abundances, with hairy false goldenaster (*Heterotheca villosa* S1) being more common and occurring in nine plots with 0.08% average cover. Other rare species abundances are described in Table 4.8.4, and 22 vulnerable to secure (S3S5) species observations are noted in Appendix A. Most of the rare species we observed are classified as apparently secure or secure (G4 or G5) at the global scale, but are rare in Nebraska as a result of these species existing on the edge of their global range in the state.

Figure 4.8.14. Photographs of two critically imperiled species in Nebraska found in plant community monitoring plots at Scotts Bluff National Monument. Left: slender wheatgrass (*Elymus trachycaulus* S1). Right: hairy false goldenaster (*Heterotheca villosa* S1) (photos from Ashton and Davis 2016).

Table 4.8.4. Rare species occurrence in Agate Fossil Beds National Monument sampling plots from 1998-2015. Status ranks are based on Nebraska Natural Heritage Program designations. Plot count is the number of unique plots a species was recorded in across all years. Mean cover is the average cover of that species across all years in plots where cover measurements were recorded.

Species name	Common name	State rank	Global rank	Plot count	Mean cover (%)
Hieracium umbellatum	Narrow-leaf hawkweed	S1	G5	1	0.00
Pseudoroegneria spicata	Bluebunch wheatgrass	S1	G5	3	0.08
Astragalus agrestis	Field milk-vetch	S1	G5	2	0.01
Danthonia spicata	Poverty oatgrass	S1	G5	1	0.00
Elymus lanceolatus	Thickspike wheatgrass	S1	G5	2	0.01
Elymus trachycaulus	Slender wheatgrass	S1	G5	44	1.52
Heterotheca villosa	Hairy goldenaster	S1	G5	9	0.02
Senecia integerrimus	Lambstongue ragwort	S1	G3	1	< 0.01
Antennaria microphylla	Little-leaf pussytoes	S2S4	G4G5	1	0.00
Fritillaria atropurpurea	Leopard-lily	S2S4	G5	1	0.00
Physaria reediana	Rock bladder-pod	S2S4	G4	1	0.00
Ericameria nauseosa	Rubber rabbitbrush	S2S4	G5	7	0.02
Vicia americana	American vetch	S2S4	G5	13	0.08

Since it has been 20 years since the last rare plant survey was done at SCBL (Rolfsmeier 1996), we recommend a survey be redone when funds are available. A full rare plant survey will be more likely to accurately quantify the status of rare plants found on the main bluffs, an area with no monitoring plots. Any future construction efforts that could disturb native vegetation (e.g. trail building), should avoid damaging species considered rare in Nebraska.

Golf Course Restoration Project

Scotts Bluff NM acquired the property of a former golf course in 1973. Just over a decade later, the park began to restore the area by removing concrete, planting millet, spraying the area with an herbicide, and mowing. In 1997, it was planted with a mix of native grasses including western wheatgrass, junegrass (*Koeleria macrantha*), needle and thread, blue grama (*Bouteloua gracilis*), sideoats grama (*B. curtipendula*), and buffalograss (*B. dactyloides*) (Huddle et al. 2001). Sedges (*Carex filifolia*) were transplanted into the restoration area, but most died after one season due to drought and exotic species pressures (personal communication, M. DeBacker, B. Manasek). Two monitoring plots were established within the restored area (LPCM_13 and 14; Figure 4.8.1) and two plots were established nearby in native prairie (LPCM_11 and 12; Figure 4.8.1). An earlier evaluation of the restoration project from 1997-2009 found mixed results: this evaluation found that the park was successful at creating a community that resembled the native prairie, except that thread leaf sedge, which is difficult to seed, was absent (Huddle et al. 2001). However, the restored sites did have a higher frequency of exotic grasses than the native prairie (James 2010).

NGPN visited the native prairie and restoration sites in 2009, 2013, and 2014. In 2014, many of the species originally planted in the restoration area were present in plots LPCM-13 and 14, but only a few were common enough to contribute to the plant cover as measured by the point-intercept method (Table 4.8.5). LPCM-13 had a high cover of western wheatgrass and trace amounts of sideoats and blue grama. The native grasses in LPCM-14 were more successful and junegrass was the only species missing from the area in 2014. However, native grasses remained in low abundance and blue grama, buffalo grass, and junegrass did not establish well in either plot. The two restored plots differ from one another (Table 4.8.5), and neither closely resembles the nearby native prairie. LPCM_13 is characterized by lower native species richness and a much higher cover of annual bromes (close to 75% cover) (Figure 4.8.15) than the control plots (which in 2014 averaged 6 native species and 12.8% cover of annual brome). LPCM-14 has a high diversity of native plants, but also has a very high cover of annual bromes (close to 50% cover). To improve the rates of success and the establishment of native species, future projects should include funds to cover weed control for many years (~10) after planting.

Table 4.8.5. Original seed mixture and composition of two restoration plots in Scotts Bluff National Monument in 2009, 2013, and 2014.

Seed (% of mix)		% Cover in restored plot LPCM-13			% Cover in restored plot LPCM-14		
Year	**1997**	**2009**	**2013**	**2014**	**2009**	**2013**	**2014**
Western wheatgrass	58	44	19	22	13	4	3
Needle and thread	23	0	0	0	51	30	36
Sideoats grama	7	0	0	0	11.5	7	5
Blue grama	6	1	0	0	1.5	0	3
Buffalo grass	5	0	0	0	0	0	0
Junegrass	Trace	0	0	0	0	0	0
Native species richness	–	5	2	3	13	8	10
Relative cover of annual bromes	–	36.9	71.7	71.9	10.5	39.4	48.9

Figure 4.8.15. Cheatgrass is the dominant species at the long-term monitoring plot, LPCM_13, at Scotts Bluff National Monument.

The Status of Riparian Forests in SCBL

In 2014, the NGPN established 20 plots in the forested area along the North Platte River to monitor status and trends in lowland riparian forest condition (Figure 4.8.16). The 2014 data provide a baseline dataset for future surveys; we plan to revisit the same plots every five years (e.g. 2019, 2024, etc.). The riparian lowland forest in Scotts Bluff NM is small (~60 acres), and comprises only about 2% of the park. The forest is fairly open and dominated by plains cottonwood (*Populus deltoides*), peachleaf willow (*Salix amygdaloides*), and green ash (*Fraxinus pennsylvanica*) (TNC 1998). There are also large areas of shrubland (Figure 4.8.16, light green and pink) and exotic-species-dominated grassland (Figure 4.8.16, green). The 20 monitoring plots were chosen randomly within the riparian corridor and fall in all of the dominant community types with the exception of narrowleaf willow (*S. exigua*) shrubland.

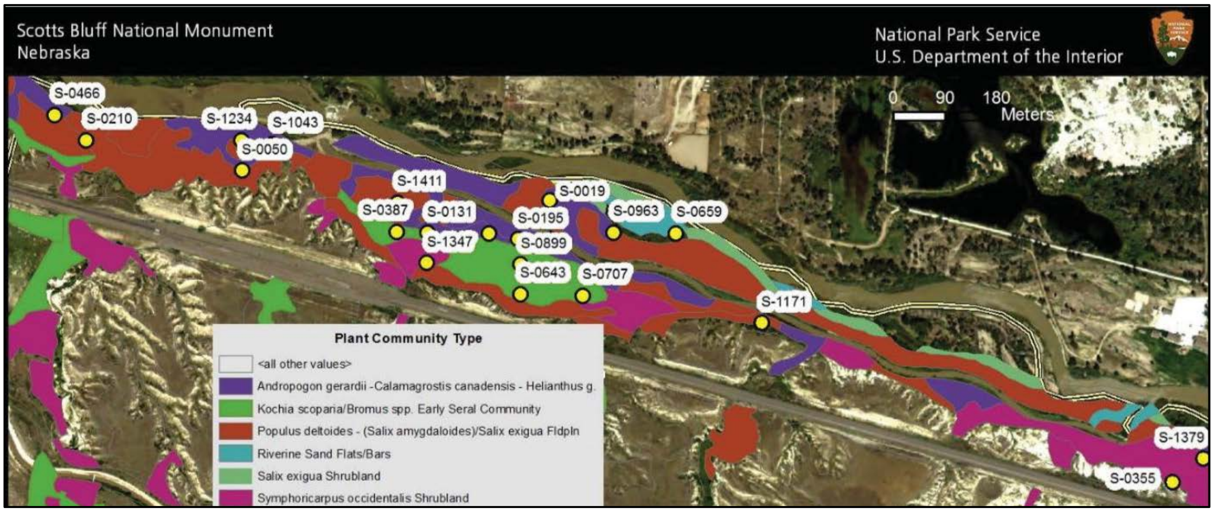

Figure 4.8.16. Map of the plant community types within the riparian area in Scotts Bluff National Monument and the location of 20 long-term monitoring plots (yellow). Vegetation classification is based on the NPS Vegetation Mapping Program report (TNC 1998).

In 2014, we found nine species of tree or tall shrub in 19 riparian forest plots at SCBL (Table 4.8.6). One plot (S-0899) did not have any tree or tall shrub species present. Our data were consistent with the 1990's vegetation map and the most common tree species were cottonwood, peachleaf willow, and green ash (Table 4.8.6). The density of large trees was similar across these three species (Table 4.8.7), but we found many fewer cottonwood seedlings compared to other species. Mature box elder (*Acer negundo*) trees occurred in only four plots (Table 4.8.6), but the average density was high (Table 4.8.7). As riparian forests along the North Platte age, cottonwood and willow forests are most often replaced with green ash and box elder forests (Johnson 1994). In 2014, we found numerous poles and seedlings of green ash and box elder but a few sites still have cottonwood and willow seedlings and poles present. Future monitoring is needed to determine if these stands will soon become dominated by green ash and box elder.

Table 4.8.6. Tree and tall shrub occurrence in 2014 at 20 plots in Scotts Bluff National Monument.

Species name	Common name	Number of plots with trees (DBH > 15 cm)	Number of plots with poles (2.5 cm ≤ DBH ≤ 15 cm)	Number of plots with seedlings
Salix amygdaloides	Peachleaf willow	8	0	2
Populus deltoids	Plains cottonwood	7	1	2
Fraxinus pennsylvanica	Green ash	6	2	9
Acer negundo	Boxelder	4	3	6
Juniperus scopulorum	Rocky Mountain juniper	1	1	0
Shepherdia argentea	Silver buffaloberry	1	0	0
Prunus virginiana	Chokecherry	0	1	4
Salix interior	Sandbar willow	0	1	2
Ulmus Americana	American elm	0	0	2

Table 4.8.7. Tree basal area and density by size class for dominant tree and shrub species in the riparian forest of Scotts Bluff NM (Ashton and Davis 2016).

Species	Indicator	Value*
Willow species	Basal area (m^2/ha)	3.4 ± 1.7
	Tree density (stems/ha)	14 ± 5
	Pole density (stems/ha)	53 ± 38
	Seedling density (stems/ha)	5282 ± 3728
	Snag density (stems/ha)	0
Plains cottonwood	Basal area (m^2/ha)	3.4 ± 1.6
	Tree density (stems/ha)	18 ± 10
	Pole density (stems/ha)	6 ± 6
	Seedling density (stems/ha)	103 ± 102
	Snag density (stems/ha)	3 ± 3
Green ash	Basal area (m^2/ha)	0.7 ± 0.3
	Tree density (stems/ha)	15 ± 7
	Pole density (stems/ha)	8 ± 6
	Seedling density (stems/ha)	1973 ± 1070
	Snag density (stems/ha)	5 ± 3

Table 4.8.7 (continued). Tree basal area and density by size class for dominant tree and shrub species in the riparian forest of Scotts Bluff NM (Ashton and Davis 2016).

Species	Indicator	Value*
Box elder	Basal area (m^2/ha)	1.6 ± 0.08
	Tree density (stems/ha)	28 ± 15
	Pole density (stems/ha)	21 ± 14
	Seedling density (stems/ha)	535 ± 273
	Snag density (stems/ha)	3 ± 2

* Mean across 20 riparian forest monitoring ± standard error of the mean.

Since the mid to late 1880’s, riparian forests have expanded along the North Platte as a result of the construction of dams and the resulting changes in water flow (Johnson 1994). Willows and cottonwoods have thrived because low flows in June allow for sufficient recruitment and lower peak flows and reduced ice scour reduce tree mortality. We compared our 2014 data to forest composition in the late 1850s to late 1880s (from Johnson 1994). The data from the late 1850s to late1880s encompasses a greater area, but the comparison shows large willows occurring in SCBL in 2014 but not historically, but also many more of the very smallest size classes (Figure 4.8.17, black bars). Cottonwoods also comprise a smaller proportion of the forest community (Figure 4.8.17, white bars), and there has been a decrease in the proportion of cottonwoods in smaller diameter classes and an increase in the large diameter classes (Figure 4.8.18).

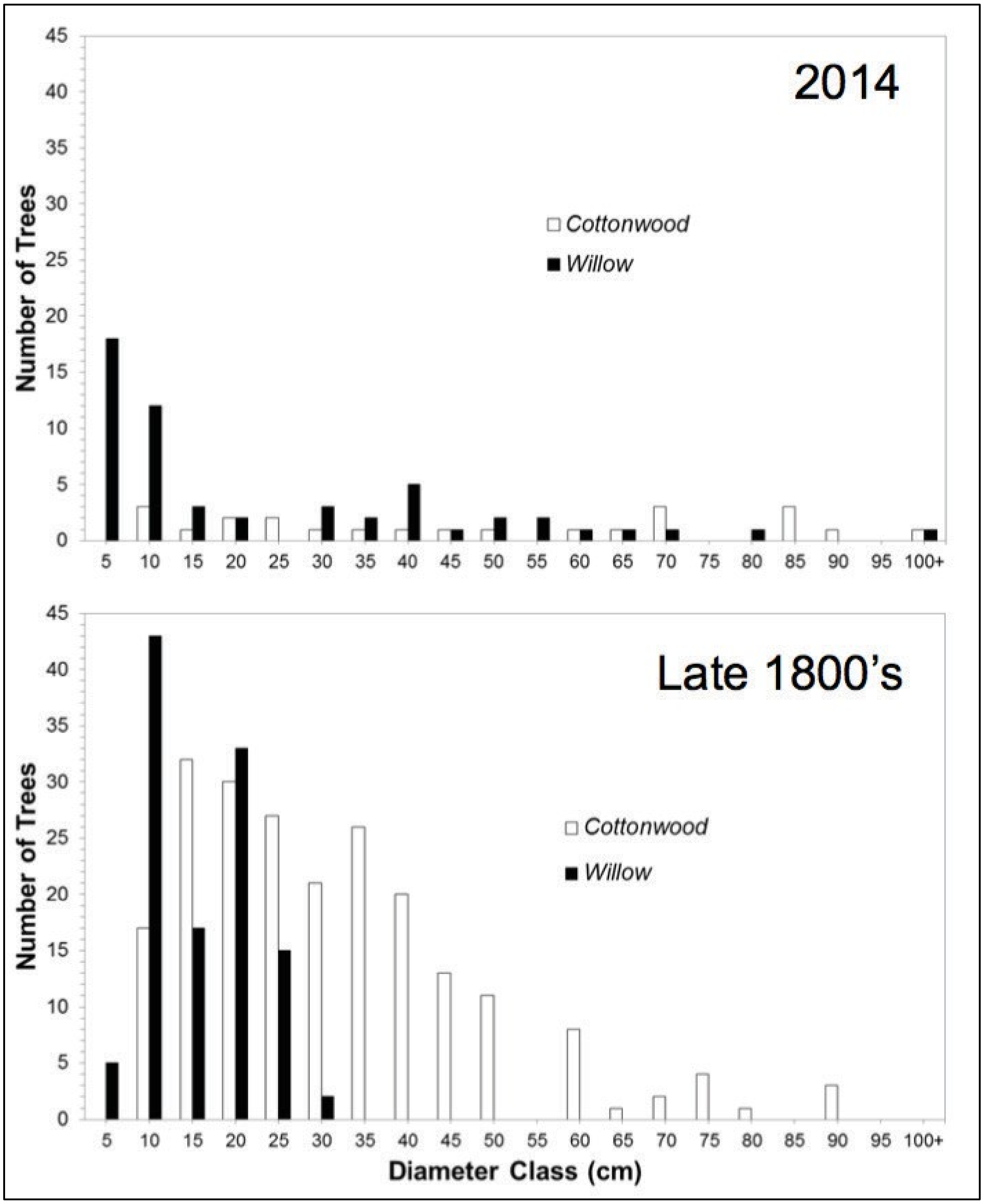

Figure 4.8.17. Diameter classes of cottonwood (*Populus*) and willow (*Salix*) trees in riparian forests along the North Platte River in Nebraska in the 1850-1880s (bottom panel; from Johnson 1994) and along the same river but only in Scotts Bluff National Monument in 2014 (top panel). Class categories indicate upper limits of each range (e.g. diameter class 10 includes individuals > 5 cm and ≤ 10 cm).

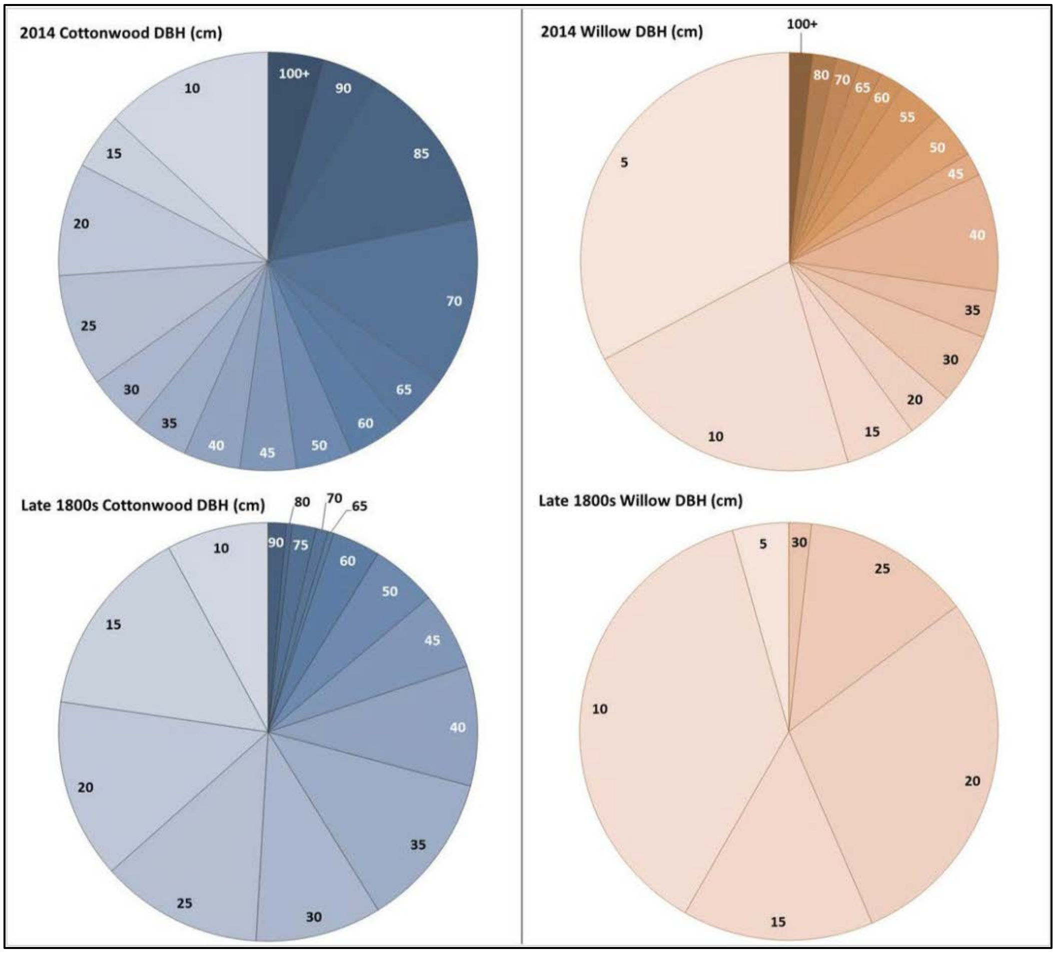

Figure 4.8.18. Size-class proportions of cottonwood (*Populus*) and willow (*Salix*) trees in riparian forests along the North Platte River in Nebraska in the 1850-1880s (bottom panels; from Johnson 1994) and along the same river but only in Scotts Bluff National Monument in 2014 (top panel). Labels in wedges indicate diameter-at-breast-height (DBH) class categories, and each number is the upper limit of that range (e.g., diameter class 10 includes individuals > 5 cm and ≤ 10 cm).

This suggests that new cottonwoods are no longer being established at the same extent or rate as they were 150 years ago. A metric developed to classify cottonwood stand successional status indicates that SCBL riparian areas are primarily composed of late seral stage cottonwood stands, also suggesting a lack of cottonwood seedling recruitment (Uresk 2015). If the goal is to maintain cottonwood forests along this section of the North Platte, management interventions such as watering and fencing around existing cottonwood saplings could ensure that the young trees survive to maturity.

Exotic Species

In riparian forests the understory of the riparian forests in SCBL is a mix of native and exotic plants. The focus of the 2014 survey was woody species, but field crews also surveyed for the presence of exotic species of management concern (e.g. musk thistle, poison hemlock) and potential early invaders (Table 4.8.1). Musk thistle and cheatgrass were found in a majority of the 20 plots (Table

4.8.8). On average, 3 exotic species were found in each plot. The only early detection we made was of perennial pepperweed (*Lepidium latifolium*); a number of plants were found in two plots in the center of the riparian corridor: SCBL_PCM_0963 and SCBL_ PCM_1141 (Figure 4.8.16). Perennial pepperweed is an invasive plant that threatens wetlands, marshes, and floodplains in the Western US (Figure 4.8.19). It is common in Wyoming, but still relatively rare in Nebraska.

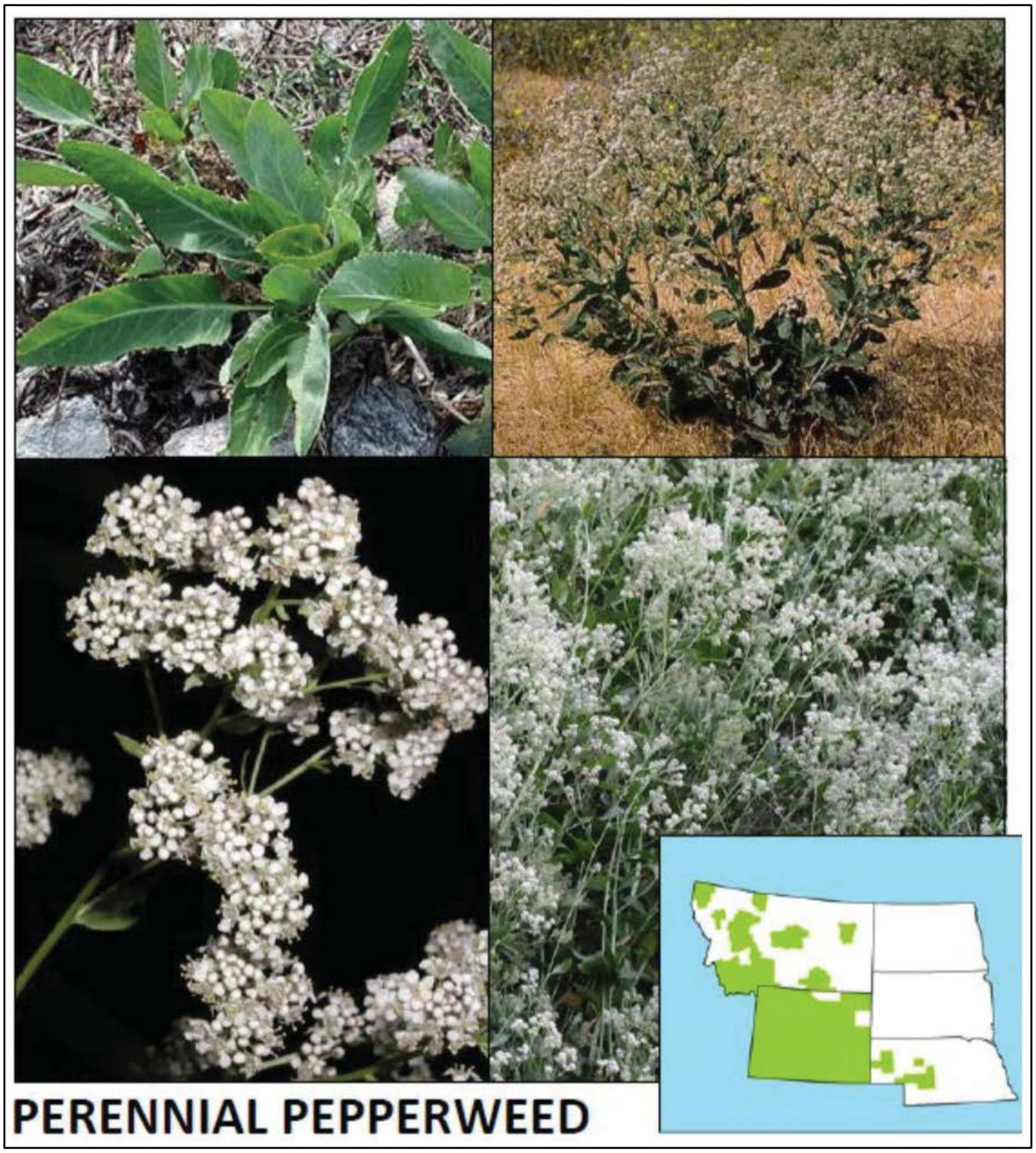

Figure 4.8.19. Perennial pepperweed, an invasive plant that threatens wetlands, marshes, and floodplains in the Western US. For more information an early detection flyer on riparian invaders can be found on the NGPN website and on the NPS IRMA Portal: https://irma.nps.gov/App/Reference/Profile/2208790/.

Table 4.8.8. Exotic species detected in 20 riparian plots in Scotts Bluff National Monument and their corresponding abundance, cover class, and estimated percent cover.

Species name	Common name	Number of plots	Average cover class	Estimated cover (%)
Carduus nutans	Musk thistle	17	2.4 ± 0.2	< 5
Bromus tectorum	Cheatgrass	12	4.3 ± 0.3	5-25
Verbascum thapsus	Common mullein	8	2.0 ± 0.3	< 1
Cirsium arvnese	Canada thistle	6	2.0 ± 0.0	< 1
Cynoglossum officiinale	Houndstongue	6	1.7 ± 0.3	< 1
Phalaris arundinacea	Reed canarygrass	5	4.6 ± 0.4	5-25
Marriubium vulgare	Horehound	4	2.0 ± 0.0	< 1
Bromus inermis	Smooth brome	3	3.0 ± 00.6	< 5
Conium maculatum	Poison hemlock	3	2.3 ± 0.3	< 5
Lepidium latifolium	Perennial pepperweed	2	2.0 ± 0.0	< 1

The NGP Exotic Plant Management Team (EMPT) is aware of the high density and cover of exotic plants in the riparian forest and much of their control efforts were concentrated in this area during the 2015 field season (Hauk 2016). The EPMT focused on the control of musk thistle (*Carduus nutans*), Canada thistle (*Cirsium arvense*), and poison hemlock (*Conium maculatum*). The NGP Exotic Management Team was notified of the perennial pepperweed, but there has not been a concerted effort at eradication. Unfortunately, the large seed bank and moist conditions will be challenging for continued control and eradication efforts of exotic species in this area. Moreover, the river continues to provide and an avenue for infestation. A more efficient use of resources may be in control efforts focused in upland areas with intact native communities (e.g. FPCM_0039, Figure 4.8.8) and rare plants (Rolfsmeier 1996).

4.8.4. Conclusion

The Northern Great Plains Inventory & Monitoring Program and Fire Effects Program have been monitoring vegetation in Scotts Bluff National Monument for over 18 years. While methods have changed slightly, this report summarizes data from over 80 locations from 1998-2015. Below, we list the questions we asked and provide a summarized answer, for more details see the Results and Discussion section. We conclude with a Natural Resource Condition Table (Table 4.8.9) that summarizes the current status and trends in a few key vegetation metrics.

Table 4.8.9. Natural resource condition summary table of plant communities in Scotts Bluff National Monument (SCBL). Current values are based on data from 2011-2015 and trends are based on data from 1998-2015.

Indicator	**Measure**	**Current value (mean ± se)**	**Reference condition and data sources**	**Condition /trend**	**Condition rationale**
Upland plant community structure and composition	Native species richness ($1m^2$ quadrats)	4.6 ± 0.3 species	3-15 species	🟡↔	SCBL plays a vital role in protecting and managing some of the last remnants of native mixed-grass prairie in the region. The park is characterized by low native species richness, but average richness is within a natural range of variability (Symstad and Jonas 2014). The lowest native diversity is in the prairie dog town and former golf course.
	Evenness (point-intercept transects)	0.67 ± 0.014	To be determined	🟢↔	Native evenness has not changed since monitoring began in 1998.
Exotic plant early detection and management	Relative cover of exotic species	41.2 ± 2.5%	< 10% cover	⇩	Many areas of SCBL have a high cover of exotic species. Annual bromes: cheatgrass and Japanese brome present the largest challenge to SCBL.
	Annual brome cover	37.2 ± 2.3%	< 10% cover	🔴⇩	Exotic cover and annual brome cover has shown an increasing trend since 1998. More research on effective management strategies is greatly needed.
Riparian forest	Plains cottonwood stand seral stage	Late seral stage	Mix of seral stages	🔴	The riparian forests of SCBL are currently a mosaic of areas dominated by willow, cottonwood, ash, and boxelder with an understory of many exotic plants. As cottonwood forests age in SCBL, green ash and box elder are likely to become more dominant.
	Percent of 20 riparian plots with native deciduous seedlings	60%	To be determined	🟢	Only 2 of 20 plots had evidence of young cottonwoods, but more than half the riparian forest in SCBL had large densities of other native tress and shrub. Forest surveys will be repeated every 5 years in SCBL and this will allow us to detect trends in condition.

What is the current status of plant community composition and structure of SCBL grasslands (species richness, cover, and diversity) and how has this changed from 1998 to 2015?

SCBL plays a vital role in protecting and managing some of the last remnants of native mixed-grass prairie in the area. Native grasses, such as western wheatgrass, and native sedges, such as threadleaf sedge, are abundant and still the dominant component of many sites. Native plant diversity is at a moderate level compared to other grasslands in the region (Table 4.8.9), but diversity is spatially variable. As expected, areas with historical and current disturbances, such as the prairie dog town and former golf course, have fewer native plants than other sites.

We found no significant trends in native diversity or evenness from 1998 to 2015, but both are threatened by the increasing cover of annual bromes (Figure 4.8.10). Annual bromes are the most abundant exotic plant species in SCBL and present the largest challenge to SCBL. There has been an increase in annual brome abundance since the 1990s and continued control efforts will be necessary to maintain native prairie within SCBL.

How do trends in grassland condition correlate with climate and fire history?

Native diversity tended to increase in wet years. The large variability in SCBL’s climate makes it difficult to discern strong patterns linking temperature, precipitation, and plant community structure (e.g. exotic cover, diversity). A longer time series of vegetation data will make it easier to elucidate trends in the future.

SCBL has been using prescribed burning as a management tool since the 1980s. There was a lower number of native species in sites that burned more recently suggesting that prescribed fire can benefit the mixed-grass prairie in SCBL, but it may take time to see the positive effects. We found no significant relationship between annual brome and years since fire. There is an adaptive management program planned for 2017 which should provide better guidance to the park on how to manage annual bromes. Ongoing research is looking at treating areas with a range of annual brome abundance with a combination of prescribed fire, herbicide, and native grass drill seeding to see which combination of treatments is most effective in reducing annual brome cover.

What, if any, rare plants were found in SCBL long-term monitoring plots?

We identified 35 rare plant species in SCBL between 1998 and 2015; eight of these are considered critically imperiled within Nebraska. These plants are found in such low abundance and in such few plots, it is unlikely that plant community monitoring will be able to detect any trends in rare plant abundance. We recommend more targeted surveys of rare plant species of concern be completed when funds are available.

Was the SCBL golf course restoration effective at creating a grassland community dominated by native species?

The golf course restoration project had mixed results. While some native grasses were established in one of the monitoring plots, establishment was poor in the other. The project area now has a very high relative cover of annual bromes (> 45%). To improve the rates of success and the establishment of native species, future projects should include funds to cover invasive plant control for many years (~10) after planting.

What is the composition and structure of riparian forests at SCBL?

The riparian forest in SCBL is a fairly diverse assemblage of cottonwood, willow species, green ash, and box elder. Seedlings are common (Table 4.8.9) and cottonwoods of all age classes are present. Exotic grasses and forbs are common in the understory of the riparian forest, and continuing control efforts will be necessary to prevent their spread. While there are fewer young cottonwood trees compared to surveys done in the late 1800s, some young cottonwoods have successfully established. However, the large abundance of green ash and box elder seedlings suggests that a transition to ash-dominated forests is underway.

4.8.5. Vegetation Overall Condition

Condition

Overall vegetation condition was determined by the average of the indicator conditions (Table 4.8.10). The NRCA authors summarized the condition, confidence, and trend for each indicator, and assigned condition points. The score for overall vegetation condition was 42 points, which placed vegetation at Scotts Bluff NM in the *Warrants Moderate Concern* category.

Confidence

Confidence was *Medium* for all indicators and measures and, therefore, confidence was *Medium* for overall vegetation condition.

Trend

Trend was *Unchanging* for upland plant community structure and composition, *Deteriorating* for exotic plant early detection and management, and *Not Available* for riparian forest. The overall trend for vegetation was *Not Available*.

Table 4.8.10. Vegetation overall condition.

Indicators	**Measures**	**Condition**
Upland plant community structure and composition	Native species richness	⇔
	Evenness	⇔
Exotic plant early detection and management	Relative cover of exotic species	⇩
	Annual brome cover	⇩

Table 4.8.10 (continued). Vegetation overall condition.

Indicators	Measures	Condition
Riparian forest	Plains cottonwood stand seral stage	🔴
	Percent of 20 riparian plots with native deciduous seedlings	🟢
Overall condition for all indicators and measures		🟡

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4.9. Breeding Birds

Black-billed magpies are an at-risk species in Nebraska. USFWS photo, Wikimedia Commons 2015.

4.9.1. Background and Importance

Birds are a critical natural resource that provide an array of ecological, aesthetic, and recreational values. As a species-rich group, they encompass a broad range of habitat requirements, and thus may serve as indicators of landscape condition (O'Connell et al. 2000). Bird communities can reflect changes in habitat (Canterbury et al. 2000), climate (Walther et al. 2002), ecological interactions (e.g., Gurevitch and Padilla 2004), and other factors of concern in ecological systems.

Parks may serve as reference sites for interpreting regional and national population trends, and the NPS has made a commitment to monitoring landbirds (Gitzen et al. 2010). Protecting birds is key to park integrity, and park units may serve as "islands" of intact habitat for birds regionally (e.g., Goodwin and Shriver 2014).

In 2013, the NPS Northern Great Plains Network (NGPN) began region-wide landbird monitoring in collaboration with the Bird Conservancy of the Rockies (formerly the Rocky Mountain Bird Observatory) and as part of a larger effort, the Integrated Monitoring in Bird Conservation Regions (IMBCR) program. The objectives of these ongoing monitoring efforts are to 1) estimate the proportion of sites occupied (occupancy estimates) for breeding birds, 2) identify changes in community dynamics, 3) estimate changes in the densities of common breeding landbirds, and 4) relate changes in environmental parameters to bird population trends.

History of Bird Surveys at Scotts Bluff National Monument

Scotts Bluff NM lists 127 species as "present" in the park and 36 species as "unconfirmed" (https://irma.nps.gov/NPSpecies). An inventory of Scotts Bluff NM occurred in 1919, but these data were not available at the time of this assessment. The first intensive inventory of birds was conducted in the 1980s. Cox and Franklin (1989) detected 96 bird species through daytime and nighttime sampling in 1986 and opportunistic sightings in 1987 and 1988. They reported the residency status of each species at the park and the relative abundance within seven habitat types. They showed that species richness and overall abundance were greatest in canal riparian habitat.

Forty-eight years of winter bird surveys (Christmas bird counts starting in 1949) were previously analyzed for trends in bird populations (Johnsgard 1998). This analysis revealed that, on average, 42 species were observed each winter (range 28–50), with 66 species observed over the entire period of the analysis. As part of developing the current inventory and monitoring program in the NGPN, bird surveys were conducted in 1999 throughout Scotts Bluff NM (Powell 2000). Thirty-six species were detected in point counts and 64 species were seen overall.

In the NGPN group of parks to which Scott Bluff NM belongs, landbirds are considered a "vital sign" of park ecosystems (Gitzen et al. 2010). Monitoring of landbirds began in 2013 with help from the Bird Conservancy of the Rockies. This conservation group established 89 permanent point count locations, detecting 47 species in 2013, 62 species in 2014, and 61 species in 2015.

General Trends

Scotts Bluff NM is located within the shortgrass prairie bird conservation region (BCR 18; Figure 4.9.1). The shortgrass prairie is an arid region with limited vegetation height and diversity. Some of North America's highest priority birds breed here, including the grasshopper sparrow (Figure 4.9.2), a species that can be found at Scotts Bluff NM.

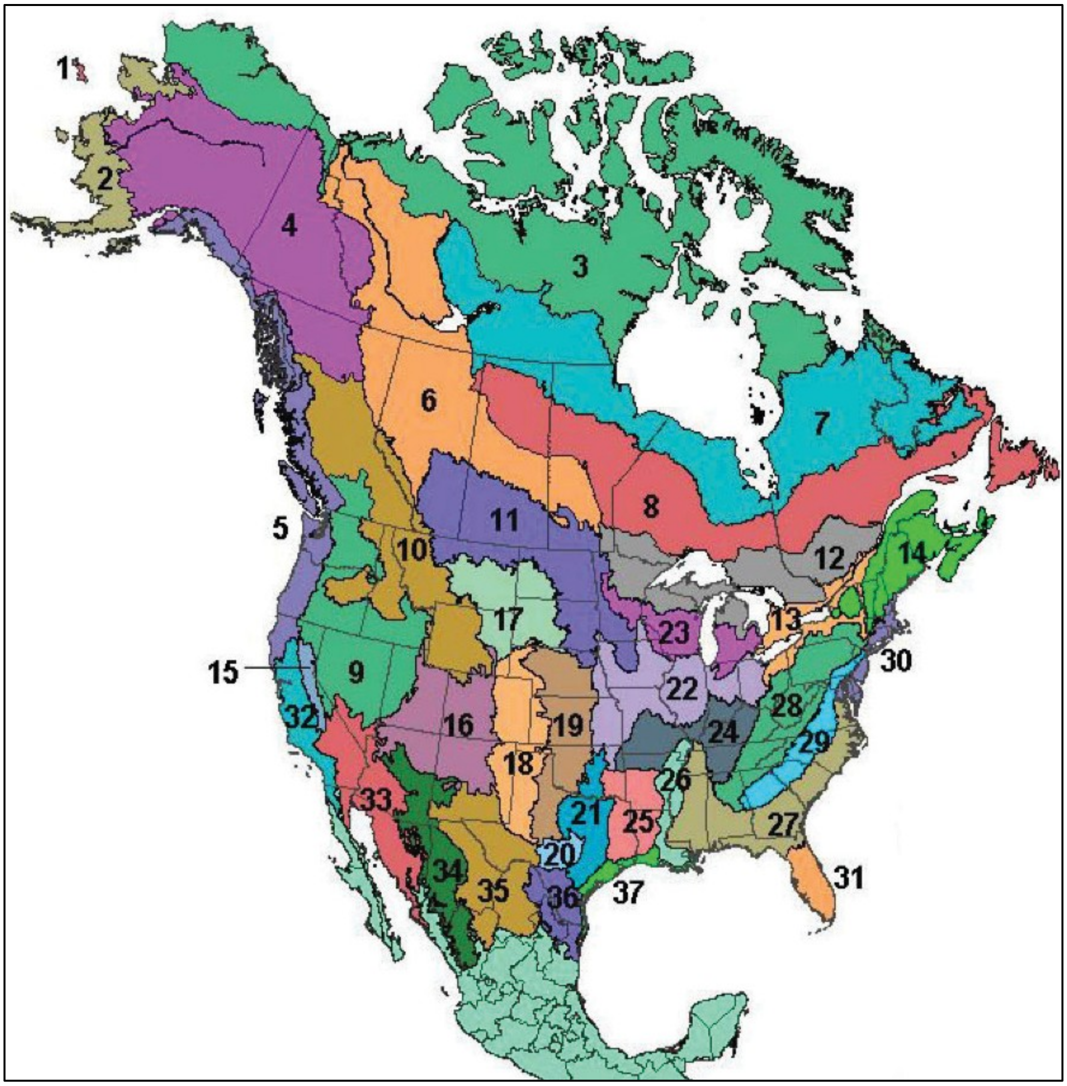

Figure 4.9.1. Bird conservation regions of North America (BCRs; www.nabci-us.org/map.html). Scotts Bluff National Monument is located within BCR18, the shortgrass prairie bird conservation region.

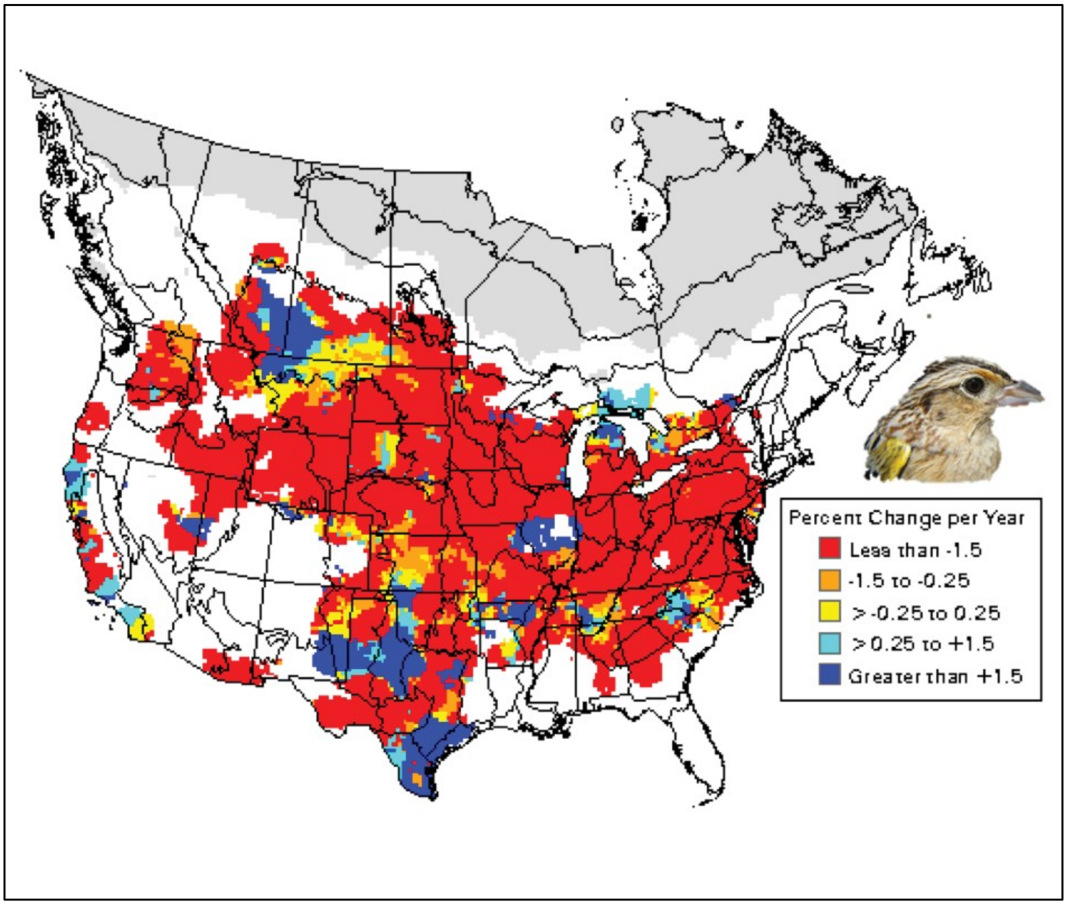

Figure 4.9.2. Percent change per year for the grasshopper sparrow in North America. The grasshopper sparrow is an example of a grassland species that has been declining for a variety of reasons, including habitat loss and degradation. This map shows population trends from 1963–2013 (Map courtesy of USGS and BBS, image from Wikipedia).

A large proportion (~40%) of habitat at Scotts Bluff NM is native prairie. Most grassland bird species are declining in North America (Peterjohn and Sauer 1995, Sauer et al. 2003). While the overall trend for birds in the shortgrass BCR is stable (Sauer et al. 2003), all of the grassland-obligate species there exhibit negative trends (Sauer et al. 2003, Sauer and Link 2011). The causes of declines in species such as the grasshopper sparrow are poorly understood but could be related to a reduction in the diversity of native herbivores, such as bison and prairie dogs that create high quality habitat for many grassland bird species. Scotts Bluff NM is small, but it contains a variety of habitat types in addition to grasslands (Figure 4.9.3). One source of important bird habitat is the riparian area along the northern border of the park. Loss of riparian habitat is a major cause of bird declines regionally (DeSante and George 1994).

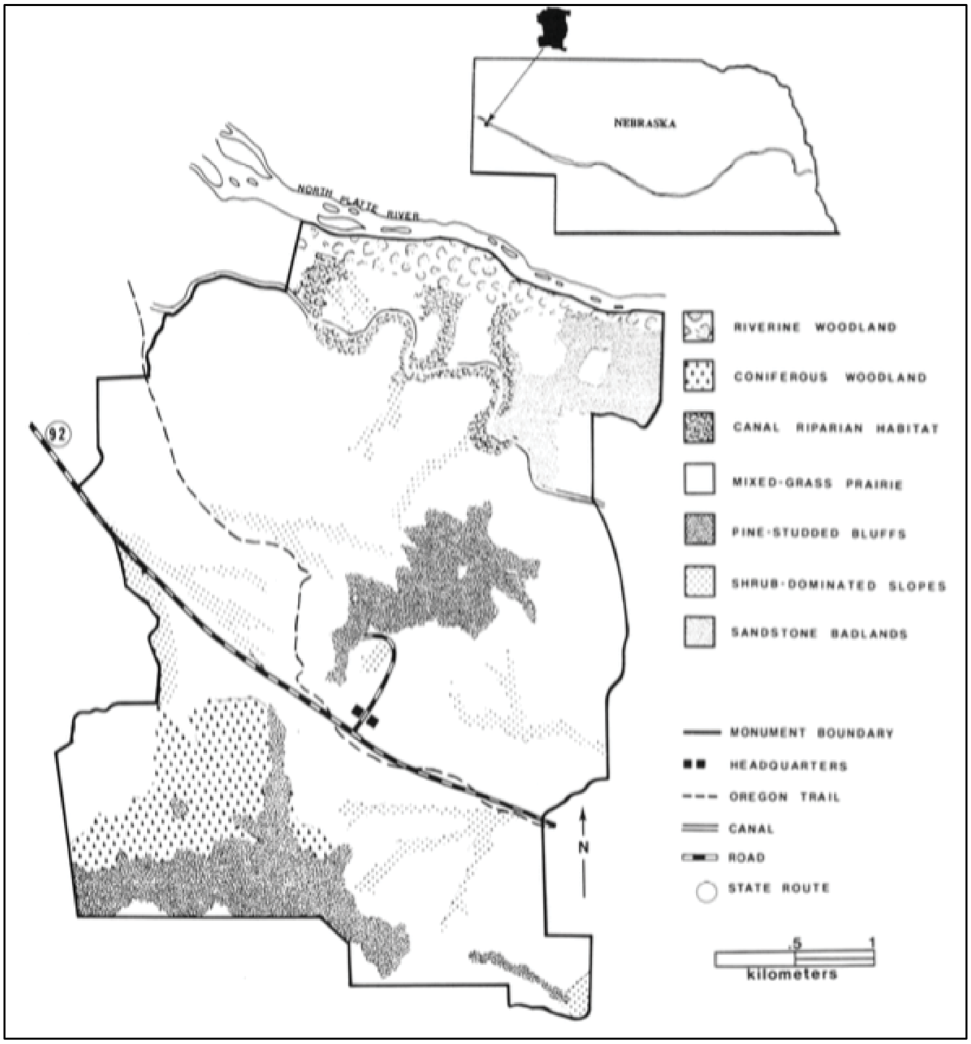

Figure 4.9.3. Habitat types in Scotts Bluff NM. Scotts Bluff NM provides diverse habitats for birds and other wildlife (Cox and Franklin 1989).

4.9.2. Resource Standards

The Migratory Bird Treaty Act of 1918 (16 U.S.C. 703-712; Ch. 128; July 13, 1918; 40 Stat. 755) protects hundreds of bird species by prohibiting the take (i.e., to kill, injure, harm, annoy, etc.) of any species of migratory bird without a permit. This act provides formal protection to most bird species that can be found at Scotts Bluff NM. Of the 124 species considered to be present at Scotts Bluff NM, 21 species are considered species of federal concern. However, none of the birds at Scotts Bluff are formally protected under the Endangered Species Act. Both bald and golden eagles are protected under the Bald and Golden Eagle Act.

Partners in Flight (PIF) maintains a list of all bird species in North America with population estimates and “priority ranking” scores. These scores are a quantitative way of assessing risk based on population trends and species traits. PIF also publishes a Watch List that identifies the species most in need of conservation action based on priority rankings (Figure 4.9.4). There are no Watch List species in Scotts Bluff NM.

Figure 4.9.4. Perched lark bunting. Based on the Partners in Flight ranking system, the lark bunting was the highest priority species observed at Scotts Bluff NM in 2015 (NPS).

Nebraska's State Wildlife Action Plan contains a list of species of greatest conservation need. Five of 22 species designated as globally or nationally at risk (Tier I At-risk Species, those species of greatest conservation need) can be found at Scotts Bluff NM: Bell's vireo, Brewer's sparrow, burrowing owl, loggerhead shrike, and short-eared owl. Additionally, 14 of 61 species designated as at-risk within Nebraska (Tier II At-risk Species) can be found at Scotts Bluff (Figure 4.9.5).

Figure 4.9.5. A black-billed magpie. The black-billed magpie is a Nebraska Tier II at-risk species frequently observed in 2015 (Wikipedia photo).

4.9.3. Methods

Indicators and Measures

We assessed overall bird condition based on three indicators: species diversity, species abundance, and conservation value. Each of these indicators contributes to different aspects of bird condition. We used measurements specified by the scientific literature and expert opinion. There was no clear or accepted standard for assigning indicator conditions, so we instead illustrate a framework that could be used to assess bird condition over time.

Indicator: Species Diversity

Species diversity informs us about the composition and number of bird species. There are a variety of ways to measure species diversity, including the most basic measure: the number of species, or species richness.

Measure of Species Diversity: Species Richness

Species richness is a basic measure of ecological diversity and integrity. Apart from the inherent value of species richness, a greater number of species also tends to reflect the quality and diversity of habitat. Because the study design of the current monitoring effort is the same from year to year, we can use data from these surveys as comparable estimates of the number of species observed over time.

Sampling effort (number of point-transects conducted) and the number of species observed may vary from year to year at Scotts Bluff NM. Imperfect detection of species can make inter-annual comparisons of species lists unreliable indicators of species that were actually present in the park unit. Occupancy estimates take these factors into account, and incorporate imperfect detection in estimates. The particular type of model used is a multi-scale occupancy model (Nichols et al. 2008; Pavlacky et al. 2012). In the case of Scotts Bluff NM, occupancy estimates (Nichols et al. 2008; Pavlacky et al. 2012) can be interpreted as the proportion of the park in which the species is expected to be found. These values may range from zero to one. Even if a species was not detected in a given year, it may have a non-zero probability of occupying the park. An occupancy estimate of one would indicate that a particular species would be expected to occur in all locations.

These occupancy estimates provide one measure of species richness (A. Green, personal communication). By summing the occupancy estimates across all species, we generated a value that we interpreted as the average species richness across the park unit, or the number of species expected in a particular survey location. We present this value with its standard error, which describes the precision of the species richness estimate. We calculated standard error using the delta method (Powell 2007). We first calculated the variance of each species-specific estimate of occupancy (standard error squared), summed the variance estimates across all species, and calculated the standard error of the richness estimates (square root of the summed variances). For our calculation of average species richness, we assigned birds that were observed but for which occupancy estimates were lacking (26–39 % of species) a value of 0.01 and a standard error estimate of 0.01.

In general, species lacking occupancy estimates were observations of a single individual in a given year. In the future, the Avian Data Center will likely provide occupancy estimates for all species observed. All data are freely available online (http://rmbo.org/v3/avian/ExploretheData.aspx).

Indicator: Species Abundance

Bird population abundance can respond to both short- and long-term drivers of habitat quality, such as vegetation structure, prey abundance, and competition or predation pressures.

Measure of Species Abundance: Mean Density

The Bird Conservancy tracks number of individuals per square kilometer over time along with precision estimates. Density estimates are derived from count data that have been corrected for imperfect detection (under-detection). This type of model assumes that there are no misidentifications of species that are not present (i.e., that there are no false positive observations).

Indicator: Conservation Value

Maximizing species richness and density is generally desirable, but these measures do not tell us about the identities of the bird species present. For example, we would value a bird community of native species more highly than one with the same number of non-native species. Similarly, one would not typically manage for increased densities of introduced nest parasitic bird species. This consideration led us to ask what we know about the conservation value of individual species, or of Scotts Bluff NM as a whole. The PIF database offers a way to assess the value of species or groups of species through the priority ranking list.

There have been a number of attempts at creating indices to rate bird communities at different spatial scales. One example is the bird community index developed for portions of the eastern United States (O'Connell et al. 2000). This index requires placing birds into guilds, and is a good indicator of habitat quality condition in those regions. This approach has been applied to National Parks in the Northeast and National Capital NPS regions to compare bird communities between parks and outside protected areas (Goodwin and Shriver 2014). This index has not been developed for the region in which Scotts Bluff NM resides, so we were unable to use this approach for the Natural Resource Condition Assessment.

We used an alternative approach to assess the conservation value of bird communities, rooting out calculations in the Partners in Flight (PIF) priority rankings (Hunter et al. 1993). Bird species in the PIF database are prioritized at both the regional (bird conservation region) and continental scales (Partners in Flight Science Committee 2012). Each species is independently ranked from one (low vulnerability) to five (high vulnerability) along the Partners in Flight Species Assessment Factors, and these category rankings may be summed to give an overall priority score for the species (from the Partners in Flight Handbook on Species Assessment Version 2012 [Committee 2005]):

- **Breeding Distribution (BD):** indicates vulnerability due to the geographic extent of a species' breeding range on a global scale.
- **Population Size (PS):** indicates vulnerability due to the total number of adult individuals in the global population.
- **Population Trend (PT)**: indicates vulnerability due to the direction and magnitude of changes in population size within North America since the mid-1960s.
- **Threats to Breeding (TB):** indicates vulnerability due to the effects of current and probable future extrinsic conditions that threaten the ability of populations to survive and successfully reproduce in breeding areas within North America.
- **Relative Density (RD)**: reflects the mean density of a species within a given BCR relative to density in the single BCR in which the species occurs in its highest density.

The criteria are assessed either at the level of the entire species range (global score) or the level of the region (regional score). These criteria are breeding distribution (global score), population size (global score), population trend (regional score), threats to breeding (regional score), and breeding relative density (regional score). The sum of these values is the regional concern score for breeding. The range of possible scores for each species at the level of the bird conservation region therefore is 5–25, with five being the lowest priority ranking and 25 being the highest.

The Partners in Flight species concern scores may be used to set conservation priorities (Carter et al. 2000). PIF-based conservation value scores may be refined by the use of species abundance to weight the PIF rankings (Nuttle et al. 2003). A comparison of the bird community index and the PIF-based conservation value approaches demonstrated the utility of the PIF method (O'Connell 2009); the two indices were strongly correlated, even when using a simple sum of PIF scores. All data are freely available online (http://rmbo.org/pifdb).

Measure of Conservation Value: Average Priority Rankings

We averaged the regional ranking for each species, excluding introduced species. Other approaches to assessing conservation value include summing rankings (O'Connell 2009), or weighting scores by abundance or occupancy (Nuttle et al. 2003). For simplicity's sake and ease of interpretability, we present an average ranking with its standard error here.

Data Collection and Sources

Field Protocol

Monitoring of birds at Scotts Bluff NM began in 2013 following a standardized protocol (Beaupré et al. 2013). Up to 89 permanent point-transect (Buckland et al. 2001) locations were surveyed each year (Figure 4.9.6). Each of these locations was surveyed for birds seen or heard calling during morning hours (beginning 30 minutes before local sunrise) at the height of the breeding season (May 15 – June 14; Beaupre et al. 2013). This approach tends to under-sample certain groups such as nocturnal birds, while sampling groups such as passerines well (Buckland 2006). By recording the distance to each observation, researchers are able to create a detection function that can be used in the calculation of bird densities (Buckland 2006). Repeat observations at sampling locations allow researchers to correct for under-detection of the number of sites occupied (MacKenzie et al. 2002).

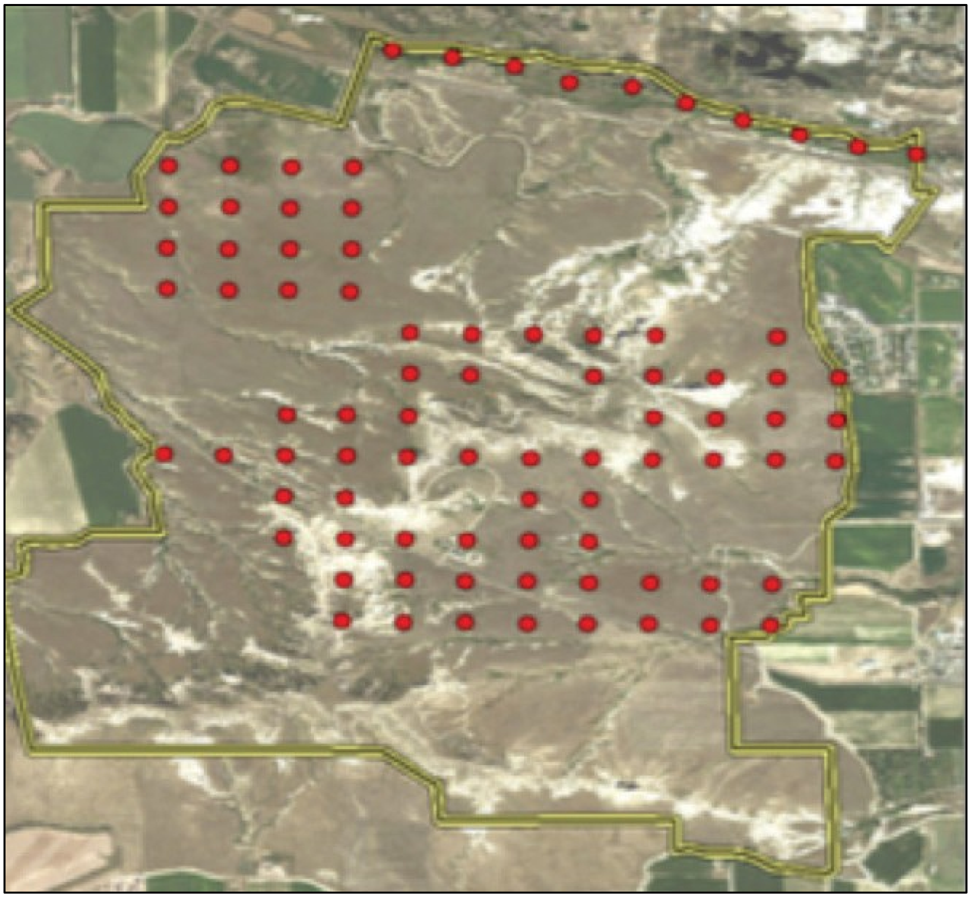

Figure 4.9.6. Bird monitoring point-transect locations at Scotts Bluff NM, of which there are 89. The surveys are located in diverse habitats: woodlands, prairie, riparian habitat, pine bluffs, shrub slopes, and badlands.

Data Management and Availability

For this assessment, we used data from two online database sources. Data on all bird species from monitoring surveys are stored on the Rocky Mountain Avian Data Center website and managed by the Bird Conservancy of the Rockies. Data for priority rankings of landbirds are stored on the Partners in Flight Species Assessment Database website and also managed by the Bird Conservancy.

Quantifying Bird Condition, Confidence, and Trend

Indicator Condition

To assess indicator condition, we used methods informed by expert opinion and described by Nuttle et al. (2003). For species not formally protected by the Endangered Species Act, calculating bird condition is not straightforward. To calculate a condition score, we would have needed empirically derived estimates of the levels of species diversity, species abundance, and conservation values that revealed the condition of the species within the park unit. Those criteria are absent from the literature, and assigning a condition score without them would have been unwarranted. In lieu of condition scores, we present values for indicators based on the best available data; natural resource managers can reference these values in current and future park planning.

The results for Scotts Bluff NM are presented along with a comparison of the same calculations at the level of the bird conservation region. IMBCR is working to develop complete coverage of BCR18, but is still in the process of adding new monitoring locations. For this reason, BCR-wide estimates were not currently available. Here we present results for the Colorado portion of BCR18, since this state accounted for 75% of all sampling locations in 2015.

Occupancy, density, and count data were extracted from the Avian Data Center for using “NE-BCR18-SB” as the “individual stratum” for Scotts Bluff National Monument and the “super stratum: CO-BCR18” for the Colorado portion of BCR18.

Indicator Trend

Calculating a trend estimate requires sufficient statistical power and surveys were designed with this in mind. However, detecting a trend based on the IMBCR survey design will likely require at least five years of continued monitoring. The monitoring program at Scotts Bluff NM is relatively new, having commenced in 2013, so data were not sufficient at the time of this assessment to calculate trends in bird populations.

Indicator Confidence

Confidence ratings were based on data availability (number of years) and data quality (e.g., survey design, estimation techniques). We gave a rating of *High* confidence when surveys were conducted regularly, data were collected recently, and the data were collected methodically. We assigned a *Medium* confidence rating when surveys were not conducted regularly, data were not collected recently, or data collection was not repeatable or methodical. *Low* confidence was assigned when there were no good data sources to support the condition.

Overall Breeding Bird Condition, Trend, and Confidence

We deferred to the expert scientific community to assign an overall breeding bird condition, trend, and confidence.

4.9.4. Breeding Bird Conditions, Confidence, and Trends

Species Diversity

○

Condition: Not Available
Confidence: High
Trend: Not Available

Condition

To calculate species diversity, we used results from point transect surveys conducted from 2013–2015 (Table 4.9.1, Figure 4.9.7). Across 58 point-transect locations, 46 species were observed in 2013. Across 74 point-transect locations, 43 species were observed in 2014. Across 89 point-transect locations, 61 bird species were observed in Scotts Bluff NM in 2015. Of these observations, four non-native species were observed in 2013 and 2014 (Eurasian Collared-dove, European Starling, Ring-necked Pheasant, and Rock Pigeon) with the addition of a fifth non-native species, House Sparrow, in 2015. These introduced species were excluded from richness estimates.

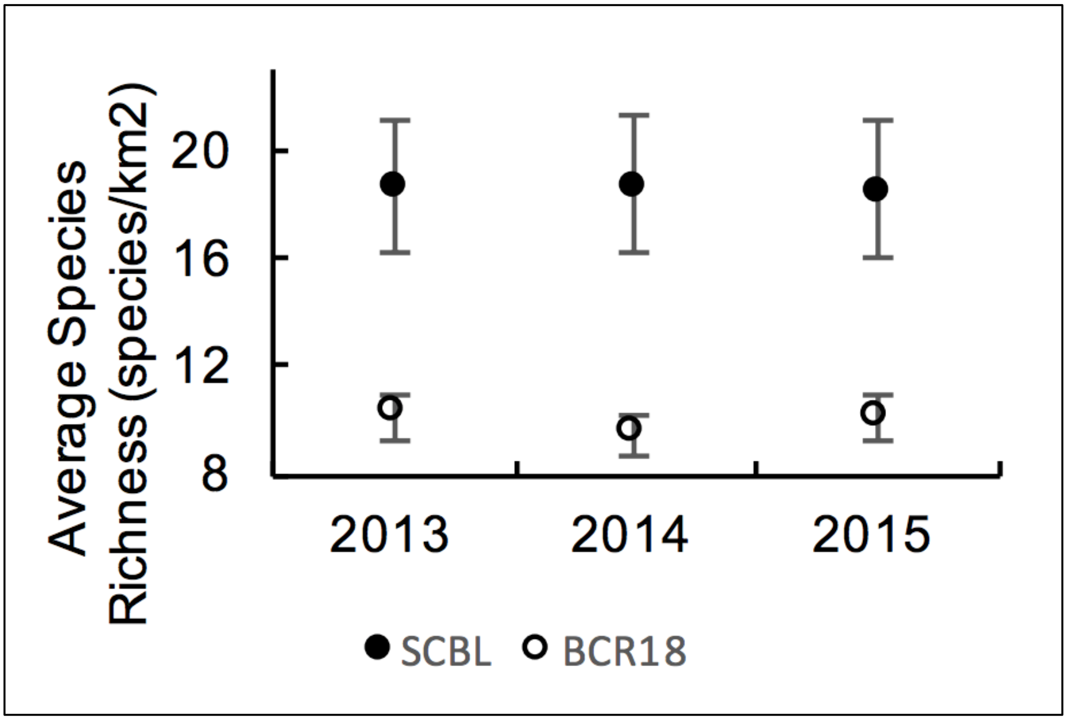

Figure 4.9.7. Average species richness with 95% confidence intervals of breeding birds within Scotts Bluff NM and the Colorado portion of the shortgrass prairie bird conservation region (BCR18).

Table 4.9.1. Average species richness of breeding birds at Scotts Bluff National Monument (SCBL) and within the Colorado portion of the shortgrass prairie bird conservation region (BCR18).

Location	Year	Number of locations surveyed	Number of species observed	Number of species with density estimates	Number of non-native species	Average density ± standard error
SCBL	2013	58	46	34	4	13.34 ± 2.85
	2014	74	43	35	4	7.41 ± 1.01
	2015	89	61	43	5	7.21 ± 1.15
BCR18	2013	971	197	87	5	2.61 ± 0.15
	2014	938	178	97	5	3.07 ± 0.21
	2015	1832	187	90	5	3.50 ± 0.25

While species richness at Scotts Bluff NM was nearly double the richness of the BCR in which the park is situated, reference criteria were unavailable to identify what amount of richness constituted good or bad condition (Table 4.9.1, Figure 4.9.7). Condition for species richness was *Not Available*.

Confidence

We calculated species diversity from high quality occupancy estimates from three years of monitoring data from up to 89 locations within the park. The confidence was *High*.

Trend

There were three years of point transect data available from Scotts Bluff NM. The lowest number of species (47) was observed in the year when the fewest number of point count surveys were conducted (58 of 89). It is too early to calculate a trend in species richness, but the richness estimates were consistent among the three survey years.

Species Abundance

Condition: Not Available
Confidence: High
Trend: Not Available

Condition

We examined species abundance across three years of monitoring data (Table 4.9.2, Figure 4.9.8). We used available density estimates for native species to calculate an average density for the study area (number of birds/kilometer^2). In general, density estimates should be fairly sensitive to short-term changes in habitat quality, such as food availability.

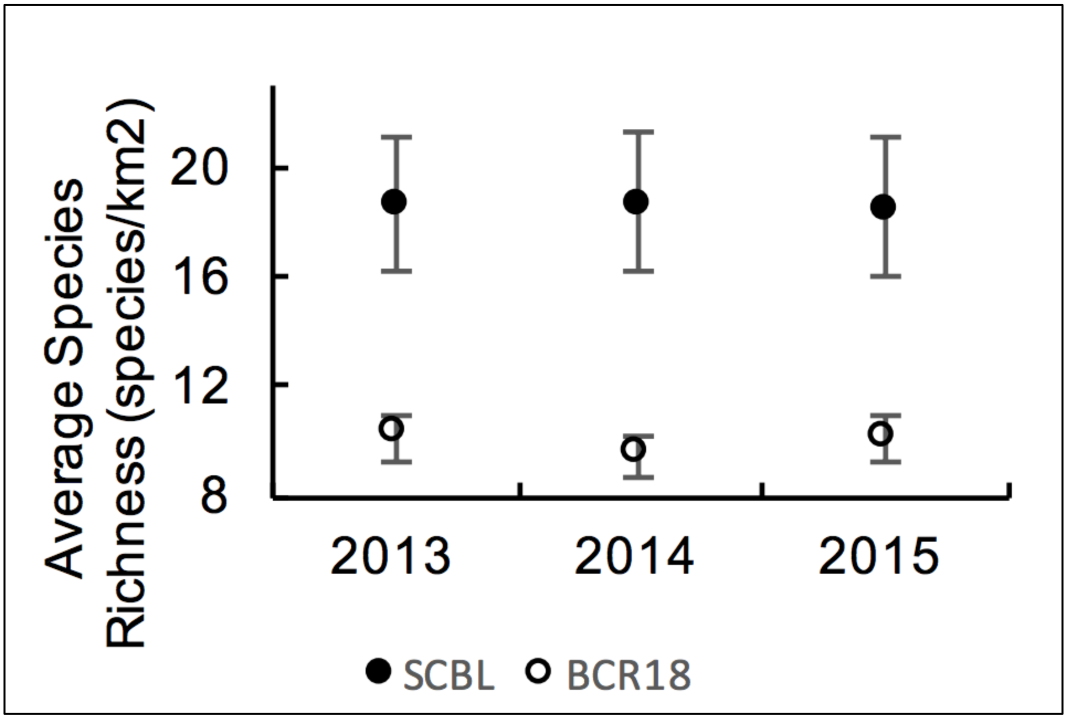

Figure 4.9.8. Average density with 95% confidence intervals of breeding birds within Scotts Bluff NM and the Colorado portion of the shortgrass prairie bird conservation region (BCR18).

Table 4.9.2. Average density of breeding birds at Scotts Bluff NM (SCBL) and within the Colorado portion of the shortgrass prairie bird conservation region (BCR18). The number of species is all native species for which there were density estimates.

Location	Year	Number of locations surveyed	Number of species observed	Number of species with density estimates	Number of non-native species	Average density ± standard error
SCBL	2013	58	46	34	4	13.34 ± 2.85
	2014	74	43	35	4	7.41 ± 1.01
	2015	89	61	43	5	7.21 ± 1.15
BCR18	2013	971	197	87	5	2.61 ± 0.15
	2014	938	178	97	5	3.07 ± 0.21
	2015	1832	187	90	5	3.50 ± 0.25

While species abundance at Scotts Bluff NM was nearly double species abundance of the BCR in which the park is situated, reference criteria were unavailable to identify what abundance numbers constituted good or bad condition. Condition for species abundance was *Not Available*.

Confidence

Species abundance was calculated from high-quality occupancy estimates from three years of monitoring data from up to 89 locations within the park. The confidence was *High*.

Trend

There were three years of point count data available from Scotts Bluff NM. The highest average densities were observed in 2013 (approximately 13 birds/kilometer^2). The most abundant bird species were white-throated swift in 2013 (91 birds/kilometer^2), common grackle in 2014 (39 birds/kilometer^2), and grasshopper sparrow in 2015 (59 birds/kilometer^2). It is too early to calculate a trend in species abundance, but the density estimates varied among the three survey years.

<u>Conservation Value</u>

○

Condition: Not Available
Confidence: High
Trend: Not Available

Condition

To assess conservation value, we used park monitoring data combined with Partners in Flight priority rankings (Table 4.9.3, Figures 4.9.9 and 4.9.10). The combination of more species present at a park and/or the higher priority rankings of individual species increases the conservation value of the park unit.

Table 4.9.3. Conservation value score of native breeding landbirds at Scotts Bluff NM and within the shortgrass prairie bird conservation region (BCR18).

Location	Year	Number of locations surveyed	Number of species observed	Number of species with density estimates	Average density ± standard error	Number of non-native species
SCBL	2013	58	46	41	4	10.56 ± 0.27
	2014	74	43	36	4	10.53 ± 0.43
	2015	89	61	51	5	10.84 ± 0.34
BCR18	2013	971	149	110	5	11.18 ± 0.24
	2014	938	145	106	5	11.15 ± 0.23
	2015	1832	159	121	5	11.18 ± 0.22

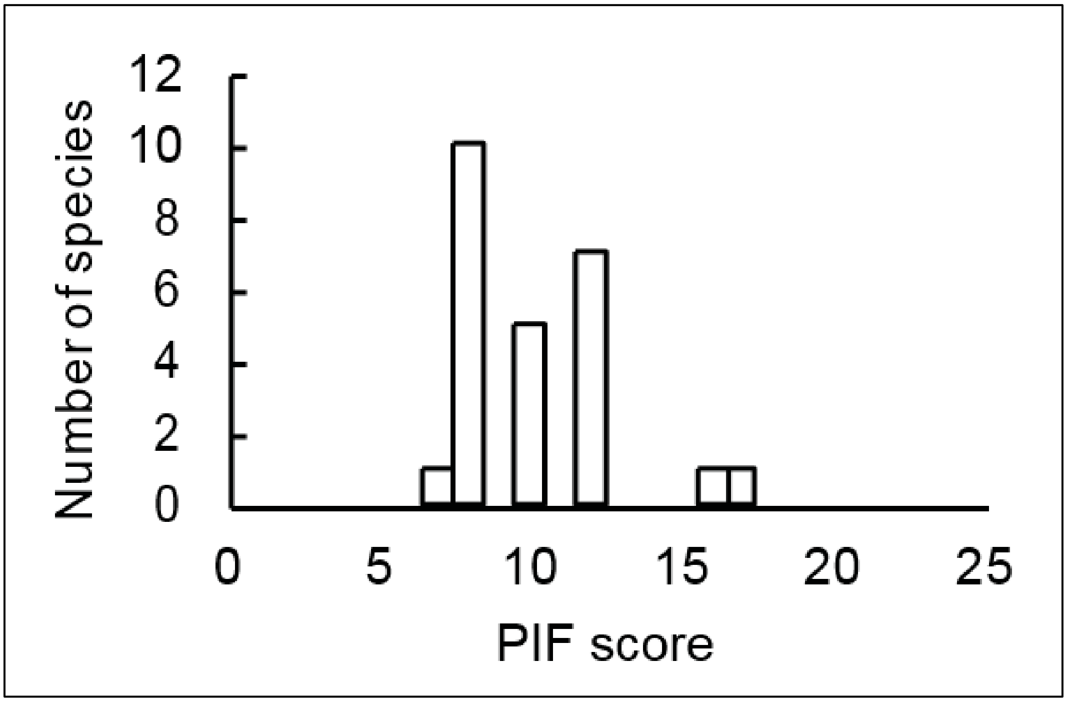

Figure 4.9.9. The distribution of Partners in Flight priority rankings for landbird species seen in 2015 at Scotts Bluff NM. The average ranking was 10.6 ± 0.3 out of a total possible score of 25. We assigned five non-native species a rank of zero. The lowest ranked native species was American robin with a score of six. The highest ranked native species was lark bunting with a score of 17.

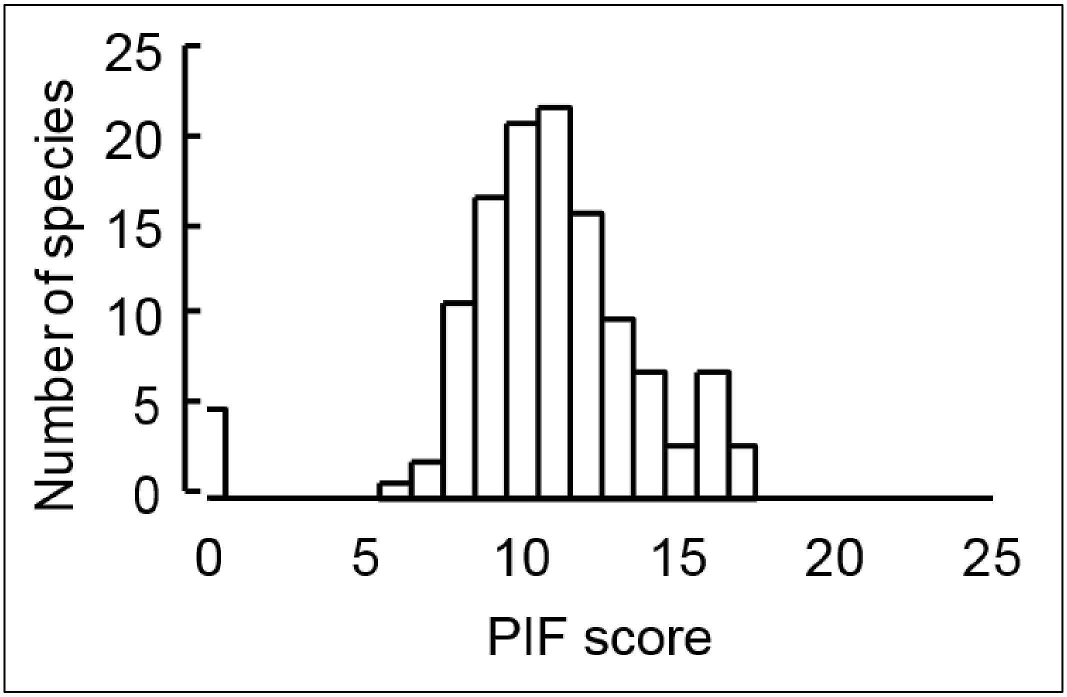

Figure 4.9.10. The distribution of Partners in Flight priority rankings for landbird species seen in 2015 within the Colorado portion of BCR18. The average ranking was 11.2 ± 0.2 out of a total possible score of 25. We assigned five non-native species a rank of zero. The lowest ranked native species was American robin with a score of six. The highest ranked native species were ferruginous hawk, lark bunting, and prairie falcon with scores of 17.

The BCR-wide average priority ranking for all landbirds known to occur was 11.24 (n = 194). In 2013, six landbird species for which PIF rankings were unavailable were reported within the BCR (blackpoll warbler, olive-sided flycatcher, orange-crowned warbler, rose-breasted grosbeak, white-crowned sparrow, and Wilson's warbler). In 2014, eight landbird species for which PIF rankings were unavailable were reported within the BCR (clay-colored sparrow, Lincoln's sparrow, olive-sided flycatcher, rose-breasted grosbeak, Swainson's thrush, veery, white-crowned sparrow, and Wilson's warbler). In 2015, eight landbird species for which PIF rankings were unavailable were reported within the BCR (clay-colored sparrow, Lincoln's sparrow, MacGillivray's warbler, northern goshawk, orange-crowned warbler, ruby-crowned kinglet, Swainson's thrush, and white-crowned sparrow).

While conservation values at Scotts Bluff NM were similar to those of the BCR in which the park is situated, reference criteria were unavailable to identify what conservation values constituted good or bad condition. Condition for conservation value was *Not Available*.

Confidence

Species abundance and occupancy were obtained from high-quality estimates from three years of monitoring data from up to 89 locations within the park. Partners in Flight priority rankings are reviewed periodically and are based upon the best available data and expert opinion. The confidence for both of these data sources was *High*.

Trend

PIF rankings may be updated periodically, but are not designed as a measure for assessing trend in risk. Occupancy/density estimates are calculated annually, but there are too few years to be able to calculate a trend in these parameters.

Breeding Birds Overall Condition

We did not assign an overall breeding bird condition to Scotts Bluff NM, due to a lack of clear or accepted standards for doing so (Tables 4.9.4 and 4.9.5). It may be possible to assign a condition in the future with the eventual availability of trend data or with clearly defined goals for the bird community or individual species. The total score for overall bird condition was *Not Available* for Scotts Bluff NM.

Table 4.9.4. Breeding Birds overall condition.

Indicators	Measures	Condition
Species diversity	Species richness	○
Species abundance	Mean density	○
Conservation value	Mean priority ranking	○
Overall condition for all indicators and measures		○

Table 4.9.5. Summary of breeding bird indicators and measures.

Indicator	Measure	Condition	Confidence	Trend	Condition Rational
Species diversity	Species richness	Not available	High	Not available	Species richness from 2013–2015 was 18.64 species/km^2. The data were collected as part of a rigorously designed monitoring program, so confidence was *High* and trend was *Not Available*.
Species abundance	Mean density	Not available	High	Not available	Mean density from 2013–2015 was 9.32 birds/km^2. The data were collected as part of a rigorously designed monitoring program, so confidence was *High* and trend was *Not Available*.
Conservation value	Mean priority ranking	Not available	High	Not available	The mean priority ranking from 2013–2015 was 10.6. The data were gathered from a rigorous assessment, so confidence was *High* and trend was *Not Available*.

Confidence

Confidence was *High* for all three indicators. The score for overall confidence was 100 points, which met the criteria for High confidence in overall bird condition.

Trend

Trend data were *Not Available* for any indicators, so overall trend for birds was *Not Available*. While trend data were unavailable for Scotts Bluff NM, the following section presents some more general BCR trend data for high priority species and non-native species found in the park unit.

Top-ranked Priority Species

The top three priority species observed at Scotts Bluff NM in 2015 were lark bunting, grasshopper sparrow, and American kestrel. The grasshopper sparrow was the most abundant and widely distributed of these three species (Table 4.9.6). We present general trends for these priority species using BBS data at the level of the bird conservation region.

Table 4.9.6. Occupancy and density estimates for the top-ranked priority species in Scotts Bluff NM in 2015. RCS-b is the PIF regional priority ranking, count is the number of individuals observed, Psi is the occupancy estimate, %CV is the coefficient of variation, D is the density estimate, and N is the estimated population size at Scotts Bluff NM.

Common Name	RCS-b	Count	Psi	% CV	D	% CV	N
Lark Bunting	17	2	0.143	93	0.31	96	4
Grasshopper Sparrow	16	83	0.725	24	59.77	40	777
American Kestrel	15	6	0.556	64	0.49	69	6

Breeding Bird Survey results and analyses, including species trends by bird conservation regions, are available online (Sauer et al. 2014). These results include a yearly percentage change in abundance, credible intervals, and an annual index of relative abundance (the mean count of birds on a typical route in the region for a year). The following figures show changes in the relative abundance index since the start of BBS surveys in the region. The lark bunting and grasshopper sparrow have both experienced significant regional declines (Figures 4.9.11 and 4.9.12). The American kestrel appears to be stable in the shortgrass region based on BBS data (Figure 4.9.13), but received high ranks for regional population trend (four out of five) and regional density (five out of five). Non-native priority species in Scotts Bluff NM include house sparrows, ring-necked pheasants, rock pigeons, European starlings, and Eurasian collared-doves (Figure 4.9.14).

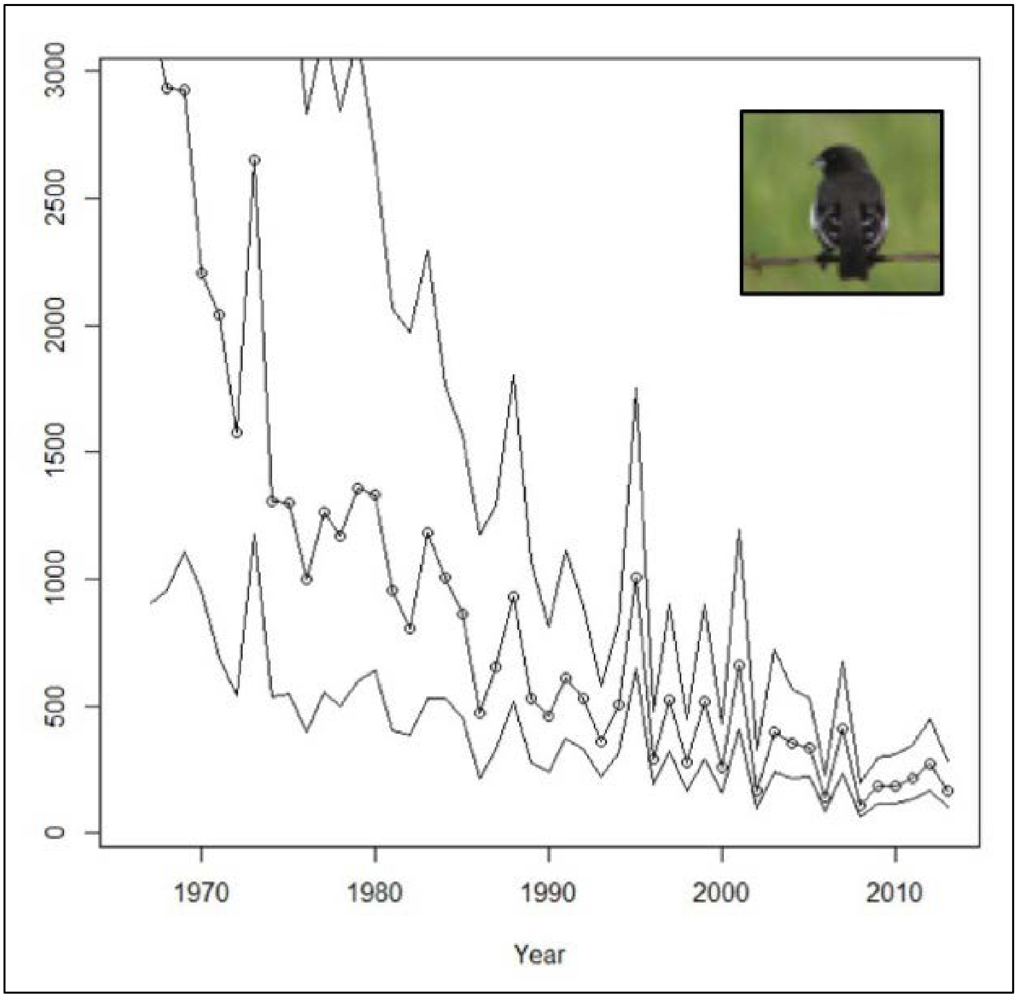

Figure 4.9.11. Abundance trends for the lark bunting within the shortgrass prairie bird conservation region for 1968 to 2013. The lark bunting has experienced an average 6.2% (95% credible interval of -9.2 to -3.6) annual decrease in abundance.

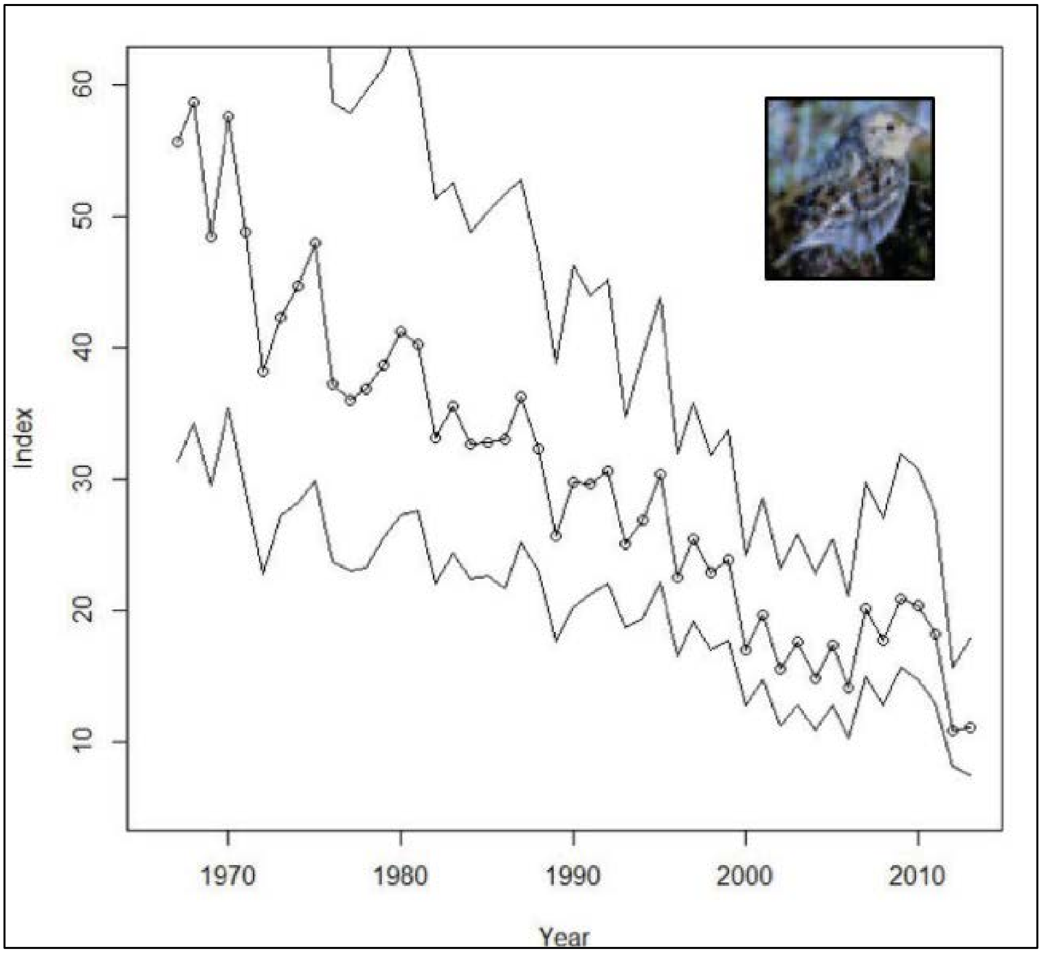

Figure 4.9.12. Abundance trends for the grasshopper sparrow within the shortgrass prairie bird conservation region from 1968 to 2013. The grasshopper sparrow has experienced an average 3.4% (95% credible interval: -5.0 to -2.0) annual decline.

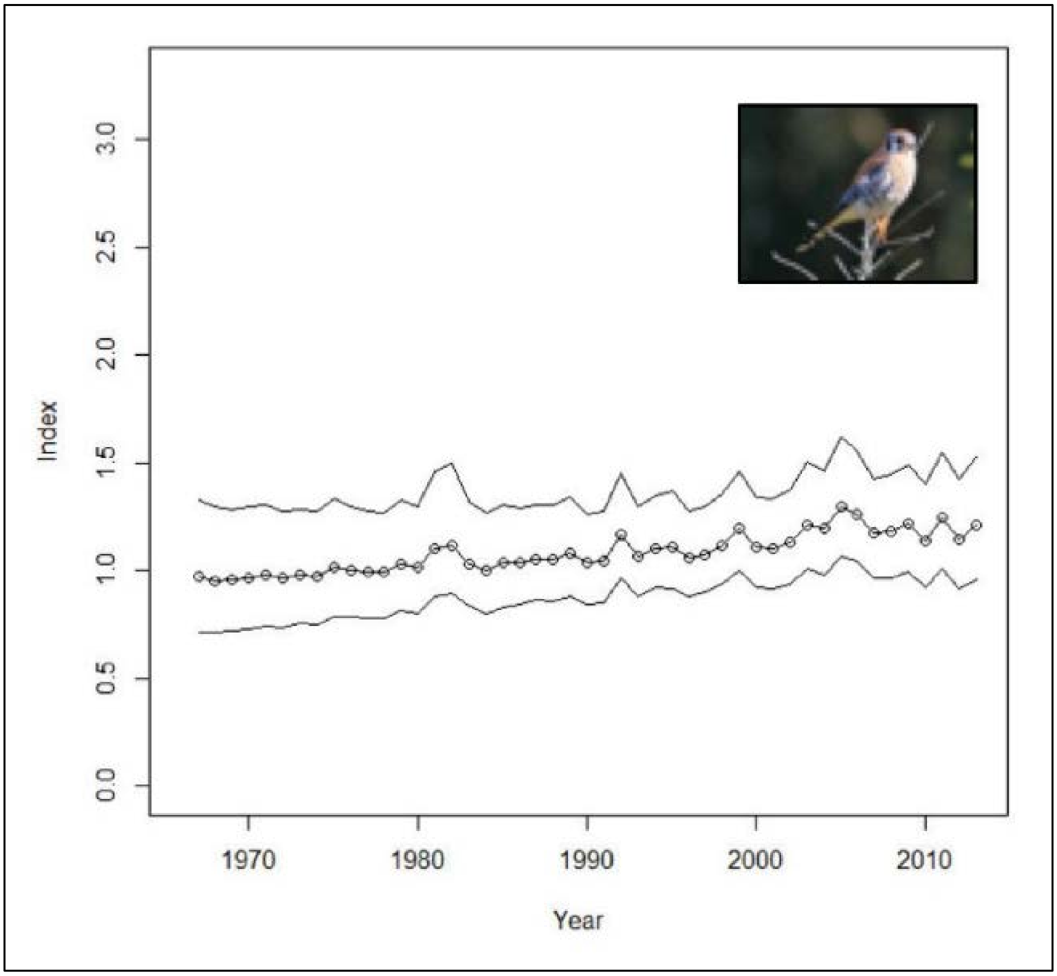

Figure 4.9.13. Abundance trends for the American kestrel within the shortgrass prairie bird conservation region from 1968 to 2013. American kestrel populations have remained stable (0.5% annual increase, 95% credible interval: -0.4 to 1.5).

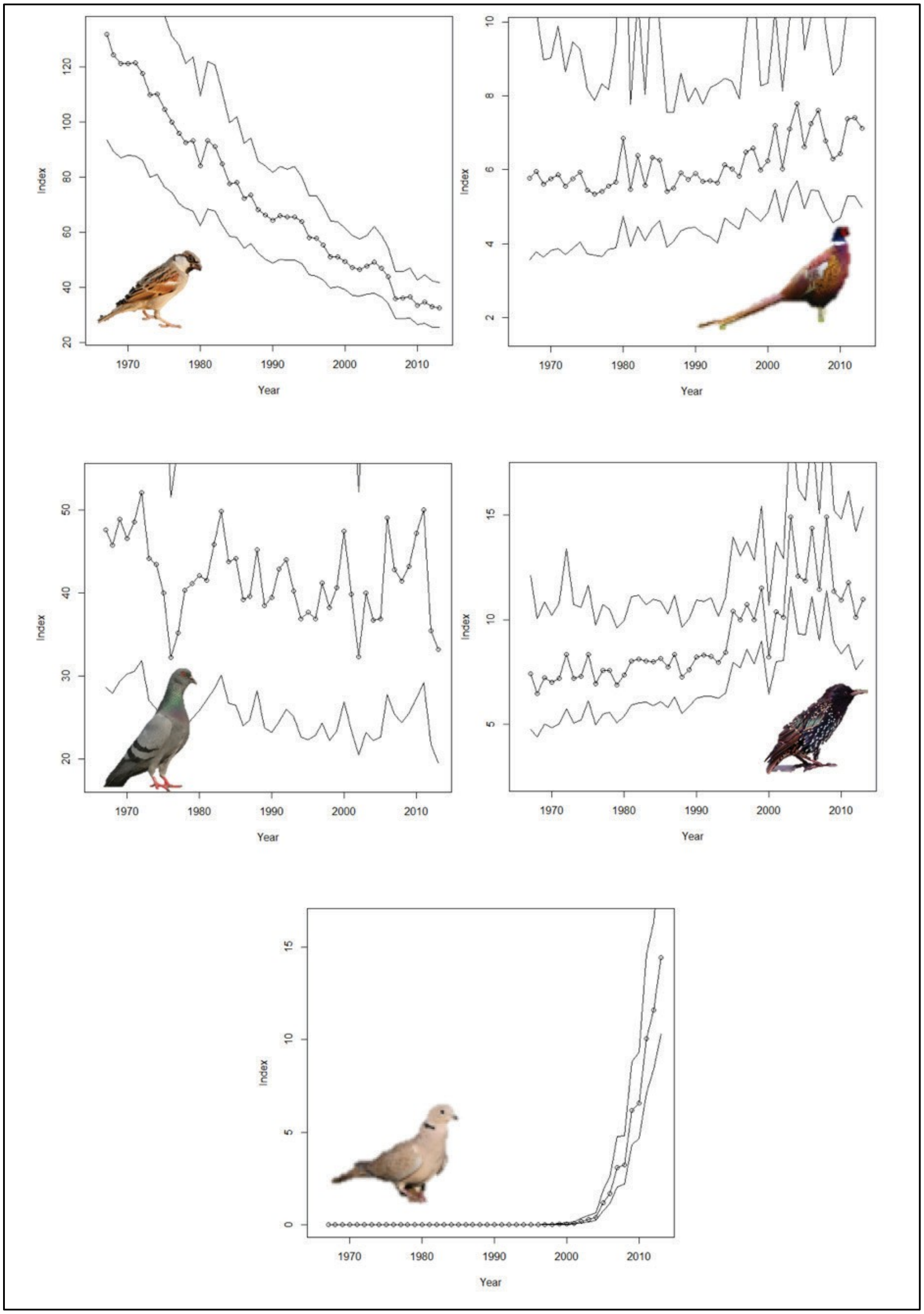

Figure 4.9.14. Region-wide trend data for five non-native species found at Scotts Bluff NM. From the top left: the house sparrow (PIF rank 12) has experienced significant declines in the shortgrass prairie since the 1960s. Ring-necked pheasant (PIF rank 14) and rock pigeon (PIF rank 8) populations have remained stable in the shortgrass region. European starling (PIF rank 8) populations have remained stable over the long-term, but may have been decreasing over the last decade. The Eurasian collared-dove (PIF rank 7) has increased significantly in the region.

The breeding bird survey regional trends presented below show all available data for each species within the shortgrass bird conservation region. The vertical axis represents the relative abundance index, with the point estimate indicated by a circle. The 95% credible interval is indicated by the bounding lines. Other top-priority species assumed to be present in the park, but not detected in 2015 include: prairie falcon (17), burrowing owl (16), northern harrier (16), and barn owl (15).

4.9.5. Stressors

Habitat loss and degradation are the primary causes of grassland bird declines (Peterjohn and Sauer 1995). The loss of native grasslands to agriculture, urban development, and forest regeneration amount to reductions in available habitat for grassland birds. Habitat degradation in the forms of fragmentation, grazing, fire, and intensive agricultural practices are additional factors that can cause declines in grassland bird populations. Population declines in birds are, however, rarely attributable to any one cause.

Mortalities and noise associated with roads can negatively impact bird populations (Kociolek et al. 2011). Climate change has been implicated in phenological and geographic distribution shifts of birds globally (Walther et al. 2002). West Nile virus has caused widespread declines of birds in North America in recent decades (LaDeau et al. 2007).

The majority of bird species are migratory and populations likely experience other stressors on wintering grounds. Likewise, numerous threats to migration routes may largely be driven by changes occurring outside of parks (Berger et al. 2014). The effects of introduced bird species on native species have not been well studied in the region. It is possible that these non-native species may compete with native species, possibly contributing to declines. However, it is also clear that some of these introduced species are declining themselves (Figure 4.9.14), perhaps due to the same causes of population decline in native species.

4.9.6. Data Gaps

The IMBCR surveys were designed to be able to detect a three-percent annual decline in occupancy or density over a period of 30 years, or the equivalent of a 60% population decline over the same time period (Beaupré et al. 2013). The greater the rate of change, the fewer years of monitoring data necessary to detect a decline or increase, although natural population fluctuations can obscure trends over short time scales. It will likely take at least 10 years of monitoring data before conclusions can be drawn about trends within individual parks.

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4.10. Black-tailed Prairie Dog

4.10.1. Background and Importance

Black-tailed prairie dogs (*Cynomys ludovicianus*) are ground-dwelling rodents of the Sciuridae family (Figure 4.10.1) and are one of five prairie dog species native to North America. Black-tailed prairie dogs (hereafter "prairie dogs") are the most numerous and widely distributed prairie dog species, ranging from southern Canada to northern Mexico (Figure 4.10.2).

Figure 4.10.1. Black-tailed prairie dogs at a burrow entrance (NPS/LARRY MCAFEE, 2011).

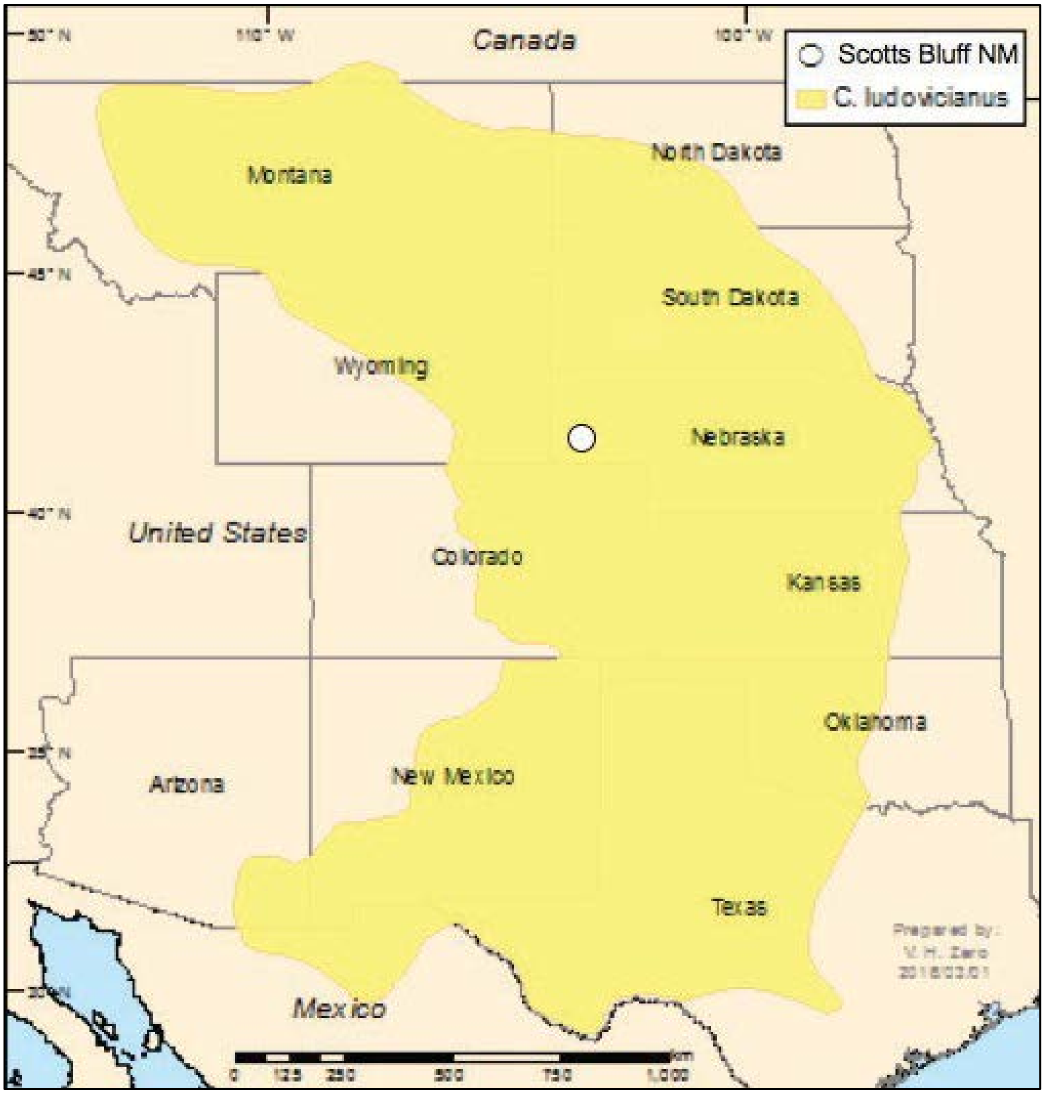

Figure 4.10.2. Historical geographical distribution of the black-tailed prairie dog (*Cynomys ludovicianus*). Range data from International Union for the Conservation of Nature (IUCN 2016).

Prairie dogs are social creatures that live in small family groups that may occupy the same territory over multiple generations (Hoogland 1995). These family groups, called coteries, cluster in areas of suitable habitat to build large colonies which, historically, may have covered tens of thousands of acres (Sidle et al. 2001, Knowles et al. 2002). This diurnal species remains active aboveground throughout the year. Individuals may live five to seven years, typically first reproducing in their second year.

Prairie dogs construct burrows systems for shelter and breeding; colonies are easily recognized by the dirt piles, or mounds, surrounding burrow entrances. Suitable habitat typically includes flat, open areas with short vegetation and frequently includes disturbed areas, such as those grazed by cattle (e.g., Licht and Sanchez 1993). Black-tailed prairie dogs attempt to maintain vegetation height at ~

30 centimeters or less, both through forage consumption and clipping to maintain visibility for predator avoidance (Hoogland 1995).

Prairie dog activities (burrowing, vegetation clipping) influence the composition of the landscape so greatly that mounds and colony boundaries often are clearly visible from the air (Figure 4.10.3). The effect is not just visual; they regulate ecosystem function by affecting nutrient cycling, soil mixing, and energy flows (Kotliar et al. 1999). Black-tailed prairie dogs are regarded as a keystone species (Kotliar et al. 1999), and their presence may confer a range of ecosystem services (Martiñez-Estevez et al. 2013).

Figure 4.10.3. The prairie dog colony at Scotts Bluff National Monument as seen from the air at two resolutions. At fine scales, individual mounds are visible. At the landscape level, the colony can be seen in relation to its surroundings. Approximate colony boundary is shown in green.

Prairie dogs create open habitat and change plant composition and vegetation structure, creating heterogeneity across spatial scales. Several plants, such as prairie dog weed (*Dyssodia papposa*) and scarlet globe mallow (*Sphaeralcea coccinea*), grow best on prairie dog colonies and may also be consumed by prairie dogs (Hoogland 1995). In some regions, prairie dogs may be important for maintaining herbaceous cover and reducing the impacts of invasive woody cover (Miller et al. 2007).

More than 200 vertebrate species are associated with prairie dog colonies to varying degrees (Agnew et al. 1986, Sharps and Uresk 1990, Kotliar et al. 1999). A handful of these species that can be found at Scotts Bluff NM are of conservation concern and appear to be tied to the fate of the prairie dog (Figure 4.10.4). Burrowing owls (*Athene cunicularia*) inhabit prairie dog colonies and exhibit population declines with reductions in prairie dogs (Desmond et al. 2000). Horned larks (*Eremophila alepestris*) exhibit substantially higher abundances on colonies than they do off colonies (Agnew et al. 1986). Golden eagles (*Aquila chrysaetos*) make extensive use of prairie dog colonies where available, declining locally with prairie dog reductions (Cully 1991, Seery and Matiatos 2000).

Figure 4.10.4. Examples of species that exhibit varying levels of dependence upon prairie dog colonies. Clockwise from top left: Horned larks (*Eremophila alpestris*) are found in greater densities on prairie dog colonies than they are elsewhere. Prairie dog weed (*Dyssodia papposa*), is uncommon away from prairie dog colonies. Burrowing owls (*Athene cunicularia*) use prairie dog burrows for nesting and roosting habitat. Golden eagles (*Aquila chrysaetos*) decline when prairie dogs decline. Scarlet globe mallow (*Sphaeralacea coccinea*) grows well on prairie dog colonies (Photos courtesy of NPS and Wikipedia).

Maintaining healthy black-tailed prairie dog populations is fundamental to the character and ecological integrity of Scotts Bluff National Monument. In 2009, Scotts Bluff NM accounted for less than one percent of the acreage occupied by black-tailed prairie dogs on all NPS lands (Licht et al. 2009).

General Trends

Black-tailed prairie dogs may have once covered ~35 million hectares (~86 million acres; Anderson et al. 1986) of shortgrass prairie, mixed-grass prairie, sagebrush steppe, and desert grasslands. Occupied acreage has decreased as much as 98% over the range of the species since the early 1900s (Miller et al. 2007) to the current estimated area of ~800,000 hectares (~2 million acres) across 11 states (McDonald et al. 2015).

The causes of prairie dog decline include land conversion, wide-scale poisoning, shooting, and, more recently, sylvatic plague. Upon initial settlement of the West, many native grasslands were converted to agriculture. During the first half of the 20th century, there were large-scale, government-sponsored exterminations of prairie dogs to reduce competition with livestock. Poisoning and shooting still occur today to varying degrees. In protected areas or other areas that are minimally disturbed, epizootic plague outbreaks are the primary threat to prairie dog populations (Licht et al. 2009). The largest management issue facing prairie dogs across much of their range is sylvatic plague caused by *Yersinia pestis*, a lethal, generalist, non-native bacterium. Plague may have reduced the acreage of active prairie dog colonies within Scotts Bluff NM in 1987–1989 and again in 1995 (R. Manasek, personal communication, 28 June 2016).

Historically, prairie dogs were found in most of Nebraska, but they are now found in less than three quarters of counties where they occurred historically (U.S. Fish and Wildlife Service 2009). Estimates of historical distribution of black-tailed prairie dogs in Nebraska range from 2,428,000 hectares (6,000,000 acres) to 3,651,000 hectares (9,021,000 acres; USFWS, 2009). Loss of habitat and systematic exterminations reduced occupied area estimates to an all-time low in 1961. Subsequent federal restrictions in 1972 began to limit the types of poisons used; these changes may have allowed prairie dogs to expand in Nebraska (Figure 4.10.5).

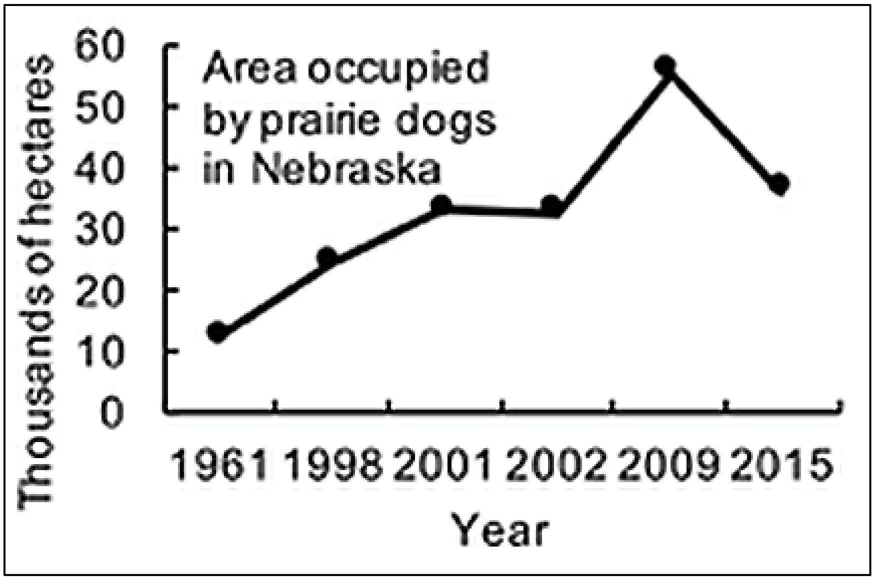

Figure 4.10.5. Estimates of area (in thousands of hectares) occupied by black-tailed prairie dogs in Nebraska. Post-2009 declines may have resulted from the removal of the black-tailed prairie dog from the candidate endangered species list. Note that estimates of historic occupied acreage are as high as 3.6 million hectares (data not shown). References: Bureau of Sport Fisheries and Wildlife 1961 (for 1961), Johnsgard 2005 (for 1998 and 2002), Sidle et al. 2001 (for 2001), U.S. Fish and Wildlife Service 2009 (for 2009), and McDonald et al. 2015 (for 2015).

The most recent range-wide survey of black-tailed prairie dogs, in 2015, was based on interpretation of aerial photographs (McDonald et al. 2015). The resulting estimate of occupied prairie dog area, corrected for missed colonies (false negatives), was 36,101 hectares (89,208 acres) in Nebraska (McDonald et al. 2015), a substantial reduction from historic levels.

Historic declines were primarily driven by land conversion and poisoning. While prairie dogs were expanding slowly for several decades, occupied area has declined since about 2009. Nebraska now contains around 11% of all predicted black-tailed prairie dog habitat (Ernst et al. 2006) and around 5% of currently occupied habitat in the United States (McDonald et al. 2015).

4.10.2. Resource Standards

Concerns over range-wide declines motivated petitions to have the black-tailed prairie dog federally protected under the Endangered Species Act. A series of petitions and actions occurred between 1994 and 2007. The species was briefly designated as “Warranted but Precluded” from ESA listing in 2000. That status was revoked in 2004. Another petition was submitted in August 2007, resulting in a “Substantial” 90-day decision by USFWS in December 2008 followed by a “Not Warranted” 12-month decision in December 2009 (Federal Register 74 FR 63343). Many experts assume that additional ESA listing petitions for the black-tailed prairie dog will occur in the future.

The black-tailed prairie dog is designated as a rangeland pest in Nebraska (Nebraska statute 23-3801). Shooting is permitted year-round and poisoning is permitted as well, but restricted to pesticides legally allowed for use on black-tailed prairie dogs. Shooting is not permitted in Scotts Bluff National Monument.

Nebraska is a participant in the interstate Black-Tailed Prairie Dog Conservation Assessment and Strategy, which sets guidelines for the management, maintenance, and enhancement of prairie dog populations and habitat (VanPelt 1999). The state, however, does not meet some of the objectives stated in the plan (USFWS 2009).

4.10.3. Methods

Indicators, Measures, and Data Sources

Here we evaluate overall black-tailed prairie dog condition based on one main indicator: colony area. The configuration of prairie dog colonies may also influence the temporal dynamics of prairie dog condition, but is not often evaluated for condition (see the following "Configuration" section). To assign a condition to colony area, we used measurements consistent with NPS goals and the scientific literature. Potential conditions were: *Resource in Good Condition, Warrants Moderate Concern, and Warrants Significant Concern*. We then used indicator condition to assess overall black-tailed prairie dog condition at Scotts Bluff NM.

Configuration

When interpreting landscape characteristics, it is important to consider not only the total amount of a particular land cover type, but how that cover type is arranged on the landscape. The size, shape, and spacing of patches are just some of the characteristics that can influence habitat quality and population dynamics. To our knowledge, there are no resource standards for colony configuration to qualify these measures, nor has much research focused on optimal metrics of colony configuration (but see Lomolino et al. 2004, Stapp et al. 2004). Early attempts at identifying ideal prairie dog colony configurations for black-footed ferrets have largely been abandoned (Houston et al. 1986). Furthermore, the same aspects of colony configuration could be advantageous for prairie dogs in the absence of plague, for example, and detrimental in the presence of plague.

Colony Size

The presence of large colonies is likely important for the long-term persistence of black-tailed prairie dogs and dependent species. Managing for colony size is complicated in the presence of plague. Some research has shown that large colonies (~100 hectares) persist better regardless of plague status (Lomolino et al. 2004), while other research has shown that intermediate colonies (3–16 hectares) persist better in the presence of plague (Stapp et al. 2004). The concentration of prairie dog colonies into a few, large patches with large cores is thought to be necessary for recovery of the black-footed ferret (Jachowski et al. 2011).

Colony Distribution

The spatial arrangement of prairie dog colonies may influence dispersal, metapopulation dynamics, and the spread of plague. Large, compact clusters of colonies should facilitate movement and dispersal of prairie dogs and dependent species. While some researchers recommend clusters of large colonies (Lomolino and Smith 2003), closely spaced colonies may facilitate the spread of plague (Shoemaker et al. 2014). Isolated colonies may be at an advantage during plague outbreaks, but are less likely to persist in the absence of plague (Lomolino et al. 2004). The maximum observed dispersal distance for black-tailed prairie dogs is ~10 kilometers. We can also measure colony aggregation—the degree to which colonies are clustered or spread out. One measure of aggregation is the nearest neighbor ratio, or the observed average distance between colonies divided by the expected distance if the colonies were randomly placed. The smaller the ratio, the more clustered the colonies; a ratio of one would mean that the colonies are distributed randomly throughout the park.

Colony Shape

The quality of habitat edge is often different from quality in core habitat. We can look at shape metrics (standardized perimeter/area ratios) to see how the average amount of edge changes over time. One measure of shape complexity is fractal dimension. The higher the fractal dimension, the more edge on the colony. Edge can be indicative of colony expansion, as seen in the years leading up to plague. There is limited evidence that ferrets may avoid colony edges (Eads et al. 2012), but prairie dog densities may be higher here. Evidence from the 1960s in South Dakota showed that colony centers “go dead” as the colony expands outward (D. Biggins, personal communication, 1 March 2016). Habitat quality for prairie dogs increases with increasing distance from the colony center (Cincotta 1985).

Indicator: Colony area

The most basic measure of resource condition is the quantity of that resource. Prairie dogs exist in metapopulations that require many colonies connected to some degree by dispersal. Population performance of associated species such as the burrowing owl is positively associated with large tracts of prairie dog colonies.

Prairie dog colony acreage is often used to assess prairie dog condition, as prairie dog numbers are difficult to estimate and demographic information is labor-intensive to collect. Acreage is strongly correlated to population size, so we can generally interpret increasing total colony area as an increasing population of prairie dogs (Biggins et al. 2006), although prairie dog densities may fluctuate widely at Scotts Bluff NM (Morrison and Peitz 2011).

Measure of Colony Area: Proportion of Suitable Habitat Occupied

There is some general guidance on standards for prairie dog acreage. At the landscape or regional level, Mulhern and Knowles (1997) recommend a minimum 1–3% of suitable grasslands be occupied by prairie dogs. They further suggest that federal lands should be held to a higher standard, and recommend a goal of 5–10% occupancy. They acknowledge that these recommendations may not represent the true area required for a functioning prairie dog ecosystem, but their recommendation is in line with research that estimated 2–15% of lands were historically occupied by prairie dogs (Knowles et al. 2002). At the time of this assessment, Scotts Bluff NM was not actively managing for any particular acreage of prairie dogs.

Cox and Franklin (1989) identified 785 hectares (1,940 acres) of suitable black-tailed prairie dog habitat at Scotts Bluff NM, although it is not clear how they identified “inhabitable grassland.” They also estimated that 47%, or 568 hectares (1,404 acres), of the park unit is mixed-grass prairie. At the time of this assessment, park management estimated that about 628 hectares (1,552 acres) were potential prairie dog habitat (R. Manasek, personal communication, 7 September 2016).

We applied a 5% threshold to the lowest category, *Warrants Significant Concern* (Table 4.10.1) based on the recommendation of Mulhern and Knowles (1997). To assign values to the *Warrants Moderate Concern* category, we created an even break between the lowest and highest categories (5–10%). Finally, for the *Resource in Good Condition* category, we assumed that anything above 10% occupancy would be desirable (Mulhern and Knowles 1997).

Table 4.10.1. Black-tailed prairie dog condition categories for percentage of suitable habitat occupied.

Resource condition		Percentage of suitable habitat occupied
Warrants significant concern	🔴	x < 5%
Warrants moderate concern	🟡	5% ≤ x < 10%
Resource in good condition	🟢	x ≥ 10%

Data Collection

To assess black-tailed prairie dog condition, we used data collected by NPS from 1995–2013. Park personnel recorded the boundaries of active prairie dog colonies using standardized ground mapping methods and monitored colonies with global positioning system mapping (Plumb et al. 2001). We used ArcMap 10.2.2 to calculate colony metrics in each year.

Quantifying Black-tailed Prairie Dog Condition, Confidence, and Trends

We assessed overall black-tailed prairie dog condition by examining colony area. We assigned points to this measure based on NPS management goals and the recommendations of Mulhern and Knowles (1997) to obtain a score for colony area.

Indicator Trend

Potential trend categories were *Improving, Unchanging*, or *Deteriorating*. To calculate a trend, we required data that were quantified in the same way over multiple years. We fit a regression from 1995–2013. If the regression was significant and the slope was positive, the trend was *Improving*. If the regression was not significant and the slope was close to 0, the trend was *Unchanging*. If the regression was significant and the slope was negative, the trend was *Deteriorating*.

Indicator Confidence

Confidence ratings were based on data availability (number of years) and data quality (e.g., survey design and estimation techniques). We gave a rating of *High* confidence when surveys were conducted regularly, recently, and methodically. We assigned a *Medium* confidence rating when surveys were not conducted regularly, data were not collected recently, or data collection was not repeatable or methodical. *Low* confidence was assigned when there were no good data sources to support the condition.

Overall Black-tailed Prairie Dog Condition

To assess overall black-tailed prairie dog condition, we used the single measure of colony area. The condition of this indicator was, therefore, the overall condition of black-tailed prairie dogs at Scotts Bluff NM.

Overall Black-tailed Prairie Dog Trend

We used the single measure of colony area to assess overall black-tail prairie dog trend; the trend of this indicator was the overall trend for black-tailed prairie dogs.

Overall Black-tailed Prairie Dog Confidence

We used the single measure of colony area to assess overall black-tail prairie dog confidence; the confidence in this indicator was the overall confidence for black-tailed prairie dogs.

4.10.4. Black-Tailed Prairie Dog Conditions, Confidence, and Trends

Colony Area

⇧

Condition: Warrants Moderate Concern
Confidence: High
Trend: Improving

Condition

To assign a condition to colony area, we used a proportion of suitable habitat occupied by prairie dog colonies. In 2013, there were 35.1 hectares of active prairie dog colonies. The latest estimate of suitable prairie dog habitat (based on observations using ArcMap) from 2015 was 628 hectares (R. Manasek, personal communication, 7 September 2016). Therefore, 5.59 % of suitable habitat was occupied by prairie dogs in 2013. This value placed black-tailed prairie dog area for Scotts Bluff NM in the *Warrants Moderate Concern* category.

Confidence

Occupancy was calculated from maps in ArcMap 10.2.2. Because all colonies were mapped each year and the same procedure was used for all surveys, the confidence was *High*.

Trend

We used 18 years of mapped colonies to assess a trend in black-tailed prairie dog acreage (Figure 4.10.6 and 4.10.7). We used the raw area occupied instead of converting to a percentage area because potential habitat area did not change over this time period. We used a linear model to identify trend, and found the slope of the trend line following was positive (R2 = 0.439, P = 0.00274). Trend was *Improving*.

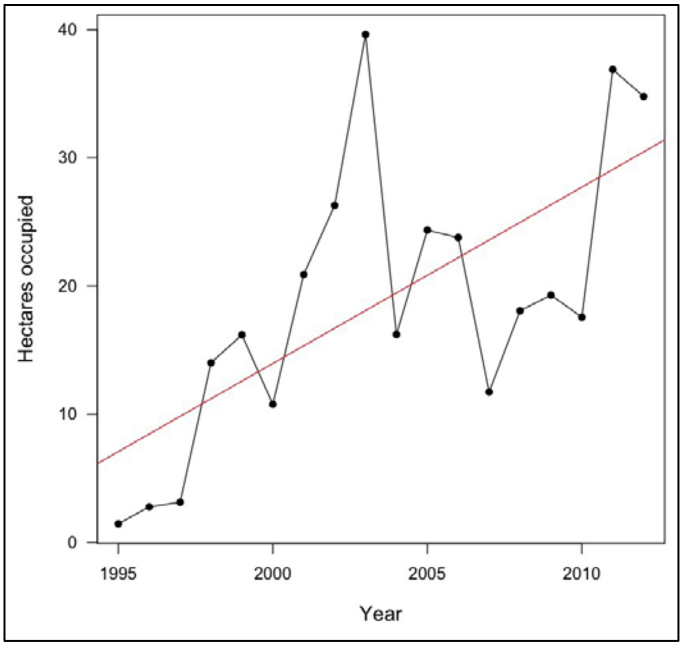

Figure 4.10.6. Change in the area occupied by black-tailed prairie dogs in Scotts Bluff NM from 1995–2013. Data obtained from Wilson et al. (2013).

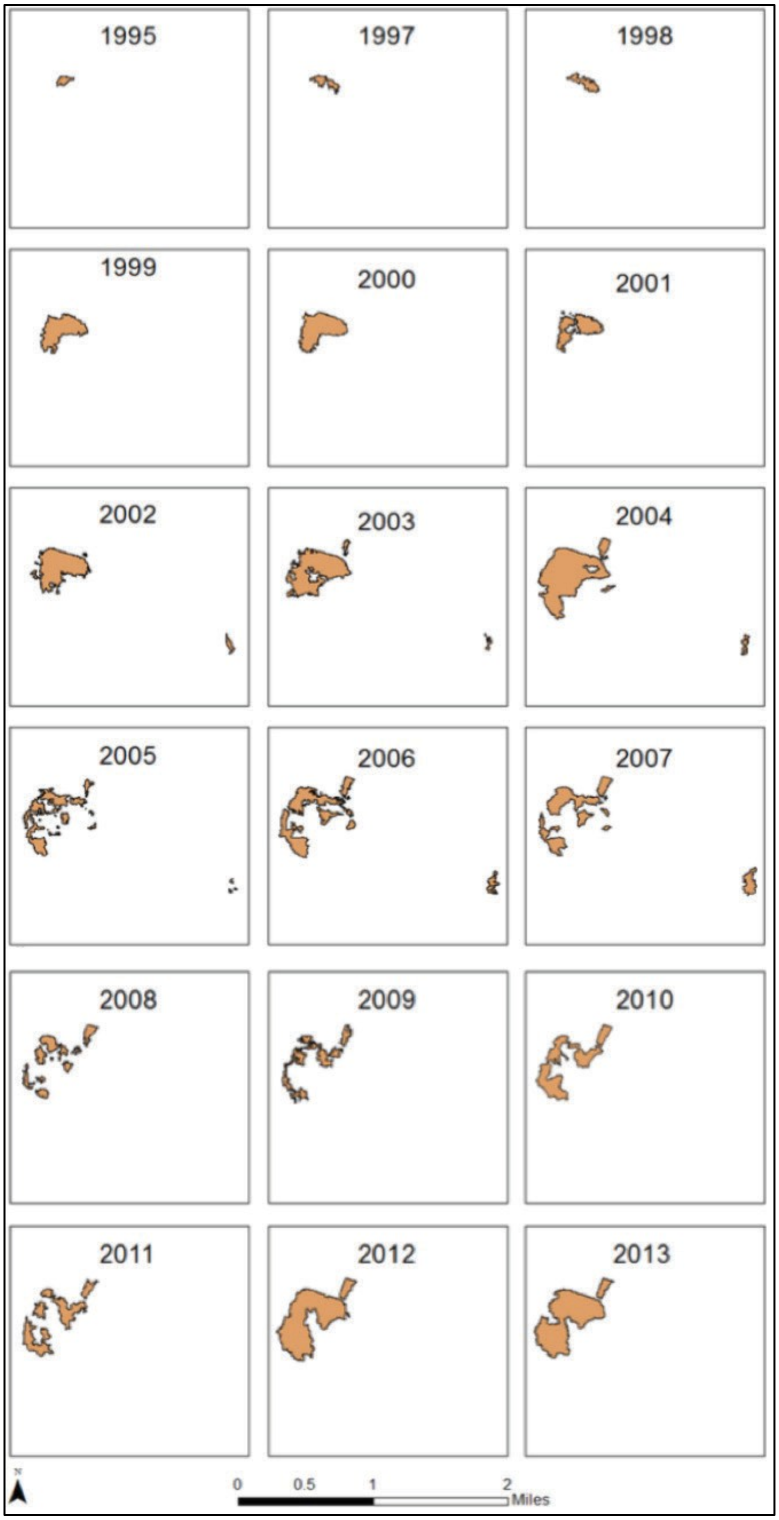

Figure 4.10.7. Changes in the distribution of black-tailed prairie dog colonies in Scotts Bluff NM between 1995 and 2013 (Wilson et al. 2013). Acreage peaked at 38.8 hectares in 2008. During this time period, acreage was the lowest in 1995.

Black-tailed Prairie Dog Overall Condition

Condition

The overall black-tailed prairie dog condition was the same as the single indicator condition (Tables 4.10.2 and 4.10.3), which placed the condition of black-tailed prairie dogs at Scotts Bluff National Monument in the *Warrants Moderate Concern* category.

Table 4.10.2. Black-tailed prairie dog overall condition.

Indicators	Measures	Condition
Colony area	Percentage of suitable habitat occupied	⇧
Overall condition for all indicators and measures		⇧

Table 4.10.3. Summary of black-tailed prairie dog indicators and measures.

Indicator	Measure	Condition	Confidence	Trend	Condition Rational
Colony area	Percentage of suitable habitat occupied	Warrants moderate concern	High	Improving	Acreage was 5.59% of suitable habitat in 2013; this value placed prairie dogs in the *Warrants Significant Concern* category. Colonies were mapped in the same way at least every other year, so confidence was *High*. Acreage declined from 2008-2015, so trend was *Deteriorating*.

Confidence

Confidence was *High* for prairie dog condition.

Trend

Trend data were Available for colony acreage from 1995–2013 and overall trend for black-tailed prairie dogs was *Improving*.

4.10.5. Stressors

Disease

Sylvatic plague is the greatest threat to prairie dogs and associated species throughout their range. Plague is a non-native, generalist bacterium that is highly lethal for black-tailed prairie dogs. Plague likely originated in Asia where many species of small mammal evolved varying levels of resistance to plague (Biggins and Kosoy 2001). Despite a volume of research on plague, there are many aspects of plague biology that are still poorly understood.

Plague may have been introduced to North America by ship to the west coast around 1900 (Biggins and Kosoy 2001). Following introduction, plague spread eastward (Antolin et al. 2002). The distribution of active plague just barely enters the Nebraskan panhandle. Scotts Bluff NM is considered to be east of the distribution of active plague (Mize and Britten 2016).

Researchers determined that plague-positive fleas were present at Scotts Bluff NM from 2009–2011, and that plague was enzootic in the park unit. It is not clear if epizootic events have occurred in the past at Scotts Bluff NM, and it is not known whether they are likely to occur in the future. The primary strategy for controlling plague outbreaks is “dusting” burrow entrances with insecticide to kill the fleas that transmit plague. Dusting has not been employed at Scotts Bluff NM. Dusting, while largely successful, is not the panacea for black-tailed prairie dog recovery. Fleas may develop resistance to the dusting insecticide (deltamethrin), so the success of longer-term dusting efforts hinges on finding an alternative insecticide.

Dusting is also an expensive endeavor. Researchers are investigating the viability of an oral vaccine bait for prairie dogs. The vaccine is currently made in-house and is therefore expensive. The utility of this oral vaccine will hinge upon demonstrated efficacy and reducing manufacturing costs.

Invasive Plants

Invasive plants have the potential to affect the colony in the future, but did not negatively affect the colony at the time of this assessment. The most problematic weed problem at Scotts Bluff is the riparian area of the North Platte River. The water table is much too close to the surface for this area to support a prairie dog colony, and lately a portion of this area is covered by water most spring seasons as the North Platte River escapes its banks (R. Manasek, personal communication, 7 September 2016).

4.10.6. Data Gaps

Disease Ecology

Although discussion of plague typically centers around its lethality to prairie dogs, the disease is transmitted by many other species of small mammal (Biggins and Kosoy 2001). Despite a volume of research on plague, many aspects of its biology remain poorly understood. There is ongoing research into the basic ecology of plague in Badlands to monitor population responses of prairie dogs and associated mammals to plague outbreaks (Biggins 2016a). USGS biologists are also working in Badlands NP to examine the role of small mammals in the plague cycle (Biggins 2016b). They are hoping to learn whether these species are chronically affected by enzootic plague and to identify hosts that serve as plague reservoirs in black-tailed prairie dog colonies. They are also studying the use of deltamethrin insecticide for flea control.

Habitat Quality

Vegetation is one factor that may limit colony expansion. Prairie dogs avoid tall vegetation, so colony expansion may be limited in wet years due to increased plant productivity. The types of forage available may also affect reproductive rates and colony expansion. Prairie dogs rely on a small number of grass species for the majority of their diet. Some of their preferred native forage species (Roe and Roe 2003) that can be found within Scotts Bluff NM include (Ashton and Davis 2016):

western wheatgrass (*Pascopyrum smithii*; ~ 20% of total plant cover in the park), blue grama (Bouteloua *gracilis*; ~ 2% of total plant cover), buffalograss (*Bouteloua dactyloides*), sand dropseed (*Sporobolus cryptandrus*), three species of sedge, including threadleaf sedge (*Carex filifolia*, ~ 30% of cover), scarlet globemallow (*Sphaeralcea coccinea*; ~ 1% of total plant cover), and plains prickly pear (*Opuntia polyacantha*).

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4.11. Invertebrate Pollinators

Monarch butterflies are present at Scotts Bluff NM. Photo © K.D. HARRELSON, Wikimedia Commons 2007.

4.11.1. Background and Importance

Pollinators, animals that assist in the reproduction of plants, include a diverse group of organisms globally, from invertebrates to reptiles (Olesen and Valido 2003) to mammals (Fleming et al. 2001) and birds. The diversity and richness of pollinators have declined since the mid-20th century, and some species have disappeared altogether. This massive decline in pollinator health is attributable to a combination of disease, pesticides, and habitat loss (Goulson et al. 2015a). In North America, the decline in invertebrate pollinators in particular is likely to have extensive consequences for native plants (Potts et al. 2010, Thomann et al. 2013) and agriculture (NRC and NAP 2007). Invertebrate pollinators are found in many groups, including ants, beetles, birds, flies, butterflies, bees, and wasps.

Declines in populations of European honey bees (*Apis mellifera*) have received much attention due to their role in agricultural production, but losses have been observed in wild (native) pollinators too (NRC and NAP 2007). With the exception of a few wild bees and butterflies, however, population data are scarce for these unmanaged invertebrate species (NRC and NAP 2007). Even so, declines in many wild pollinator species are unfortunately obvious (Goulson et al. 2015b). Nearly 3,000 bee species are native to North America and about 40 of these bees are bumble bees—important pollinators of native plants (Koch et al. 2012). Losses to these bees could have extensive, cascading effects on ecosystems. A coordinated national monitoring effort would be the first step to understanding population trends and consequences of population changes in native invertebrate pollinators (Pollinator Health Task Force 2015).

National Park Service lands are critical reference and monitoring sites for invertebrate pollinator populations. The NPS is dedicated to protecting pollinators and their habitat; pollinator studies have been part of research programs at several national parks and pollinator education programs were growing at the time of this assessment (NPS 2016).

Regional Context

Invertebrate pollinators in Nebraska include native insects and honey bees, all of which have varying food and habitat needs (Xerces Society 2016a, 2016b). Scotts Bluff NM is home to a total of 19 confirmed butterfly species (Lawson 2004), and may be host to even more species. Monarch butterflies (*Danaus plexippus*) – a species of high conservation concern - were present in the park (Figure 4.11.1A); also present were two- tailed swallowtails (*Papilio multicaudata*) (Figure 4.11.1B) and red admirals (*Vanessa atalanta rubria*) (Lawson 2004, Figure 4.11.1C). While bumble bees (*Bombus* sp.) and other invertebrate pollinators are likely present (Koch et al. 2012) in Scotts Bluff NM, local census data are lacking for the park.

Figure 4.11.1. Butterfly species present at Scotts Bluff NM (Lawson 2004) include A) Monarch butterfly (*Danaus plexippus*), B) two-tailed swallowtails (*Papilio multicaudata*), and C) a red admirals (*Vanessa atalanta rubria*). Photos by K.D. Harrelson (2007), J. Williams (2006), and B. Kohl (2009), respectively.

4.11.2. Resource Standards

Pollinator declines have captured national attention (Pollinator Health Task Force 2015), but national standards for the protection of pollinators are lacking. The EPA (2016) has proposed standards for pesticide toxicity levels to protect pollinators, but habitat protection guidelines only exist on a case-by-case basis for species currently listed in the Endangered Species Act (16 U.S.C. § 1531 et seq. 1973), if recovery plans have been completed. At the time of this assessment, no invertebrate pollinators in Nebraska were listed species under ESA, but several butterflies and bees were under review for listing (USFWS 2016).

4.11.3. Methods

Indicators and Measures

We assessed invertebrate pollinator condition at Scotts Bluff NM based on three indicators: species diversity, species abundance, and status of vulnerable species. Each of these indicators contributes to different aspects of pollinator condition.

We used measurements specified by the scientific literature and expert opinion. At the time of this assessment, no clear or accepted standard for assigning indicator conditions was available. In lieu of a full condition assessment we present potential indicators and measures, identify currently available data, and illustrate a framework that could be used to assess pollinator condition in the future. We focused on butterflies and bees here because the best available data pertain to these groups, but ideally other pollinator groups would be included in pollinator inventories and long term monitoring.

Indicator: Species Diversity

Quantifying biodiversity is a basic approach to assessing ecosystem condition. High diversity of species in a community can protect that community from disturbance (Tilman et al. 2006), promote productivity (Tilman et al. 1997), and preserve aspects of ecosystem function in variable environmental conditions (Brittain et al. 2013).

Measure of Species Diversity: Shannon Index

Species diversity is a combination of the number of species in a community and the proportional abundances of each of those species. A population approach to measuring diversity is to use Shannon's diversity index (H′), which quantifies a level of uncertainty (Shannon 1948). A higher value of H′ indicates a higher level of diversity. Expected diversity is likely to differ among habitat types; at the time of this assessment, no standard existed for expected level of diversity by ecosystem type.

Indicator: Species Abundance

Pollinator population abundance can change with alteration in land use (e.g., Foley et al. 2005, Potts et al. 2010) and consequent shifts in vegetation structure, competition, or predation pressures. This index is an important complement to diversity, as pollinator communities could have high diversity but at very low numbers. Further, different species may be affected unequally by land use change and other stressors, so monitoring the abundance of different pollinator species may be key to understanding the overall condition of a pollinator community.

Measure of Species Abundance: Pollinator Visitation Rate

Pollinator researchers frequently measuring pollinator abundance by visitation rate, to flowers, plants, or groups of plants (e.g., Utelli and Roy 2000). Observers record the number of invertebrates that visit flowers within a pre-determined sampling plot during a set period of time. Ideally, multiple observers collect data at different locations over the same time periods.

Measure of Species Abundance: Density in Pollinator Traps

Another approach to estimating pollinator abundance, and one that may require fewer person-hours in the short-term, is to deploy traps that capture pollinators. A variety of trapping methods can be successful, depending on the habitat (Lebuhn et al. 2013), but some methods may be biased towards certain taxa. With this potential bias in mind, several trapping approaches may be ideal. The trapping methods used should, at least, be standardized across sampling locations.

Indicator: Vulnerable Species

Like vertebrates and plants, invertebrate species can also receive special conservation status. Important pollinators on these lists may warrant extra protection from chemical spraying and habitat alteration.

Measure of Vulnerable Species: Level of Conservation Concern

Species of conservation concern are often given a special protection status or conservation priority by governing agencies. The highest level of legal protection for species in the U.S. is a listing under the Endangered Species Act (ESA), but other listings, such as the Xerces Society Red Lists (Xerces Society 2016a), indicate a level of concern for the species. This qualitative approach to assessing condition could enable managers to identify condition of various invertebrate pollinator groups through a simple census of species present at Scotts Bluff NM. The method for assigning condition should be standardized across parks and could be separated by taxa or combined into an overall pollinator condition.

Data Collection and Sources

Data Management and Availability

For this assessment we used all available data, which included a butterfly census report (Lawson 2004) and Xerces Society Red Lists for native bees (Xerces Society 2016a) and butterflies and months (Xerces Society 2016b). We also searched museum records for specimens collected in Scotts Bluff NM.

Quantifying Pollinator Condition, Confidence, and Trend

Indicator Condition

To quantify invertebrate pollinator condition, we identified indicators, measures, and condition categories based on the scientific literature, regulatory standards, and expert opinion. We deferred to data collected most recently and most rigorously. Standards were unavailable for invertebrate pollinator condition, but when data and standards are available, managers can use a points system to assign each indicator to a category. This point system is based on the NPS methods that were developed to calculate overall air quality condition (NPS-ARD 2015), a methodical and rigorous assessment approach that can be applied to other resources as well. In this approach, we would assign zero points to the condition *Warrants Significant Concern*, 50 points to *Warrants Moderate Concern*, and 100 points to *Resource in Good Condition*. The average of all measures determines the condition category of the indicator; scores from 0–33 fall in the *Warrants Significant Concern* category, scores from 34–66 are in the *Warrants Moderate Concern* category, and scores from 67–100 indicate *Resource in Good Condition*.

Indicator Confidence

Confidence ratings were based on data availability (number of years) and data quality (e.g., survey design, estimation techniques). We assigned a rating of *High* confidence when surveys were conducted regularly, data were collected recently, and data were collected methodically. We assigned a *Medium* confidence rating when surveys were not conducted regularly, data were not collected recently, or data collection was not repeatable or methodical. *Low* confidence ratings were assigned when there were no good data sources to support the condition.

Indicator Trend

Potential trend categories were *Improving, Unchanging,* or *Deteriorating*. To assign a trend to diversity or abundance we required at least three years of data. If no data were available that met these monitoring requirements for a particular indicator, we indicated that trend was *Not Available* for that indicator.

Overall Pollinator Condition, Trend, and Confidence

If good quantitative data were available, we used the general approach for combining indicator conditions, trends, and confidence described in Chapter 3 (Methods 3.2.2) to calculate overall pollinator condition, trend, and confidence (Table 4.11.1). In the absence of adequate quantitative data, we assigned condition based on qualitative information, expert opinion, and consultation with NPS scientists.

Table 4.11.1. Summary of invertebrate pollinators' indicators and measures.

Indicator	Measure	Condition	Confidence	Trend	Condition rational
Diversity	Shannon index (H')	Not available	Low	Not available	Data were unavailable and standards for assigning condition did not exist
Abundance	Observed visitation rate	Not available	Low	Not available	Data were unavailable and standards for assigning condition did not exist
	Mean density in traps	Not available	Low	Not available	Data were unavailable and standards for assigning condition did not exist
Vulnerable species	Level of conservation concern	Warrants moderate concern	Low	Not available	Data were unavailable for species diversity and abundance; species of concern and species being considered for ESA listing could be present in the park.

4.11.4. Pollinator Conditions and Trends

Few data on pollinators were available for Scotts Bluff NM, though we were able to reference a butterfly census survey (Lawson 2004). Xerces Society Red Lists identified a number of species of concern in Nebraska and we were able to associate vulnerable status with a butterfly know to occur in Scotts Bluff NM, but only able to guess at the vulnerable bees likely to occur in the park.

Diversity

◌

Condition: Not Available
Confidence: Low
Trend: Not Available

Condition

A butterfly species lists existed for Scotts Bluff NM (Lawson 2004), but no such list was available for other invertebrate pollinators. The butterfly survey involved a census of species present within the park. Sampling was conducted on five occasions at two sites between June–September 2004, and species indicated as present if observed (Lawson 2004).

In the future, surveys of invertebrate pollinators at specified sampling locations, repeated on multiple occasions, and yielding abundance counts would provide a good start to measuring of overall pollinator diversity. Condition was *Not Available*.

Confidence

Few data existed for invertebrate pollinators at Scotts Bluff NM, and were collected for only one type of invertebrate pollinator. Confidence was *Low*.

Trend

Trend was *Not Available*.

Abundance

◌

Condition: Not Available
Confidence: Low
Trend: Not Available

Condition

No pollinator abundance data were available for Scotts Bluff NM. Condition was *Not Available*.

Confidence

No abundance data were available. Confidence was *Low*.

Trend

Trend was *Not Available*.

Vulnerable Species

🟡

Condition: Warrants Moderate Concern
Confidence: Low
Trend: Not Available

Condition

Monarch butterflies (*Danaus plexippus*) – a species of high conservation concern - were present in the park (Figure 4.11.1A). Other butterflies in Nebraska were also identified as species of concern, but not confirmed as present within the park; these species included arogos skipper (*Atrytone* *arogos*), ottoe skipper (*Hesperia ottoe*), and regal fritillary (*Speyeria idalia*), all of which the Xerces Society deems to be vulnerable species (Xerces Society 2016b). Western bumble bees (*Bombus occidentalis*), also being considered for ESA listing, are likely to be present at Scotts Bluff NM (Xerces Society 2016a), but had not been confirmed as present. One pollinator of conservation concern was identified as present within Scotts Bluff NM and other species of concern were likely to be present as well. Condition was *Warrants Moderate Concern*.

Confidence

Few data existed for invertebrate pollinators at Scotts Bluff NM, and were collected for only one type of invertebrate pollinator. Confidence was *Low*.

Trend

Trend was *Not Available*.

Invertebrate Pollinators Overall Condition

●

Condition: Warrants Moderate Concern
Confidence: Low
Trend: Not Available

Condition

Condition was unavailable for the diversity and abundance indicators due to a lack of reference standards and data. One species of butterfly within the park was a species of conservation concern, and other species of concern could be present. Condition was *Warrants Moderate Concern*.

Confidence

Few data existed for invertebrate pollinators at Scotts Bluff NM, and were collected for only one type of invertebrate pollinator. Confidence was *Low*.

Trend

Trend was *Not Available*.

4.11.5. Stressors

Invertebrate pollinators are threatened globally and their decline could have major consequences for the health of many ecosystems, as well as commercial agriculture. In Nebraska, insecticide use, land conversion, and changes in climate could contribute to these declines. Many invertebrate pollinators rely on specific host plants, depositing their eggs so that larvae can feed on the plants before metamorphosing; protecting these plants is key to protecting specialized pollinators.

Scotts Bluff NM has the potential to be an important reference and monitoring site for pollinators; balancing the preservation of pollinators with other management goals, such as mosquito control, is a challenge to consider in the future.

4.11.6. Data Gaps

Butterfly data collected over 10 years prior to this assessment (Lawson 2004) and the Xerces Society Red Lists (Xerces Society 2016a, 2016b) formed the basis of our assessment. A comprehensive survey of all potential pollinators would be an important step to understanding condition of pollinators in Scotts Bluff NM, but monitoring should be designed so that methods can be consistent among NPS units (L. Tronstad, personal communication, 1 September 2016). Additionally, experts have yet to identify good measures of tolerance and susceptibility among invertebrate pollinates akin to those that exist for aquatic invertebrates (see Water Quality, 4.5.3.1.3). Until such metrics are developed, pollinator researchers and managers may find some agreement about expected levels of diversity in various ecosystem types.

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Chapter 5. Discussion of Natural Resource Condition Assessment Findings and Considerations for Park Planning

5.1. Introduction

This chapter serves as a summary (Table 5.1.1) of natural resource conditions, potential threats and stressors to those resources, scientific needs and data gaps, and management issues for Scotts Bluff National Monument. The summaries and suggestions presented here were the result of a discussion among park managers, park administrators, and the authors of this assessment. In addition to the resource-specific summaries, this chapter contains details of overall concerns and pressing study needs for Scotts Bluff NM that would enable managers to maintain or improve resource conditions. Complete descriptions of each resource and detailed analyses are available in the individual natural resource sections.

Table 5.1.1. Summary of natural resource conditions, confidence, trends, and rationale for resource condition.

Priority resource	Condition, confidence, trend	Summary of overall condition
Viewshed	🟡	Viewshed condition depended on two indicators: scenic quality of view and land cover content within the viewshed. Three measures of scenic quality (landscape character integrity, vividness, and visual harmony) indicated good condition, but a 49% natural land cover and 25% developed land cover indicated condition of significant concern. Overall condition was of moderate concern.
Night Sky	🔴	NPS Natural Sounds and Night Skies Division used interpolated remote sensing data to assess condition of natural light environment and overall night sky condition. These data indicated significant concern; light pollution from the cities of Gering and Scottsbluff negatively affect the night skies in the national monument.
Soundscape	🔴	To assess soundscape conditions, we used data modeled by the Natural Sounds and Night Skies Division and a measure of impact identified by the division. A single indicator, anthropogenic impact, indicated that soundscape condition was of significant concern. Stressors included vehicle traffic from the cities of Scotts Bluff and Gering as well as train noise and air traffic.
Air Quality	🟡	Scottsbluff NM is a Class II airshed and held to high air quality standards. Air quality indicators of ozone, visibility, nitrogen deposition, sulfur deposition, and mercury deposition indicated a condition of moderate concern for the park.

Table 5.1.1 (continued). Summary of natural resource conditions, confidence, trends, and rationale for resource condition.

Priority resource	Condition, confidence, trend	Summary of overall condition
Surface Water Quality	🔴⇔	We assessed water quality using the most recent data available for core water quality indicators (acidity, dissolved oxygen, temperature, specific conductivity), biological indicators (invertebrate assemblage, fecal indicator bacteria), and impairment status. Core indicators were in good and moderate condition, while aquatic invertebrates, generally reflective of more long term quality aspects, indicated moderate concern. By EPA standards, the North Platte River was impaired in 2016 and has been impaired, from various causes, since 1998. The condition was of significant concern.
Geology	🔴	The bluff that forms the major physical attraction at Scotts Bluff NM is also the major geologic resource. Recent erosion and weathering rates were outside the range of natural variation, so geology condition was of significant concern.
Paleontological resources	🔴	Paleontological resource condition at the park depended on the potential for fossil loss, which was of significant concern. Vandalism, theft, and natural erosion were the primary stressors on paleontological resources.
Vegetation	🟡	A complete vegetation assessment was completed for Scotts Bluff NM in the course of this NRCA and we based our assessment entirely on those results. Several measures of upland plant community, exotic plan detection, and changes in the riparian forest indicated moderate concern.
Birds	○	We presented a framework for assessing bird condition using species diversity, abundance, and conservation value, but at the time of this assessment no standards or consensus existed for evaluating condition of bird community. Condition was not available.
Prairie Dogs	🟡⇧	Black-tailed prairie dogs were reduced to very low regional population rates by the 1960s, but their numbers increased again following some federal protections. The areas inhabited by prairie dogs in the park indicated moderate condition, though that acreage has increased since 1995.
Pollinators	🟡	We presented a framework for assessing pollinator condition using species diversity, abundance, and vulnerability status, but at the time of this assessment no standards or consensus existed for evaluating condition of pollinator community. We used vulnerability status to assign a condition of moderate concern.

5.2. Connecting Natural Resource Condition Assessment Findings to Park Purpose and Significance

Natural resources in the Scotts Bluff NM contribute to the NPS Mission of preserving natural and cultural resources for future generations (NPS 2016) and are important for the protection of habitat and species within the region.

5.3. Resource Data Gaps and Management Issues

Several management themes emerged across natural resources. First, park staff discussed the vulnerability of Scotts Bluff NM to land use changes and activities on adjacent lands, and the importance of staying informed of impending changes in the surrounding towns and counties that could affect park resources.

Also, the park shares some characteristics with Agate Fossil Beds NM in that both are relatively small but have important natural resources. A recurring point that ran through our discussions with both Scotts Bluff NM and Agate Fossil Beds NM was that both parks would benefit from pooling funding resources to meet some needs that are not currently met. In particular, high erosion rates in portions of these parks lead to frequent exposure of fossils. To make these fossils available for public education and research, a paleontologist must keep pace with fossil discovery and focus on collecting, cataloguing, and preparing specimens. This task is a challenging one, and leadership at Scotts Bluff NM and Agate Fossil Beds NM discussed how much both parks would benefit from sharing a paleontologist—an individual who would be fully devoted to these two parks.

Additionally, native prairie grasslands have been so degraded across their historic range that very little intact and untouched prairie habitat remains; remnant patches of native prairie are present within these parks and provide important habitat for grassland birds and other wildlife. Both Scotts Bluff NM and Agate Fossil Beds NM felt that they would benefit from a shared biological technician or vegetation specialist who could focus on these natural resources.

Finally, one of the most heavily used areas of the park is Scotts Bluff itself. Hikers trek up and down the Saddle Rock Trail, although, at the time of this assessment, it was temporarily closed because of a major rockslide. The Summit Road is open to cyclists and hikers after hours. Erosion rates are high around these features and pose a risk to park visitors. Climate change and consequent shifts in precipitation patterns may be responsible for observed and future increases in erosion rates within the park. Park leadership at Scotts Bluff NM identified this relationship as one that has significant relevance to the park and its founding purposes.

5.4. Resource Summaries and Management Issues

In addition to the management issues discussed above, we present resource-specific details on management concerns. For each resource we present a brief description of the context at Scotts Bluff NM, summarize condition of the resource, and then describe data gaps and management issues. For full context, background, methods, and results, please consult the individual natural resource sections in Chapter 4.

5.4.1. Viewshed

At Scotts Bluff NM, exposed geologic history, cultural landscapes, and expansive views of western Nebraska are an important part of the visitor experience. The landscapes in and around the park, including Scotts Bluff, Chimney Rock, and other named rock formations offer visitors an opportunity to enjoy a visual setting with features that served as landmarks for peoples from Native Americans to emigrants on the Oregon, California, and Mormon Trails.

To settlers traveling along these migration trails, Scotts Bluff was more than a scenic feature of the western landscape; it was a guiding landmark that signaled the end of the plains and the beginning of the mountains on the journey west. Today the bluff is visible from miles away, as it was in the 1800s, and dominates the skyline.

Viewshed Condition Summary

Viewshed condition depended on two indicators: scenic quality of view and land cover content within the viewshed. Three measures of scenic quality (landscape character integrity, vividness, and visual harmony) indicated good condition, but a 49% natural land cover and 25% developed land cover indicated condition of significant concern. Overall condition was of moderate concern. Viewshed condition was *Warrants Moderate Concern*, confidence in condition was *High*, and trend was *Not Available* (Table 5.1.1).

Viewshed Gaps and Management Issues

On-site monitoring and a full Visual Resource Inventory by the Air Resource Division would provide more detailed data than the remote sensing and modeling approach necessarily used here. This process began at Scotts Bluff in 2015 and ARD needs to work with the park to finish the viewshed inventory with volunteers, seasonal staff, and the natural resource manager. Part of this inventory involves taking photographs and uploading them to the Scotts Bluff NM website for future monitoring. Some building development has occurred on the east boundary of the park, but Scotts Bluff NM has no documentation of that change. Photos would help to explain vulnerability on various fronts. Following this inventory, the park can develop a monitoring approach.

To reduce the potential for new structures and residential areas that would encroach on the viewshed, the park Superintendent attends local zoning meetings and endeavors to improve communication with the city of Gering and Scotts Bluff County. At the time of this assessment, the park was not receiving official notice of development projects in the city or county.

While Scotts Bluff NM has limited official capacity to engage in public planning process and few people to tackle a broad range of management issues, managers monitor conditions and threats, especially to the west of the park. Residential development has already filled in much of the area east of the park, but there is potential for rapid change on the west boundary (D. Morford and R. Manasek, personal communication, 27 September 2016). At the time of this assessment zoning to the west was agricultural, but the zoning laws allowed for some structures (house, garage, etc.) to be built on two lots in that area. Additional management issues include air pollution from the sugar beet factory and dust in the air during agricultural harvest and periods of drought. This pollution can affect visibility.

5.4.2. Night Sky

Increases in light pollution in North America over the past century have placed the US as the country with the sixth greatest amount of light pollution, as of 2016. Night skies helped to guide early settlers, fur trappers, and traders to Nebraska, and park visitors can still come to Scotts Bluff NM for stargazing experiences.

A night sky talk took place at Scotts Bluff NM in 2015 for the first time and was attended by about thirty park visitors. In 2016, the park unit ran a constellation program and a planets program using the newly purchased Celestron telescope.

Night Sky Condition Summary

NPS Natural Sounds and Night Skies Division (NSNSD) used interpolated remote sensing data to assess condition of natural light environment and overall night sky condition. These data indicated significant concern; light pollution from the cities of Gering and Scotts Bluff negatively affect the night skies in the national monument. Night sky condition was *Warrants Significant Concern*, confidence in condition was *Medium*, and trend was *Not Available* (Table 5.1.1).

Night Sky Gaps and Management Issues

Data used in this assessment were modeled using NSNSD methods, but no useable data had been collected on site in Scotts Bluff NM. One attempt to collect this data was thwarted by cloud cover. At the time of this assessment, park management had submitted a technical request for final night sky data collection.

Management issues include air pollution from the sugar beet factory and dust in the air during agricultural harvest and periods of drought. This pollution can affect night sky as it affects visibility. City lights as well as lights outside the cities contribute to poor night sky visibility. The cities of Gering and Scottsbluff have largely used directional lights and L.E.D. sources, thereby mitigating its total light pollution. Despite this proactive use of directional lights, twenty acres of city-owned property lie between Scotts Bluff NM and the city of Gering that, if developed, would add more street lights and light in general (D. Morford and R. Manasek, personal communication, 27 September 2016). One potential talking point with communities is for park management to encourage all cities in the area to redirect lights and to use lights in a red spectrum.

In general, these issues are similar to those for viewshed; Scotts Bluff NM has limited official capacity to engage in public planning process, as well as few people to tackle a broad range of management issues. Knowing the sources of light that are or are likely to be of particular concern would help Scotts Bluff NM managers to engage in solution-oriented discussions with neighbors to minimize light.

5.4.3. Soundscape

Scotts Bluff NM is surrounded by agricultural fields, residential areas, a public golf course, the North Platte River, and some remnant prairie. Primary sources of non-natural sounds within the park include noise from the nearby cities of Gering and Scottsbluff, train traffic, agricultural activities, automobile traffic within the park and on surrounding roads, and air traffic passing overhead.

Soundscape Condition Summary

To assess soundscape conditions, we used data modeled by the Natural Sounds and Night Skies Division and a measure of impact identified by the division. A single indicator, anthropogenic impact, indicated that soundscape condition was of significant concern. Stressors included vehicle traffic and train noise from the cities of Scotts Bluff and Gering as well as air traffic. Soundscape condition was *Warrants Significant Concern*, confidence in condition was *High*, and trend was *Not Available* (Table 5.1.1).

Soundscape Gaps and Management Issues

Initial soundscape inventory was conducted in 2014 in two different locations. One was in the quietest area of SCBL, the old picnic area and the other was collected in the maintenance area, the busiest area of the park, which is also near the Visitor Center and public parking lot. The monitoring equipment picked up traffic, air craft, and railroad. Park managers were concerned that the maintenance location may have biased the mean sound levels for Scotts Bluff NM included in the soundscape model, but it did provide a comparison with the quietest area of SCBL.

Some possibilities exist for changes to the transportation network in the region, including the addition of a third track on the Union Pacific line, however this is dependent on more coal development in Wyoming. Scotts Bluff NM now has baseline reference data if these proposed changes materialize, and managers would like to see monitoring continue in the long term to record changes of the soundscape.

5.4.4. Air Quality

Most emissions that contribute to air pollution have declined substantially in the U.S. since 1970 despite population and economic growth, but current air quality conditions are mixed across states and regions. Scotts Bluff NM is located in Scotts Bluff County where there were not enough monitoring data from 2013–2015 to assign a grade for ozone pollution, but short-term particle pollution received the best possible grade (A) for that time period. Three of Nebraska's 93 counties had sufficient data for the ALA to assign an overall grade to ozone pollution, and six counties received a grade for particle pollution; grades ranged from A to C, indicating heterogeneity in air quality.

Air Quality Condition Summary

Scottsbluff NM is a Class II airshed and held to high air quality standards. Air quality indicators of ozone, visibility, nitrogen deposition, sulfur deposition, and mercury deposition indicated a condition of moderate concern for the park. Air quality condition was *Warrants Moderate Concern*, confidence in condition was *Medium*, and trend was *Not Available* (Table 5.1.1).

Air Quality Gaps and Management Issues

Some site-specific data were available, particularly for ozone and mercury, and the sampling conducted outside of the park was at monitoring locations close enough to provide good data for a condition assessment. Monitoring has been conducted at a level sufficient for the purposes of air quality management in Scotts Bluff NM.

Management concerns included the particularly high atmospheric mercury deposition in the park (K. Paintner, personal communication, 27 September 2016). Also, particulate matter related to agricultural operations could affect visitor experience through both respiratory discomfort and degraded visibility.

5.4.5. Water Quality

Scotts Bluff NM is located in southwest Nebraska in the North Platte River Drainage (Middle North Platte-Scotts Bluff Watershed) that flows into the Platte River, which eventually flows east into the Missouri River. The Platte River was a guiding natural feature on the western migration of settlers, explorers, and trappers on the Oregon/California/Mormon Trails in the 1800s, and remains an important resource for agriculture, recreation, and wildlife in the region today. The 1.25 miles of the North Platte River that borders the park is the highest-priority waterbody at Scotts Bluff NM. Additional surface water features include three irrigation canals, including the Central Canal, the Gering/Fort Laramie Canal, and the Gering Canal, and a former natural spring—Scotts Spring—that has been dry since about 2010. Scotts Spring was used by pioneers and mentioned in several of their diaries.

Water Quality Condition Summary

We assessed water quality using the most recent data available for core water quality indicators (acidity, dissolved oxygen, temperature, specific conductivity), biological indicators (invertebrate assemblage, fecal indicator bacteria), and impairment status. Core indicators were in good and moderate condition, while aquatic invertebrates, generally reflective of more long term quality aspects, indicated moderate concern. By EPA standards, the North Platte River was Impaired in 2016 and has been impaired, from various causes, since 1998. Overall water quality condition was *Warrants Significant Concern*, confidence in condition was *High*, and trend was *Unchanging* (Table 5.1.1).

Water Quality Gaps and Management Issues

While general data are regularly collected for the segment of the North Platte River bordering the park, more detailed data are lacking. Detailed water quality data for core indicators and invertebrates at Scotts Bluff NM were limited to samples collected between 2004 and 2005, with no more than three samples collected from any one location during that time.

The segment of the North Platte River that flows past Scotts Bluff NM was impaired for several designated uses due to high levels of *E. coli* and hazard index compounds. This section of the river has been impaired, for these uses and several others, since 2002. Upstream infrastructure and activities most likely to affect water quality in the North Platte River include agriculture and urban development. Changes to land use or land management practices could have consequences in the future. Additionally, the proposed development of eastern Wyoming in the Greater Crossbow Oil and Gas Project poses a significant industrial threat to water supply competitive demand and water quality, in the general region.

Management issues for water quality are similar to as those for the other resources affected by processes at a broad landscape context, though are focused on activities upstream of the park; Scotts Bluff NM has limited direct influence on these activities.

5.4.6. Geology

Weathering and erosion are important geologic resource issues within Scotts Bluff National Monument. Weathering and erosion impact the condition of geologic resources in Scotts Bluff

National Monument due to the nature of the strata that compose the Bluff and nearby rock formations. Mass wasting, the geologic process of sediment, rock, and soil moving downslope, is another important geologic resource issue within Scotts Bluff National Monument. Mass wasting is a natural process that occurs as a result of water, ice, and/or wind acting on loosely consolidated strata, which then fails under the pull of gravity. Mass wasting can also be exacerbated by human activities such trail building and off-trail use by the visiting public. Because Scotts Bluff NM is based around the strata of the bluff, mass wasting of these strata results in loss of an important park resource.

Geology Condition Summary

The bluff that forms the major physical attraction at Scotts Bluff NM is also the major geologic resource. Recent erosion and weathering rates were outside the range of natural variation, so geology condition was of significant concern. Geologic resource condition was *Warrants Significant Concern*, confidence in condition was *Medium*, and trend was *Not Available* (Table 5.1.1).

Geology Gaps and Management Issues

Park management identified the need to measure erosion rates within the park at multiple locations. This monitoring approach would allow managers to discern how much sediment removal typically occurs from natural weathering and erosion and how much is likely due to anthropogenic activities. Anecdotally, increases in precipitation that have added to sediment loss could be caused by climate change, but much more data is needed in the park to analyze this relationship (D. Morford and R. Manasek, personal communication, 27 September 2016).

From a management perspective, weathering and erosion become problematic when sediment loss and mass wasting events affect visitors on the Summit Road and Saddle Rock Trail.

5.4.7. Paleontologic Resources

Although Scotts Bluff National Monument was not established specifically to protect fossil resources, many vertebrate fossils are known and have been collected from the monument. Most fossils have been collected from the Orella Member of the Brule Formation, White River Group, which is exposed in badlands within the Monument. Taxa from this rock unit include numerous tortoises, oreodonts and other artiodactyls, nimravids, canids, and lagomorphs.

Paleontologic Resource Condition Summary

Paleontological resource condition at the park depended on the potential for fossil loss, which was of significant concern. Overall paleontological resource condition was *Warrants Significant Concern,* confidence in condition was *Medium,* and trend was *Not Available* (Table 5.1.1).

Paleontologic Resource Gaps and Management Issues

Fossils are important natural resources at Scotts Bluff NM, but focusing on specific areas in the park might be the most efficient way to manage fossil recovery and curation (D. Morford and R. Manasek, personal communication, 27 September 2016). Park managers discussed their uncertainty in how best to manage this recovery and curation; various approaches for protecting and curating fossils hold merit, from an all-inclusive perspective wherein a paleontologist collects all fossils, to a more targeted perspective focused on specific fossil groups.

The park currently has a paleo monitoring program for fossils, corresponding remotely with the NPS network paleontologist, but identified a need to have a single paleontologist tied more closely with Scotts Bluff NM and Agate Fossil Beds NM. Leadership at both parks discussed how much both parks would benefit from sharing a paleontologist—an individual who would be fully devoted to these two parks.

5.4.8. Vegetation

From the vegetation reports written by Isabel W. Ashton and Christopher J. Davis (2016):

Scotts Bluff National Monument is dominated by mixed-grass prairie with smaller areas of juniper woodlands, badlands, and riparian forests. Vegetation monitoring began at SCBL in 1997 by the Heartland Inventory & Monitoring Program and the Northern Great Plains Fire Ecology Program. In 2010, SCBL was incorporated into the Northern Great Plains Inventory & Monitoring Network (NGPN). At that time, vegetation monitoring protocols and plot locations were shifted to better represent the entire park and to coordinate efforts with NGPFire. A total of 34 plots were established by NGPFire and NGPN in SCBL and the combined sampling efforts began in 2011. In 2014, an additional 20 plots were established in the riparian forest to assess forest condition. In this report, we use the data from 2011–2015 to assess the current condition of park vegetation and the data from 1998–2015 are used to look at longer-term trends.

Vegetation Condition Summary

A complete vegetation assessment was completed for Scotts Bluff NM in the course of this NRCA, and we based our assessment entirely on those results. Several measures of upland plant community, exotic plant detection, and riparian forest indicated moderate concern. Overall vegetation condition *Warrants Moderate Concern*, confidence in condition was *Medium*, and trend was *Not Available* (Table 5.1.1).

Vegetation Gaps and Management Issues

Data were thorough, but considering the historical context of vegetation within the park is also very important. Managers at Scotts Bluff NM agreed that obtaining a summary of environmental history of the park would be helpful for this context. Additionally, the park would benefit from a close comparison of existing plant communities and historic composition of native prairie species curation (D. Morford and R. Manasek, personal communication, 27 September 2016).

These goals are consistent with those discussed by managers at Agate Fossil Beds NM, and both parks agreed that they would benefit from sharing a biotechnician or ecologist to focus on these issues.

5.4.9. Birds

Scotts Bluff NM is located within the shortgrass prairie bird conservation region (BCR). The shortgrass prairie is an arid region with limited vegetation height and diversity. Some of North America’s highest priority birds breed here, including the grasshopper sparrow, a species that can be found at Scotts Bluff NM. A large proportion (~40%) of habitat at Scotts Bluff NM is native prairie. While the overall trend for birds in the shortgrass BCR is stable, all of the grassland-obligate species there exhibit negative trends. Habitat loss is a major cause of grassland bird declines; habitat loss may be related to a reduction in the diversity of native herbivores, such as bison and prairie dogs that create high quality habitat for many grassland bird species. Scotts Bluff NM is small, but it contains a variety of habitat types in addition to. One source of important bird habitat is the riparian area along the northern border of the park. Loss of riparian habitat is a major cause of bird declines regionally.

Bird Condition Summary

For species not formally protected by the Endangered Species Act, calculating bird condition is not straightforward. To calculate a condition score, we would have needed empirically derived estimates of the levels of species diversity, species abundance, and conservation values that revealed the condition of the species within the park unit. Those criteria are absent from the literature, and assigning a condition score without them would have been unwarranted. In lieu of condition scores, we presented values for indicators based on the best available data; natural resource managers can reference these values in current and future park planning.

We presented a framework for assessing bird condition using species diversity, abundance, and conservation value, but at the time of this assessment no standards or consensus existed for evaluating condition of bird community. Overall condition of birds was *Not Available*, confidence in condition was *High*, and trend was *Not Available* (Table 5.1.1).

Bird Gaps and Management Issues

To identify condition of birds in the park in the future, NPS will need to identify management goals. An ongoing natural history program could coordinate with the data collection to monitor species over time.

5.4.10. Prairie Dogs

Prairie Dog Condition Summary

Black-tailed prairie dogs were reduced to very low population numbers by the 1960s, but their numbers increased again following some federal protections. Area inhabited by prairie dogs in the park indicated moderate condition, though that acreage has increased since 1995. Overall condition of prairie dogs was *Warrants Moderate Concern*, confidence in condition was *High*, and trend was *Improving* (Table 5.1.1).

Prairie Dog Gaps and Management Issues

Prairie dog data were thorough, though plague monitoring was irregular prior to this assessment (R. Manasek, personal communication, 27 September 2016). Plague monitoring has occurred in the past, which revealed that some of the fleas are carriers. The colony has decreased several times, but has been improving.

Scotts Bluff NM needs to have a prairie dog action plan (K. Painter, personal communication, 20 September 2016) in place to conduct any management action. While considered vermin in Nebraska, the species is protected in the park. Managers will examine the existing management plan for Deveils Tower NM, which is a similar size and deals with similar issues for prairie dogs.

5.4.11. Pollinators

Invertebrate pollinators in Nebraska include native insects and honey bees, all of which have varying food and habitat needs. Scotts Bluff NM is home to a total of 19 confirmed butterfly species (Lawson 2004), and may be host to even more species. Monarch butterflies (*Danaus plexippus*) where present in the park, where the endangered species spends summer; other butrerflies also present were two-tailed swallowtails (*Papilio multicaudata*) and red admirals (*Vanessa atalanta rubria*). While bumble bees (*Bombus* sp.) and other invertebrate pollinators are likely present in Scotts Bluff NM, local census data are lacking for the park.

Pollinators Condition Summary

We presented a framework for assessing pollinator condition using species diversity, abundance, and vulnerability status, but at the time of this assessment no standards or consensus existed for evaluating condition of pollinator community. We used vulnerability status to assign a condition of *Moderate Concern*. Confidence in condition was *Low* and trend was *Not Available* (Table 5.1.1).

Pollinators Gaps and Management Issues

Butterfly data collected over 10 years prior to this assessment and the Xerces Society Red Lists formed the basis of our assessment. A comprehensive baseline inventory of all pollinators is key to understanding condition of pollinators in Scotts Bluff NM. Several bees and butterflies are under petition for listing under the Endangered Species Act; a baseline inventory of pollinators at the park would elucidate if those species are present or if they could be present in the park.

Following baseline inventory, monitoring protocols should be designed so that methods can be consistent among NPS units. This monitoring effort is an opportunity for Scotts Bluff NM to involve citizen science and build new connections with local universities. Managers expressed concern that the agricultural setting around the park could increase pesticide drift in the park, harming resident pollinators. Mosquito control in the surrounding communities could have a similarly detrimental effect. Damage to pollinators likely has negative consequences for bird populations in the park.

Appendix A. Viewshed details and figures for each vantage point included in the assessment

Viewshed analyses were completed for each of the following points (vantage point 5 was excluded from the final analysis as an unimportant point at which visitors could not safely stop vehicles or travel by foot to view the landscape):

Table A1. Digital viewshed analyses were completed for each of the seven following vantage points.

Vantage Point	Location	Figure
SCBL Vantage 1 or North Overlook	41.839946, -103.698980	Figure A1
SCBL Vantage 2 or South Overlook	41.834847, -103.699685	Figure A2
SCBL Vantage 3 or Covered Wagon Interpretive Area	41.829047, -103.709280	Figure A3
SCBL Vantage 4 or Scotts Bluff NM Entrance Sign	41.823349, -103.694427	Figure A4
SCBL Vantage 6 or Summit Parking Lot	41.837049, -103.700086	Figure A5

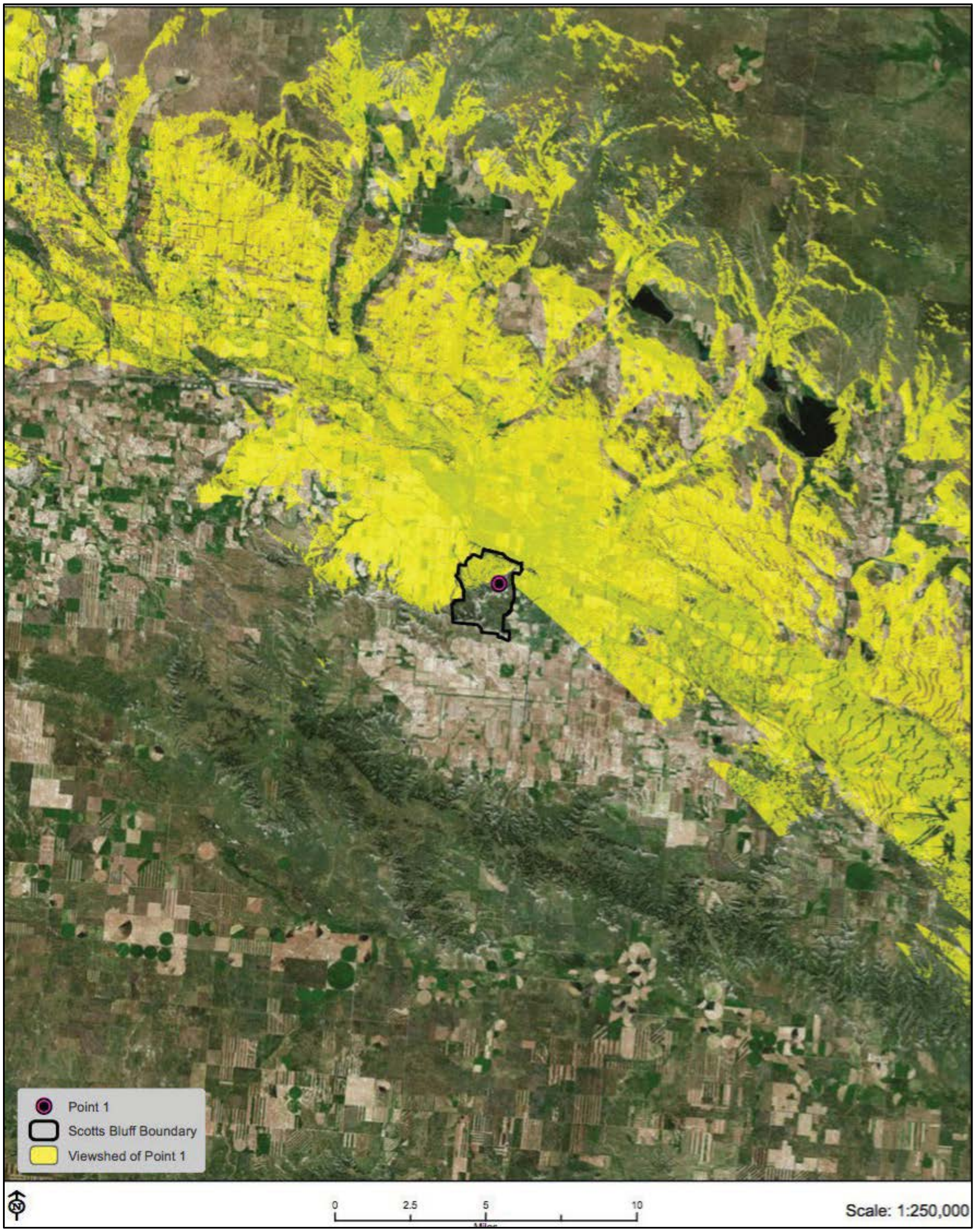

Figure A1. Viewshed for vantage point 1 in Scotts Bluff NM.

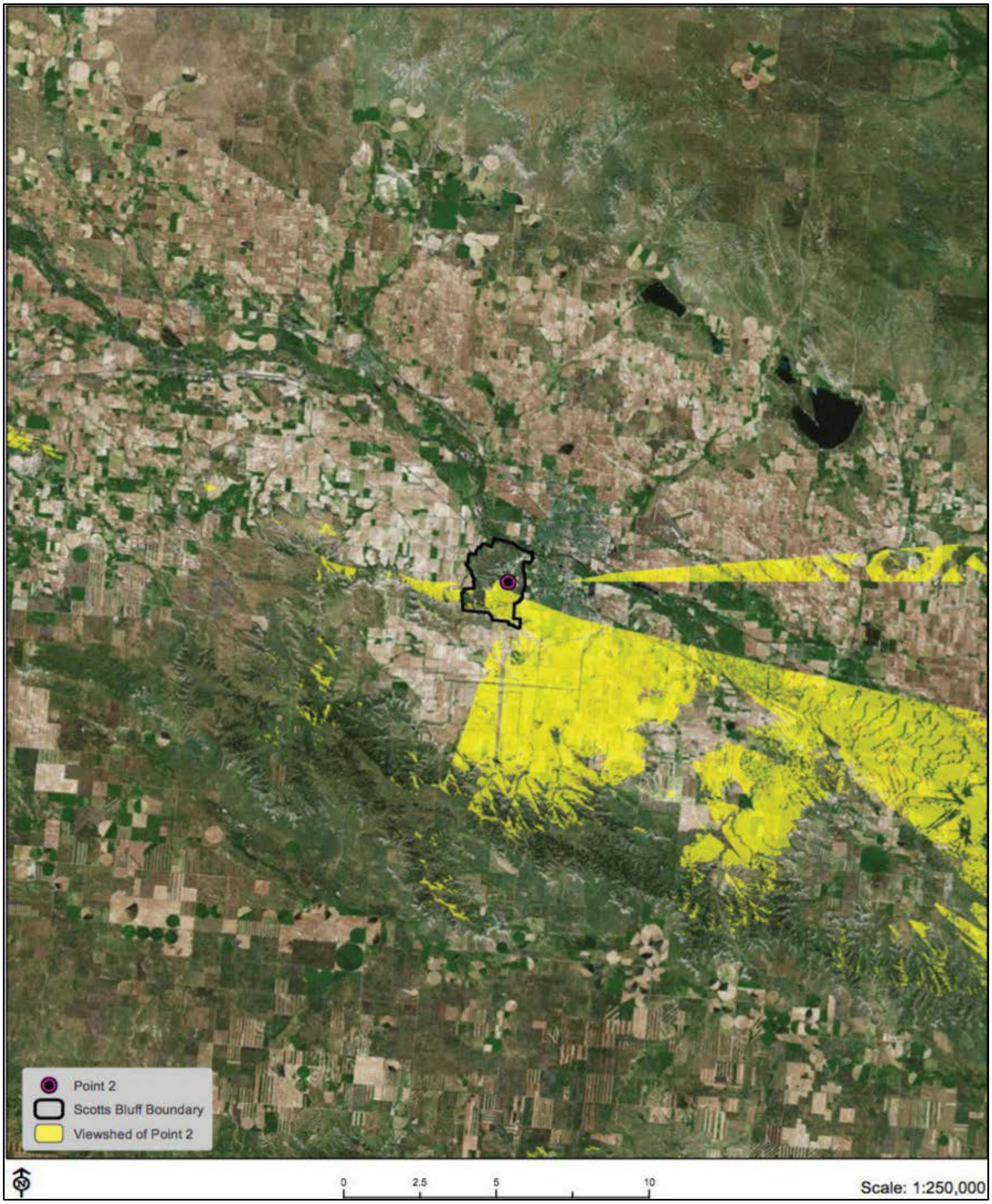

Figure A2. Viewshed for vantage point 2 in Scotts Bluff NM.

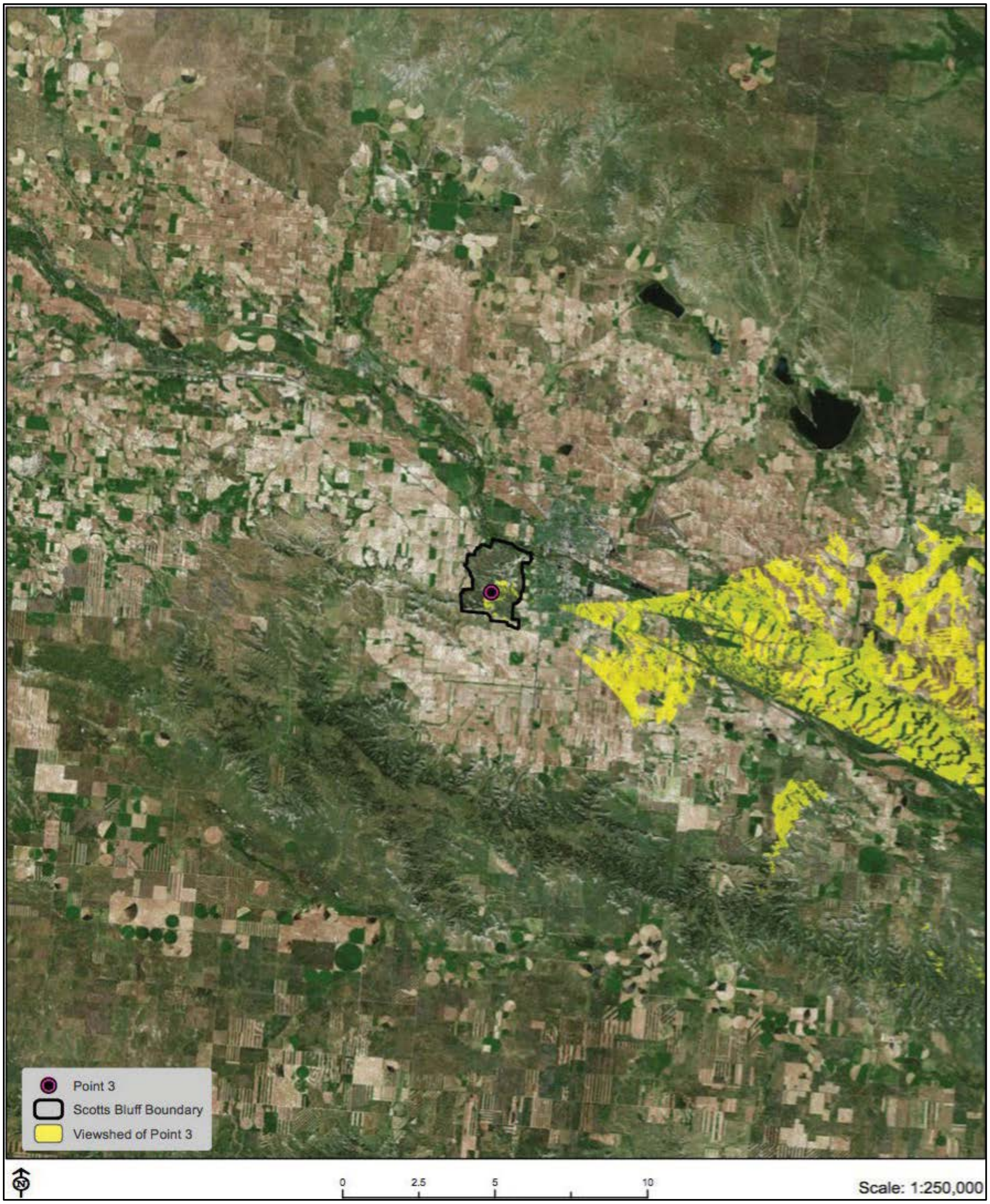

Figure A3. Viewshed for vantage point 3 in Scotts Bluff NM.

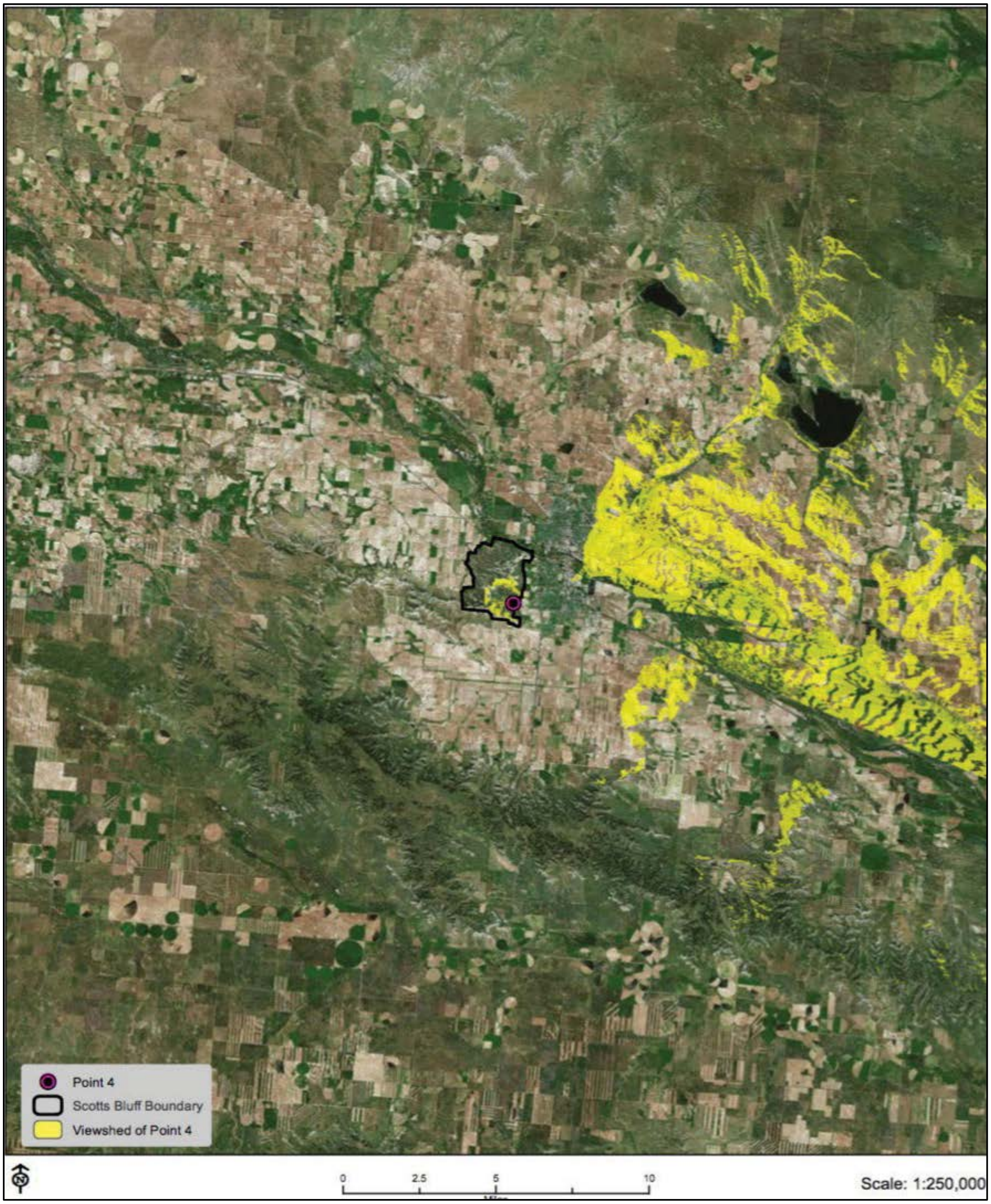

Figure A4. Viewshed for vantage point 4 in Scotts Bluff NM.

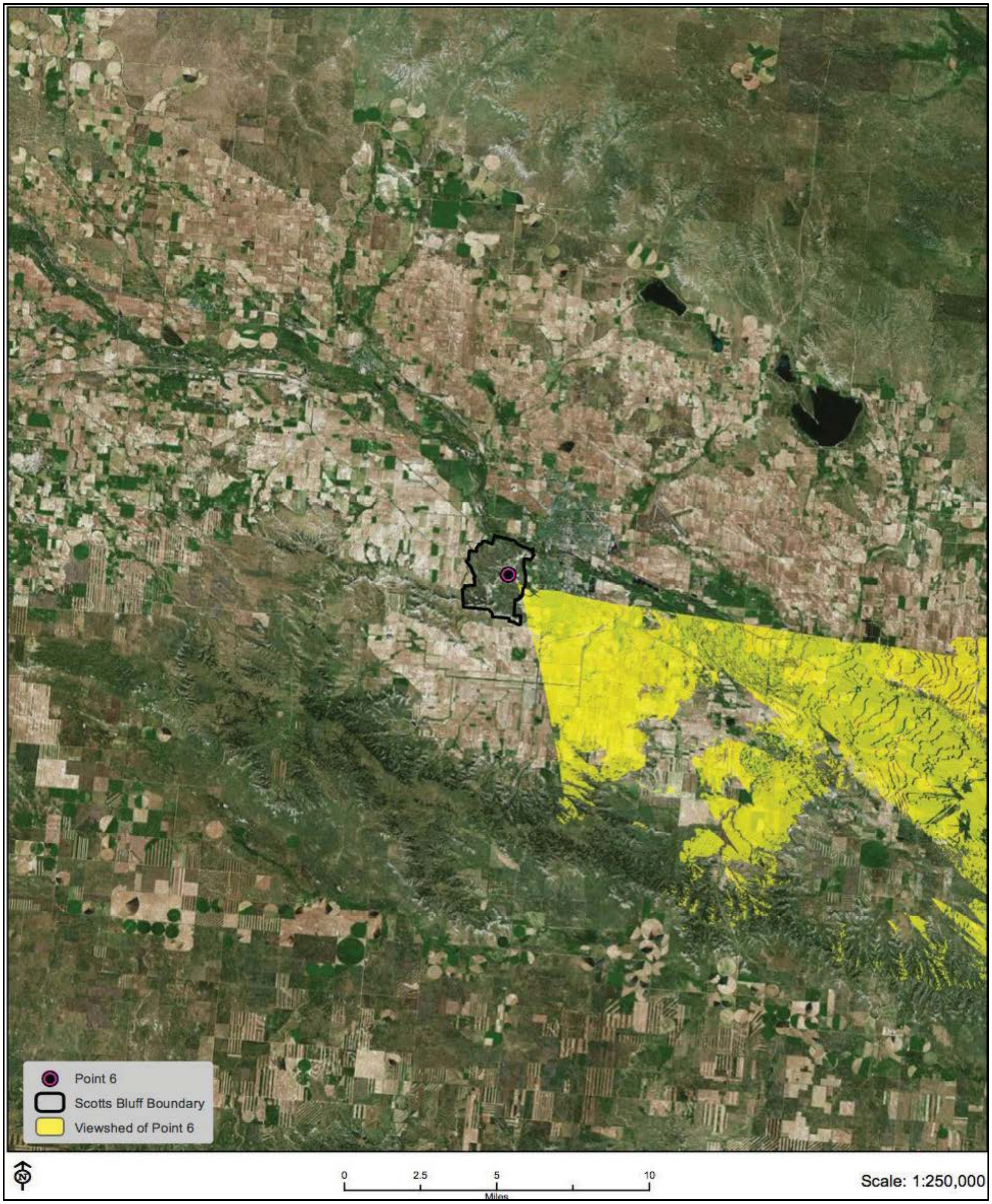

Figure A5. Viewshed for vantage point 5 in Agate Fossil Beds NM.

Appendix B. Methods for Viewshed Analysis, written by WyGISC 2016

A viewshed analysis of the study area was conducted in ArcGIS for Desktop 10.3.1, a commercial off-the-shelf GIS software product. The primary aim was to create a series of maps each one illustrating the area that is visible from a predefined location of interest (i.e. vantage point) within the study area. In addition to these viewshed maps, the following maps were also produced for the study area: (1) overview map depicting the spatial distribution of the vantage points; (2) landcover map based on the 2012 national landcover dataset (30m resolution NLCD); and (3) all vantage points viewsheds within a 60 mile radius of the study area perimeter.

The NLCD was further generalized into three landcover class of natural, developed and agriculture. Two statistics were then determined using Microsoft Excel 2013. First is the proportion of the viewshed area in each landcover class. This was calculated from aggregating the percentage of the viewshed area within each landcover class for each vantage point. The second statistic is the percentage of the viewshed area which overlapped different landcover classes within predefined distance zones of 0-0.05 miles, 0.5- 3 miles and 3-60 miles of each vantage point. The general steps followed to create these statistics plus the map products described above are described below.

Creating and analyzing viewshed areas

1. Collect project data. The following data were collected from various sources: 2012 NLCD (United States Geological Survey (USGS)), 10m resolution digital elevation data (National Elevation Dataset (NED)), national park (i.e. study area) boundary, vantage point locations (user-defined).
2. Change map projections. All datasets were re-projected to Lambert Conformal Conic Projection.
3. Create buffer region. In ArcGIS for Desktop, create a 60 mile buffer around the perimeter of the study area. The buffer tool is accessible via Analysis > Proximity > Buffer.
4. Add name attribute to vantage points layer. Create a field for storing the names of the vantage points (e.g. Point 1, Point 2, etc.) for labeling purposes.
5. Create a feature class of vantage points. Export study area vantage points into a feature class. Use the batch functionality for Conversion Tools > To Geodatabase > Feature Class to Feature Class tool with a definition query.
6. Generate viewshed for each vantage point. Use the Surface > Spatial Analyst Tools > Viewshed tool to create a viewshed for each vantage point based on the 10 m NED. Limit the analysis to the 60 mile buffer created in step 3.
7. Generalize NLCD into three landcover classes. Reclassify NCLD layer into three landcover classes of natural, developed and agriculture. Use the Spatial Analyst Tools > Reclassify tool.
8. Determine number of viewshed pixels overlaying each landcover class per vantage point. Use the Spatial Analyst Tools > Zonal tools > Zonal Statistics as Table tool to determine the number of viewshed area pixels for each landcover type per vantage point.

9. Determine percentage of viewsheds within three landcover classes. Use Microsoft Excel to determine the percentage of each viewshed (and combine viewsheds for study area) that were within each of the three landcover classes/zones
10. Finalize map products. Create cartographically-sound final maps.

Determining percentage of viewshed area that overlaps given landcover class at predefined distances from vantage points

The following steps were followed to achieve the above aim.

1. Create buffer zones of 0-0.5 miles, 0.5-3miles and 3-60 miles for each vantage point. The appropriate buffer tool is available in ArcGIS by navigating through: Analysis > Proximity
2. > Multiple Ring Buffer tool
3. Create a landcover layer restricted to viewshed for each vantage point. This is achieved using ArcGIS’ raster calculator found through: Spatial Analyst Tools > Map Algebra > Raster Calculator.
4. Separate layer created in step 2 into three layers, each one only displaying one of the landcover classes (e.g. agriculture). Use the Spatial Analyst Tools > Reclassify tool.
5. Determine number of viewshed pixels for each landcover class that falls within each buffered zone (e.g. number of agriculture pixels in 0-0.5 mile zone). Use the Spatial Analyst Tools > Zonal > Zonal Statistics as Table tool.
6. Determine percentage of each viewshed (and all viewsheds for a site combined) that fall within each landcover class (Natural, Developed, Agriculture) and within each distance zone (0-0.5 miles, 0.5-3 miles, 3-60 miles).

Notes

- The viewsheds created here assume that there are no physical features which block the observer’s line of sight.
- The NLCD was resampled to 10m to match the resolution of the NED for analysis.
- Where required, a viewshed can be generated from linear features such as road, trail or path sections.

Appendix C. List of Plant Species Found in 1998-2015 at SCBL

Tabe C1. List of all the plant species found in SCBL long-term plant community monitoring plots. The species are grouped by plant family. An “X” in the exotic column means that the species is not native to the park or, in the case where only the genus was identified, there are some species within that genus that are exotic. Species considered to be rare in Nebraska are marked in the final column and the state conservation ranks are provided. Conservation rank definitions are in Table 2 of the report.

Family	Code	Scientific Name	Common Name	Exotic	Rare
Aceraceae	ACNE2	*Acer negundo*	boxelder	–	S3S5
Agavaceae	YUGL	*Yucca glauca*	soapweed yucca	–	–
Amaranthaceae	AMARA	*Amaranthus*	pigweed	X	–
	AMRE	*Amaranthus retroflexus*	redroot amaranth	–	–
Anacardiaceae	RHAR4	*Rhus aromatica*	fragrant sumac	–	–
	RHTR	*Rhus trilobata*	skunkbush sumac	–	–
	TORA2	*Toxicodendron radicans*	eastern poison ivy	–	–
	TORY	*Toxicodendron rydbergii*	western poison ivy	–	–
Apiaceae	COMA2	*Conium maculatum*	poison hemlock	X	–
	CYGL99	*Cymopterus glomeratus*	plains springparsley	–	–
	PASA2	*Pastinaca sativa*	wild parsnip	X	–
Asclepiadaceae	ASCLE	*Asclepias* spp.	milkweed	–	–
	ASPU	*Asclepias pumila*	plains milkweed	–	–
	ASSP	*Asclepias speciosa*	showy milkweed	–	–
	ASVE	*Asclepias verticillata*	whorled milkweed	–	–
	ASVI	*Asclepias viridiflora*	green comet milkweed	–	–
Asteraceae	AGGL	*Agoseris glauca*	pale agoseris	–	S1
	AMPS	*Ambrosia psilostachya*	Cuman ragweed	–	–
	ANMI3	*Antennaria microphylla*	littleleaf pussytoes	–	S2S4
	ANTEN	*Antennaria* spp.	pussytoes	–	–
	ARCA12	*Artemisia campestris*	field sagewort	–	S3S5
	ARDR4	*Artemisia dracunculus*	tarragon	–	–
	ARFI2	*Artemisia filifolia*	sand sagebrush	–	–
	ARFR4	*Artemisia frigida*	fringed sagewort	–	–
	ASTER	*Aster* spp.	aster	–	–

Family	Code	Scientific Name	Common Name	Exotic	Rare
	BREU	*Brickellia eupatorioides*	false boneset	–	–
	CANU4	*Carduus nutans*	musk thistle	X	–
	CIAR4	*Cirsium arvense*	Canada thistle	X	–
	CICA11	*Cirsium canescens*	prairie thistle	–	–
	CIOC2	*Cirsium ochrocentrum*	yellowspine thistle	–	–
	CIRSI	*Cirsium* spp.	thistle	X	–
	COCA5	*Conyza canadensis*	horseweed	–	–
	DICA18	*Dieteria canescens*	hoary tansyaster	–	S2S4
	DYPA	*Dyssodia papposa*	fetid marigold	–	–
	ERCA4	*Erigeron canus*	hoary fleabane	–	–
	ERFL	*Erigeron flagellaris*	trailing fleabane	–	S3
	ERNA10	*Ericameria nauseosa*	rubber rabbitbrush	–	S2S4
	GRSQ	*Grindelia squarrosa*	curlycup gumweed	–	S1
	GUSA2	*Gutierrezia sarothrae*	broom snakeweed	–	–
	HEAN3	*Helianthus annuus*	common sunflower	–	–
	HELIA3	*Helianthus* spp.	sunflower	–	–
	HEPE	*Helianthus petiolaris*	prairie sunflower	–	–
	HEVI4	*Heterotheca villosa*	hairy false goldenaster	–	S1
	HIUM	*Hieracium umbellatum*	narrowleaf hawkweed	–	S1
	HYFI	*Hymenopappus filifolius*	fineleaf hymenopappus	–	–
	HASP3	*Haplopappus spinulosus*	lacy tansyaster	X	–
	LASE	*Lactuca serriola*	prickly lettuce	X	–
	LIPU	*Liatris punctata*	dotted blazing star	–	–
	LOAR5	*Logfia arvensis*	field cottonrose	X	–
	LYJU	*Lygodesmia juncea*	rush skeletonplant	–	–
	MAPI	*Machaeranthera pinnatifida*	lacy tansyaster	–	–
	MUOB99	*Mulgedium oblongifolium*	blue lettuce	–	–
	NOCU	*Nothocalais cuspidata*	prairie false dandelion	–	–
	PACA15	*Packera cana*	woolly groundsel	–	–
	PAPL12	*Packera plattensis*	prairie groundsel	–	–
	RACO3	*Ratibida columnifera*	upright prairie coneflower	–	–
	SEIN2	*Senecio integerrimus*	lambstongue ragwort	–	S1
	SENEC	*Senecio* spp.	ragwort	–	–
	SERI2	*Senecio riddellii*	Riddell's ragwort	–	–

Family	**Code**	**Scientific Name**	**Common Name**	**Exotic**	**Rare**
	SOCA6	*Solidago canadensis*	Canada goldenrod	–	S3S5
	SOLID	*Solidago* spp.	goldenrod	–	–
	SOMI2	*Solidago missouriensis*	Missouri goldenrod	–	–
	SOMO	*Solidago mollis*	velvety goldenrod	–	–
	SONCH	*Sonchus* spp.	sowthistle	X	–
	SONE	*Solidago nemoralis*	gray goldenrod	–	–
	SYER	*Symphyotrichum ericoides*	white heath aster	–	S3S5
	SYMPH4	*Symphyotrichum*	aster	–	–
	TAOF	*Taraxacum officinale*	common dandelion	X	–
	THME	*Thelesperma megapotamicum*	Hopi tea greenthread	–	–
	TRDU	*Tragopogon dubius*	yellow salsify	X	–
	XASP99	*Xanthium spinulosum*	lacy tansyaster	–	–
Boraginaceae	CRCA8	*Cryptantha cana*	mountain cryptantha	–	–
	CRCE	*Cryptantha celosioides*	buttecandle	–	–
	CRTH	*Cryptantha thyrsiflora*	calcareous cryptantha	–	S3S5
	CYOF	*Cynoglossum officinale*	houndstongue	X	–
	LAOC3	*Lappula occidentalis*	flatspine stickseed	–	–
	LIIN2	*Lithospermum incisum*	narrowleaf stoneseed	–	–
Brassicaceae	ALDE	*Alyssum desertorum*	desert madwort	X	–
	BRASS2	*Brassica*	mustard	X	–
	CAMI2	*Camelina microcarpa*	littlepod false flax	X	–
	DEPI	*Descurainia pinnata*	western tansymustard	–	S3S5
	DESCU	*Descurainia* spp.	tansymustard	X	–
	DESO2	*Descurainia sophia*	herb sophia	X	–
	DRRE2	*Draba reptans*	Carolina draba	–	–
	ERAS2	*Erysimum asperum*	western wallflower	–	–
	ERCA14	*Erysimum capitatum*	sanddune wallflower	–	–
	LEDE	*Lepidium densiflorum*	common pepperweed	–	–
	LELA2	*Lepidium latifolium*	broadleaved pepperweed	X	–
	LEPID	*Lepidium* spp.	pepperweed	X	–
	LESQU	*Lesquerella* spp.	bladderpod	–	–
	PHLU99	*Physaria ludoviciana*	foothill bladderpod	–	–
	PHRE8	*Physaria reediana*	alpine bladderpod	–	S2S4
	ROSI2	*Rorippa sinuata*	spreading yellowcress	–	–

Family	**Code**	**Scientific Name**	**Common Name**	**Exotic**	**Rare**
	SIAL2	*Sisymbrium altissimum*	tall tumblemustard	X	–
	THAR5	*Thlaspi arvense*	field pennycress	X	–
Cactaceae	ESMI3	*Escobaria missouriensis*	Missouri foxtail cactus	–	–
	ESVI2	*Escobaria vivipara*	spinystar	–	–
	OPFR	*Opuntia fragilis*	brittle pricklypear	–	–
	OPMA2	*Opuntia macrorhiza*	twistspine pricklypear	–	–
	OPPO	*Opuntia polyacantha*	plains pricklypear	–	–
	OPUNT	*Opuntia* spp.	pricklypear	–	–
Caprifoliaceae	LOTA	*Lonicera tatarica*	Tatarian honeysuckle	X	–
	SYOC	*Symphoricarpos occidentalis*	western snowberry	–	–
Caryophyllaceae	PADE4	*Paronychia depressa*	spreading nailwort	–	–
Chenopodiaceae	ATCA2	*Atriplex canescens*	fourwing saltbush	–	S3S5
	CHAL7	*Chenopodium album*	lambsquarters	X	–
	CHBE4	*Chenopodium berlandieri*	pitseed goosefoot	–	–
	CHENO	*Chenopodium* spp.	goosefoot	X	–
	CHFR3	*Chenopodium fremontii*	Fremont's goosefoot	–	–
	CHPR5	*Chenopodium pratericola*	desert goosefoot	–	–
	KOSC	*Kochia scoparia*	burningbush, kochia	X	–
	KRLA2	*Krascheninnikovia lanata*	winterfat	–	S3S5
	SAKA	*Salsola kali*	Russian thistle	X	–
	SALSO	*Salsola* spp.	Russian thistle	X	–
	SATR12	*Salsola tragus*	prickly Russian thistle	X	–
Commelinaceae	TRADE	*Tradescantia* spp.	spiderwort	–	–
	TRBR	*Tradescantia bracteata*	longbract spiderwort	–	–
	TROC	*Tradescantia occidentalis*	prairie spiderwort	–	–
Convolvulaceae	COAR4	*Convolvulus arvensis*	field bindweed	X	–
	EVNU	*Evolvulus nuttallianus*	shaggy dwarf morning-glory	–	–
	IPLE	*Ipomoea leptophylla*	bush morning-glory	–	–
Cupressaceae	JUSC2	*Juniperus scopulorum*	Rocky Mountain juniper	–	–
Cyperaceae	CADU6	*Carex duriuscula*	needleleaf sedge	–	–
	CAFI	*Carex filifolia*	threadleaf sedge	–	–
	CAIN9	*Carex inops*	sun sedge	–	–
	CAREX	*Carex* spp.	sedge	–	–

Family	Code	Scientific Name	Common Name	Exotic	Rare
Elaeagnaceae	SHAR	*Shepherdia argentea*	silver buffaloberry	–	–
	SHCA	*Shepherdia canadensis*	russet buffaloberry	–	–
Euphorbiaceae	CRTE4	*Croton texensis*	Texas croton	–	–
	EUMA8	*Euphorbia marginata*	snow on the mountain	–	–
	EUGL3	*Euphorbia glyptosperma*	ribseed sandmat	–	–
	EUSE5	*Euphorbia serpyllifolia*	thymeleaf sandmat	X	–
	EUPHO	*Euphorbia* spp.	spurge, sandmat	X	–
Fabaceae	ASAG2	*Astragalus agrestis*	purple milkvetch	–	S1
	ASBI2	*Astragalus bisulcatus*	twogrooved milkvetch	–	S3S5
	ASGR3	*Astragalus gracilis*	slender milkvetch	–	–
	ASLA27	*Astragalus laxmannii*	Laxmann's milkvetch	–	–
	ASMI10	*Astragalus missouriensis*	Missouri milkvetch	–	–
	ASMO7	*Astragalus mollissimus*	woolly locoweed	–	–
	ASTRA	*Astragalus*	milkvetch	–	–
	DACA7	*Dalea candida*	white prairie clover	–	–
	DAPU5	*Dalea purpurea*	purple prairie clover		S3S5
	DAVI	*Dalea villosa*	silky prairie clover	–	–
	GLLE3	*Glycyrrhiza lepidota*	American licorice	–	–
	LAPO2	*Lathyrus polymorphus*	manystem pea	–	–
	LUPIN	*Lupinus* spp.	lupine	–	–
	MELIL	*Melilotus* spp.	sweetclover	X	–
	MELU	*Medicago lupulina*	black medick	X	–
	MEOF	*Melilotus officinalis*	yellow sweetclover	X	–
	MESA	*Medicago sativa*	alfalfa	–	–
	OXLA3	*Oxytropis lambertii*	purple locoweed	–	–
	OXSE	*Oxytropis sericea*	white locoweed	–	–
	PEAR6	*Pediomelum argophyllum*	silverleaf Indian breadroot	–	–
	PEES	*Pediomelum esculentum*	large Indian breadroot	–	–
	PSLA3	*Psoralidium lanceolatum*	lemon scurfpea	–	–
	PSTE5	*Psoralidium tenuiflorum*	slimflower scurfpea	–	–
	THRH	*Thermopsis rhombifolia*	golden pea	–	–
	VIAM	*Vicia americana*	American vetch	–	S2S4
Grossulariaceae	RIAU	*Ribes aureum*	golden currant	–	–
	RIBES	*Ribes* spp.	currant	–	–

Family	**Code**	**Scientific Name**	**Common Name**	**Exotic**	**Rare**
	RICE	*Ribes cereum*	wax currant	–	–
Hydrophyllaceae	ELNY	*Ellisia nyctelea*	Aunt Lucy	–	–
Lamiaceae	HEDR	*Hedeoma drummondii*	Drummond's false pennyroyal	–	–
	HEHI	*Hedeoma hispida*	rough false pennyroyal	–	–
	MAVU	*Marrubium vulgare*	horehound	X	–
	MEAR4	*Mentha arvensis*	wild mint	–	–
	MOFI	*Monarda fistulosa*	wild bergamot	–	–
	MOPE	*Monarda pectinata*	pony beebalm	–	–
	NECA2	*Nepeta cataria*	catnip	X	–
	TECA3	*Teucrium canadense*	Canada germander	–	–
Liliaceae	ALTE	*Allium textile*	textile onion	–	–
	ASOF	*Asparagus officinalis*	garden asparagus	X	–
	FRAT	*Fritillaria atropurpurea*	spotted fritillary	–	S2
	LEMO4	*Leucocrinum montanum*	common starlily	–	–
	MAST4	*Maianthemum stellatum*	starry false lily of the valley	–	–
	ZIVE	*Zigadenus venenosus*	meadow deathcamas	–	–
Loasaceae	MEDE2	*Mentzelia decapetala*	tenpetal blazingstar	–	–
Malvaceae	SPCO	*Sphaeralcea coccinea*	scarlet globemallow	–	–
Melanthiaceae	TOVE2	*Toxicoscordion venenosum*	meadow deathcamas	–	–
Nyctaginaceae	MIAL4	*Mirabilis albida*	white four o'clock	–	–
	MIHI	*Mirabilis hirsuta*	hairy four o'clock	–	–
	MILI3	*Mirabilis linearis*	narrowleaf four o'clock	–	–
Oleaceae	FRPE	*Fraxinus pennsylvanica*	green ash	–	–
Onagraceae	OEBI	*Oenothera biennis*	common evening primrose	–	–
	OECE2	*Oenothera cespitosa*	Tufted evening primrose	–	S2S4
	OECU99	*Oenothera curtiflora*	velvetweed	–	–
	OESE3	*Oenothera serrulata*	yellow sundrops	–	–
	OESU99	*Oenothera suffrutescens*	scarlet beeblossom	–	–
Orobanchaceae	ORFA	*Orobanche fasciculata*	clustered broomrape	–	–
Papaveraceae	ARPO2	*Argemone polyanthemos*	crested pricklypoppy	–	–
Pinaceae	PIPO	*Pinus ponderosa*	ponderosa pine	–	–
Poaceae	ACHY	*Achnatherum hymenoides*	Indian ricegrass	–	–
	AGCR	*Agropyron cristatum*	crested wheatgrass	X	–

Family	Code	Scientific Name	Common Name	Exotic	Rare
	ANGE	*Andropogon gerardii*	big bluestem	–	–
	ARPU9	*Aristida purpurea*	purple threeawn	–	S3S5
	BOCU	*Bouteloua curtipendula*	sideoats grama	–	–
	BODA2	*Bouteloua dactyloides*	buffalograss	–	–
	BOGR2	*Bouteloua gracilis*	blue grama	–	–
	BOHI2	*Bouteloua hirsuta*	hairy grama	–	–
	BRHOH	*Bromus hordeaceus ssp. hordeaceus*	soft brome	X	–
	BRIN2	*Bromus inermis*	smooth brome	X	–
	BRJA	*Bromus japonicus*	Japanese brome	X	–
	BROMU	*Bromus* spp.	brome	X	–
	BRTE	*Bromus tectorum*	cheatgrass	X	–
	CALO	*Calamovilfa longifolia*	prairie sandreed	–	–
	DASP2	*Danthonia spicata*	poverty oatgrass	–	S1
	DISP	*Distichlis spicata*	saltgrass	–	–
	ELCA4	*Elymus canadensis*	Canada wildrye	–	–
	ELEL5	*Elymus elymoides*	squirreltail	–	–
	ELLA3	*Elymus lanceolatus*	thickspike wheatgrass	–	S1
	ELTR7	*Elymus trachycaulus*	slender wheatgrass	–	S1
	ELYMU	*Elymus* spp.	wildrye	–	–
	HECO26	*Hesperostipa comata*	needle and thread	–	–
	HESP11	*Hesperostipa spartea*	porcupinegrass	–	–
	HOJU	*Hordeum jubatum*	foxtail barley	–	–
	KOMA	*Koeleria macrantha*	prairie Junegrass	–	–
	MUCU3	*Muhlenbergia cuspidata*	plains muhly	–	–
	MURA	*Muhlenbergia racemosa*	marsh muhly	–	–
	NAVI4	*Nassella viridula*	green needlegrass	–	–
	PACA6	*Panicum capillare*	witchgrass	–	S3S5
	PASM	*Pascopyrum smithii*	western wheatgrass	–	–
	PAVI2	*Panicum virgatum*	switchgrass	–	–
	PHAR3	*Phalaris arundinacea*	reed canarygrass	X	–
	PIMI7	*Piptatherum micranthum*	littleseed ricegrass	–	–
	POPR	*Poa pratensis*	Kentucky bluegrass	X	–
	POSE	*Poa secunda*	Sandberg bluegrass	–	–

Family	Code	Scientific Name	Common Name	Exotic	Rare
	PSSP6	*Pseudoroegneria spicata*	bluebunch wheatgrass	–	S1
	SCSC	*Schizachyrium scoparium*	little bluestem	–	–
	SEVI4	*Setaria viridis*	green foxtail	–	–
	SONU2	*Sorghastrum nutans*	Indiangrass	–	–
	SPCR	*Sporobolus cryptandrus*	sand dropseed	–	–
	BUDA	*Buchloe dactyloides*	buffalograss	–	–
	FEOC3	*Festuca octoflora*	sixweeks fescue	X	–
	THIN6	*Thinopyrum intermedium*	intermediate wheatgrass	X	–
	VUOC	*Vulpia octoflora*	sixweeks fescue	–	–
Polemoniaceae	IPCO5	*Ipomopsis congesta*	ballhead ipomopsis	–	S2S4
	PHAN4	*Phlox andicola*	prairie phlox	–	–
	PHHO	*Phlox hoodii*	spiny phlox	–	–
Polygonaceae	ERFL4	*Eriogonum flavum*	alpine golden buckwheat	–	–
	ERPA9	*Eriogonum pauciflorum*	fewflower buckwheat	–	S3S5
	POAC3	*Polygonum achoreum*	leathery knotweed	–	–
	FACO	*Fallopia convolvulus*	black bindweed	X	–
	RUSA	*Rumex salicifolius*	willow dock	–	–
Ranunculaceae	CLHI	*Clematis hirsutissima*	hairy clematis	–	S1
Rosaceae	PRVI	*Prunus virginiana*	chokecherry	–	–
	ROAR3	*Rosa arkansana*	prairie rose	–	–
	ROSA5	*Rosa* spp.	rose	–	–
	ROWO	*Rosa woodsii*	Woods' rose	–	–
Rubiaceae	GAAP2	*Galium aparine*	stickywilly	–	–
Salicaceae	PODE3	*Populus deltoides*	eastern cottonwood	–	–
	SAAM2	*Salix amygdaloides*	peachleaf willow	–	–
	SAIN3	*Salix interior*	sandbar willow	–	–
Santalaceae	COUM	*Comandra umbellata*	bastard toadflax	–	–
Scrophulariaceae	BEWY	*Besseya wyomingensis*	Wyoming kittentails	–	–
	PEAL2	*Penstemon albidus*	white penstemon	–	–
	PEGR5	*Penstemon gracilis*	lilac penstemon	–	–
	PENST	*Penstemon* spp.	beardtongue	–	–
	VEAM2	*Veronica americana*	American speedwell	–	–
	VETH	*Verbascum thapsus*	common mullein	X	–
Solanaceae	PHHE4	*Physalis hederifolia*	ivyleaf groundcherry	–	S3S5

Family	Code	Scientific Name	Common Name	Exotic	Rare
	PHHE5	*Physalis heterophylla*	clammy groundcherry	–	–
	PHHI8	*Physalis hispida*	prairie groundcherry	–	–
	PHLO4	*Physalis longifolia*	longleaf groundcherry	–	–
	PHVI5	*Physalis virginiana*	Virginia groundcherry	–	–
Ulmaceae	CEOC	*Celtis occidentalis*	common hackberry	–	–
	ULAM	*Ulmus americana*	American elm	–	–
Urticaceae	PAPE5	*Parietaria pensylvanica*	Pennsylvania pellitory	–	–
Verbenaceae	VEBR	*Verbena bracteata*	bigbract verbena	–	–
	VEST	*Verbena stricta*	hoary verbena	–	–
Violaceae	VINU2	*Viola nuttallii*	Nuttall's violet	–	–
Vitaceae	PAVI5	*Parthenocissus vitacea*	woodbine	–	–

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