National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Natural Resource Condition Assessment

Badlands National Park

Natural Resource Report NPS/BADL/NRR—2018/1672

ON THE COVER

Badlands National Park, South Dakota. Photography by: Ronincmc 2006

Natural Resource Condition Assessment

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Natural Resource Report NPS/BADL/NRR—2018/1672

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All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This report received informal peer review by subject-matter experts who were not directly involved in the collection, analyses, or reporting of the data. Data in this report were collected using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of those protocols. Where quantitative data were unavailable, the authors used expert opinion of subject matter experts and reviewers to form conclusions.

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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 Badlands National Park. 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.

Badlands National Monument was established in 1939 and designated as a National Park (NP) in 1978. The purposes of the park include protecting the landforms of the White River Badlands; preserving, interpreting, and promoting scientific research of the geology and paleontological resources in the park; preserving the mixed grass prairie ecosystem; preserving the wilderness area and associated values in the park; and interpreting the history of use in the park, with an emphasis on use by the Sioux Nation and Lakota people.

The assessment for Badlands NP 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 Badlands NP. 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 and night sky were in good condition, though soundscape warranted moderate concern due to high noise levels during the summer months.

Supporting Environment—or physical environment—resources included air quality, surface water quality, geology, and paleontological resources. Air quality, surface water quality, and geology were of moderate concern; paleontological resources warranted significant concern because theft and vandalism of fossils were major concerns.

The natural resources that composed the Biological Integrity category included vegetation, birds, black-tailed prairie dogs, black-footed ferrets, bison, swift fox, bats, bighorn sheep, bobcat, mule deer, herpetofauna, and pollinators. Mule deer, bighorn sheep, and bobcat were in good condition; vegetation, bison, bats, herpetofauna, and pollinators were of moderate concern; and prairie dogs, black-foot ferrets, and swift fox warranted significant concern. Resource condition was not available for birds in the absence of specific management goals.

This assessment includes a general background on the NRCA process (Chapter 1), an introduction to Badlands NP and the natural resources included in the assessment (Chapter 2), a description of

methods (Chapter 3), condition assessments for 19 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. Badlands National Park (NP) staff members Milt Haar, Ecologist; Eddie Childers, Biologist; and Rachel Benton, Paleontologist, provided site-specific details about natural resources that substantially improved the quality of this assessment. Mike Pflaum, Superintendent of Badlands NP, 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), Lusha Tronstad (Wyoming Natural Diversity Database), Pete Penoyer (NPS), Kerensa King (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), Kit Bramblee (NPS), Wayne Thompson (NPS), Lyman McDonald (WEST, Inc.), Dean Biggins (US Geologic Survey), Travis Livieri (Prairie Wildlife Research), Randy Griebel (USFS), John Hughes (USFWS), Mark Taper (Montana State University, University of Florida), Glen Sargeant (USGS), Sarah Nevison (South Dakota State University), Kevin Robling (South Dakota Game, Fish, and Parks), John Kanta (South Dakota Game, Fish, and Parks), and Brian Kenner (NPS). 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

2.1. Introduction

2.1.1. Enabling Legislation

Badlands National Park (NP) was authorized on March 4, 1929, established as a National Monument on January 25, 1939, and designated a National Park on November 10, 1978. The purpose of the Park is to:

- Protect the unique landforms and scenery of the White River Badlands for the benefit, education, and inspiration of the public.
- Preserve, interpret, and provide for scientific research the paleontological and geological resources of the White River Badlands.
- Preserve the flora, fauna, and natural processes of the mixed grass prairie system.
- Preserve the Badlands wilderness area and associated wilderness values.
- Interpret the archaeological and contemporary history of use and settlement of lands within the park, with special emphasis on the history of the Sioux Nation and the Lakota people (NPS 2012).

Badlands National Park, South Dakota. Photo by Stefan Fussan, Wikipedia (1995).

2.1.2. Geographic Setting

Badlands NP is located in the mixed prairie grasslands of southwestern South Dakota. The park is composed of 242,756 acres, 64,144 acres of which have been designated Wilderness. Located approximately 70 miles from Rapid City, South Dakota, the park is bordered by Buffalo Gap National Grassland, the Pine Ridge Indian Reservation, as well as several private farms and ranches. The park is characterized by spectacular scenery, including highly eroded landforms that comprise a dense collection of rutted ravines, serrated towers, pinnacles, and gulches, and contains places of spiritual and historical significance to the Lakota people (NPS 2012).

2.1.3. Visitation Statistics

Annual visitation data for Badlands NP are available for 1939-2015. The total number of visitors ranged from 10,149 in 1943 to 1,518,396 in 1991, with an average of 889,444 visitors, annually. The number of recreational visitors in 2015 was 989,354. 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 September (IRMA 2016).

2.2. Natural Resources

A summary of the natural resources at Badlands NP 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, Black-footed Ferrets, Bison, Swift Fox, Bats, Mule Deer, Bighorn Sheep, Bobcat, Herpetofauna, and Pollinators.

2.2.1. Ecological Units and Watersheds

Badlands NP is located in the Northwestern Mixed Grasslands ecoregion of the Northern Great Plains, distinguished from other grassland types by the harsh winter climate; short growing seasons; periodic, severe droughts; and vegetation (Ricketts 1999). The largest grassland ecoregion in North America, this biologically important area is under threat from habitat alteration for wheat production, invasive and exotic species, and increased industrial activity (Ricketts 1999).

2.2.2. Resource Descriptions

In this section we have summarized background information about key natural resources at Badlands NP. 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.

<u>Viewshed</u>

The Badlands of South Dakota were first recognized for national significance in 1929 when congress authorized the creation of Badlands National Monument. This initial authorization stated the purpose of the monument to “preserve the scenic and scientific values of a portion of the White River Badlands and to make them accessible for public enjoyment and inspiration.” The scenic qualities and importance of the White River Badlands were further supported in the 1938 establishment of Badlands National Monument and the subsequent re-designation of the monument as a National Park in 1978. Today a main purpose of the park continues to be management that protects and preserves the landforms and scenery of the White River Badlands. Rich fossil deposits, a long human history of Native Americans and homesteaders, the largest undisturbed mixed grass prairie in the U.S., and striking visual displays of deposition and erosion in iconic formations are important aspects of the visitor experience to Badlands NP.

The long history of conservation in the Badlands of South Dakota and the largely undisturbed and undeveloped landscape surrounding the park has ensured the area continues to offer visitors an outstanding visual experience. Indeed, Native Americans and early settlers would have been likely to encounter a similar environment to that existing in the Badlands today.

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.

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.

Clear, dark night skies are a valuable natural resource at Badlands NP, and an astronomy program has been conducted during the summer months at the park since 2006. In July 2016, the Badlands NP successfully completed its 5th annual Astronomy Festival.

Natural nocturnal nightscapes are crucial to the integrity of park settings. Dark skies and natural nightscapes 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.

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.

Badlands NP is surrounded by vast areas of prairie and badlands formation, with some agricultural development bordering the park unit. Primary sources of non-natural sounds within the park include automobile traffic, visitor conversations and associated acoustics, maintenance operations, and air traffic passing overhead. Industrial activities and noise from business and heavily populated residential areas are unlikely to affect the acoustic environment in Badlands NP. The closest town with population > 10,000 is Rapid City, SD (population ~70,900), about 60 kilometers (37 miles) to the northwest.

Air Quality

Most visitors expect clean air and clear views in parks. However, air pollution
can sometimes affect Badlands NP. 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. Our ability to clearly see color and detail in distant views can also be impacted by air pollution.

The NPS is dedicated to preserving natural resources, including clear air. The National Park Service Organic Act and the Clean Air Act codify this commitment, specifying that NPS protect air quality within park units for the integrity of other natural and cultural resources.

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.

Badlands NP is part of the Northern Great Plains Network (NGPN) and is located in the Bad, Middle Cheyenne-Elk, Middle Cheyenne-Spring, Upper White, and Middle White River drainage basins. Each of these rivers flow east into the Missouri River, though only the White River runs through the park. Other water resources within the park are limited, consisting primarily of intermittent streams—Battle, Cedar, Palmer, and Sage Creeks, ephemeral water bodies, and constructed impoundments. The top water quality priority at Badlands NP is the Civilian Conservation Corps Springs, an artificial stock pond, and Sage Creek has also received monitoring attention.

Geology

Geological resources underlie and affect many other resources within National Park System units. In Northern Great Plains area where Badlands NP is located, most of the bedrock is composed of soft Upper Cretaceous and Tertiary sediment strata.

The rugged geology of Badlands National Park is a primary draw to the park for people from around the world. Surface and subsurface strata of the Great Plains physiographic province represent many different paleoenvironments spanning millions of years.

It should be noted that the human-influenced weathering and erosion that is occurring at areas of high visitor traffic and as well as near the Badlands Loop Road is degrading the quality of the geological resources in those areas.

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. Paleontological resources are non-renewable, and they hold the keys to understanding the complex history of life on Earth. Fossils are known to occur in 260 NPS units and are the main resource showcased in 13 of those parks, including Badlands NP. The fossil resources of Badlands NP include the richest accumulations of terrestrial vertebrate fossils of late Eocene and early Oligocene age in North America, if not the world.

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.

Badlands National Park was established in large part to protect fossil resources. Abundant and diverse flora and fauna are well known from the White River Badlands, and these fossils have played a large role in our understanding of the evolution and adaptation of plants and animals to climate change. Numerous vertebrate taxa as well as scarce plant fossils, petrified wood, and invertebrates have been described from these strata. While the mammalian fossils are the most well studied, fossils of bony fish, amphibians, turtles, squamates, crocodiles and alligators, and birds are also known from the Badlands.

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.

Badlands NP was established with a mission to protect and preserve 242,756 acres of rugged badlands, mixed-grass prairie, and rich fossil deposits. The vegetation is a mosaic of sparsely vegetated badlands, native mixed-grass prairie, woody draws, and exotic grasslands.

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.

In the NGPN group of parks to which Badlands NP belongs, landbirds are considered a “vital sign” of park ecosystems. Monitoring of landbirds began in 2013 with help from the Bird Conservancy of the Rockies.

Black-tailed Prairie Dog

Black-tailed prairie dogs (*Cynomys ludovicianus*) are ground-dwelling rodents of the Sciuridae family 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.

Maintaining healthy black-tailed prairie dog populations is fundamental to the character and ecological integrity of Badlands NP. Prior to being affected by plague, Badlands NP accounted for about 59% of the acreage occupied by black-tailed prairie dogs on all NPS lands. Some prairie dog colonies, such as Roberts Prairie Dog Town in the northern part of the park, are important tourist attractions. Badlands NP is dedicated to protecting the species and participates in state and federal management protocols. The largest management issue facing prairie dogs in the park is sylvatic plague caused by *Yersinia pestis*, a lethal, generalist, non-native bacterium. Plague has greatly reduced the number of active prairie dog colonies within the park since 2008. Badlands NP has engaged in multi-agency efforts to curb plague within the park and surrounding grasslands.

Badlands NP has also served as a reintroduction site for endangered and threatened species, efforts that would not have been possible without an extensive population of prairie dogs. Badlands NP was the second reintroduction site for black-footed ferrets owing to the high quality of prairie dog habitat, and swift foxes were translocated to Badlands NP beginning in 2003.

Black-footed Ferret

Black-footed ferrets (*Mustela nigripes*) are charismatic, globally endangered carnivores endemic to North America. They are nocturnal, solitary, territorial animals that are closely tied to prairie dog (*Cynomys* spp.) colonies. Prairie dogs are a primary prey source for ferrets and their burrows provide shelter for this unique member of the weasel family (Mustelidae).

The black-footed ferret was listed as a federally endangered species in 1967 and as a South Dakota endangered species in 1978. Later thought to be extinct in the wild, a remnant population was rediscovered in Wyoming in 1981 and the remaining 18 individuals were removed for captive breeding. Reintroductions began in 1991 and extended to Badlands NP in 1994 and Conata Basin (Buffalo Gap National Grassland) in 1996. There are 26 total reintroduction locations to date. Black-footed ferret populations in Conata Basin/Badlands are now considered one biological population so we refer to them jointly throughout our assessment. The black-footed ferret remains one of the rarest free-ranging mammals in North America, with an estimated self-sustaining population of 167 mature individuals range-wide.

The Conata Basin/Badlands population of ferrets remains one of the most successful reintroduction efforts to date, largely due to the quantity and quality of black-tailed prairie dog colonies at these sites. Since the time of reintroductions, the black-footed ferret population has been monitored annually.

Bison

The American bison (*Bison bison*) is an iconic species in North America. Badlands NP hosts one of two subspecies of American bison, the plains bison (*Bison bison bison*). Historically, an estimated 30–70 million plains bison ranged from central Canada to Mexico in herds of up to 10,000 animals. These herds played a key role in the grassland ecosystems of North America, shaping both the landscape and the way of life for native cultures in the region.

Badlands NP is one of nine NPS units that currently supports bison and is also one of the most recent to participate in bison restoration. Substantial numbers of bison historically inhabited the grasslands within the park. From 1963–1964, 50 bison from Theodore Roosevelt National Park and three from Fort Niobrara National Wildlife Refuge were introduced into the Badlands Wilderness Area. An additional 20 bison from Colorado National Monument were added to the Badlands NP herd in 1983. Badlands NP currently has a management goal of maintaining 500–700 bison in the 23,458-hectare (57,967-acre) Badlands Wilderness Area. The herd is culled opportunistically, and surplus bison are given to the neighboring Oglala Sioux Tribe and distributed to other native tribes through the InterTribal Bison Cooperative.

Swift Fox

The swift fox (*Vulpes velox*) is a small-sized member of the dog family, typically weighing about two kilograms. Historically, they were thought to be common or locally abundant throughout much of the shortgrass and mixed-grass prairies of the Great Plains.

The NPS reintroduced a swift fox family to Badlands NP in 1987 from the nearby Pine Ridge Reservation, but failed to establish a population. Additional reintroductions were accomplished from 2003–2006 with 114 individual foxes brought from Colorado and Wyoming.The swift fox is one of four native species that has been reintroduced to Badlands NP in an effort to restore the native prairie ecosystem, the others being the black-footed ferret (*Mustela nigripes*), bighorn sheep (*Ovis canadensis*), and American bison (*Bison bison*).

Bats

Bats have many important ecological roles and are one of the most diverse groups of mammals, accounting for about 20% of all mammal species globally (1,200). These winged mammals consume thousands of pounds of insects annually, including some damaging agricultural pests, thereby saving billions of dollars in agricultural costs. In some regions, bats are critical for the propagation of many plants. Even bat guano (droppings) provides unique habitat to some specialist organisms. Some bats are considered by researchers to be keystone species, a species that has a much greater effect on its ecosystem than would be expected given its biomass, and can be bioindicators of the health of a broad range of organisms.

National Park Service lands are important reference and monitoring sites for bat populations. The NPS is dedicated to protecting bats and their habitat; at the time of this assessment, over 40 parks were host to at least 43 projects to protect bats and gain insight into white nose syndrome. Among NPS units that have caves, mines, and old buildings for roosting, about 40 of the 47 resident of US bat species occur on NPS land.

Eleven bat species are found in Badlands NP and three of these species are of particular concern to the state, receiving a listing as high priority Species of Greatest Conservation Need in the South Dakota State Wildlife Action Plan. Additional bat species have a Special Species Status for the state, Sensitive Species designation for the region, and/or a federal listing under the Endangered Species Act.

Bighorn Sheep

Bighorn sheep (*Ovis canadensis*) are native to western North America and exhibit a patchy distribution over what was once a more continuous range. There are several subspecies of bighorn sheep; the badlands or Audubon's bighorn (*Ovis c. auduboni*) was historically found in the badlands region, but went extinct by 1925. The NPS introduced the Rocky Mountain bighorn sheep (*Ovis c. canadensis*) to Badlands NP in 1964.

Bighorn sheep populations have a tenuous hold in many areas, largely owing to disease susceptibility. Studies show that bighorn populations inhabiting larger areas, kept at greater distances from domestic sheep, exhibiting longer migratory movements, and in larger herds are more likely to persist. It is generally accepted that disease is the main threat to wild sheep populations, and that management efforts aimed at mitigating the frequency and severity of disease outbreaks are a conservation priority.

National Park Service lands are important reference and monitoring sites for animal populations, and the NPS is dedicated to protecting bighorn sheep and their habitat.

Bobcat

Bobcat (*Lynx rufus*) are the most widely distributed native cats in North America. Bobcat are adaptable to a wide variety of habitat types, from deserts to forests, consuming prey as diverse as birds, hares, and the occasional scavenged moose. Because of their value as a furbearer species, bobcat nearly went extinct in the eastern US by the mid-1900s. Federal legislation and state-level management restored the species to self-sustaining populations by the early 1990s.

In the 1960s, some data indicated that bobcat populations were declining in the western United States, but more recent evidence suggests that bobcat have been increasing throughout their native range. Bobcat are susceptible to plague (*Yersinia pestis*) both directly and through the decline of plague-infected prairie dogs. National Park Service lands are important reference and monitoring sites for animal populations, and the NPS is dedicated to protecting bobcat and their habitat.

Mule Deer

Mule deer (*Odocoileus hemionus*), named for their large ears, are native to western North America and are concentrated in the Rocky Mountain region, ranging from Alaska through the Rockies to northern Mexico and southern Baja. This ungulate has experienced population fluctuations throughout its range over at least a century, and has drawn the attention of conservation and hunting groups. Variably harsh winters, changes in resource availability, and land use alteration may be contributing factors to these vacillations, though proximate causes are likely to vary with region and herd size.

National Park Service lands are important reference and monitoring sites for animal populations, and the NPS is dedicated to protecting mule deer and their habitat. Three mule deer herd units overlap portions of Badlands NP. The herd units surrounding BADL are managed for hunting and for non-consumptive wildlife-viewing. Deer are managed by NPS within BADL boundaries, and hunting is not allowed within the park.

Herpetofauna

Herpetofauna, a taxonomic grouping of amphibians and reptiles, are important organisms in a wide variety of ecosystems. Reptiles and amphibians are important prey for other organisms and are often considered to be indicators of ecosystem health.

National Park Service lands are important reference and monitoring sites for reptile and amphibian populations, especially considering the susceptibility of these groups to land use change. Many herpetofauna have minimum habitat area requirements that can guide management actions in NPS units in and around those habitats.

Thirty reptile species and 15 amphibian species are known to occur throughout South Dakota, of which eight amphibians and 12 reptiles were suspected or confirmed to occur in Badlands NP. At the time of this assessment, two of these species were of particular concern to the state, receiving a listing as high priority Species of Greatest Conservation Need in the South Dakota State Wildlife Action Plan. Additional species had special conservation status from USDI Bureau of Land Management, at the state level, and within the Rocky Mountain Region of the USDA Forest Service.

Pollinators

Most South Dakota pollinators are native insects and honey bees, all of which require fairly undisturbed habitat and a variety of food sources. Badlands NP is home to a total of 69 confirmed species. Monarch butterflies (*Danaus plexippus*) feed on milkweed in the park where the endangered species spends summer, two-tailed swallowtails (*Papilio multicaudata*) lay eggs on choke cherry and wild plum trees, and melissa blue butterflies (*Plebejus melissa*) persist throughout the park. While bumble bees (*Bombus* sp.) and other invertebrate pollinators are likely present in Badlands NP, local census data are lacking for the park.

2.2.3. Resource Issues Overview

The natural resources found in Badlands National Park are central to the founding goals of the park and provide opportunity for education, outreach, and research. Maintaining the health of the natural resources is critical to attracting visitors.

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. Collecting updated inventory data for a variety of natural resources and maintaining a consistent monitoring program for natural resources are park priorities (see Chapter 5 for further discussion) and will contribute to the founding goals of Badlands NP.

2.3. Resource Stewardship

2.3.1. Management Directives and Planning Guidance

From the 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.

2.4. Literature Cited

Integrated Resource Management Applications (IRMA). 2016. https://irma.nps.gov/. United States Department of the Interior, National Park Service, Washington, D.C., USA.

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Chapter 3. Study Methods

3.1. Preliminary Scoping

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 Badlands NP 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.

Badlands National Park, South Dakota. Photo by Chris Light, Wikipedia (2011).

3.2. Study Design

3.2.1. Indicator Framework, Focal Study Resources and Indicators

We used a two-phase process for completing the assessment for Badlands NP. 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 Badlands NP 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 Badlands NP and NGPN to start the project.

Phase 1 – Assessment and Planning

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 Badlands NP.

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 3.1) 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 3.1. Natural Resource Condition Assessment Framework for Badlands NP.

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
	Air quality	Mercury	Methylmercury rating
	Water quality	Acidity	pH
	Water quality	Dissolved oxygen	mg/L
	Water quality	Specific conductivity	s/m
	Water quality	Temperature	°C
	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

Table 3.1 (continued). Natural Resource Condition Assessment Framework for Badlands NP.

Context	Resource	Indicator	Measure
II. Supporting environment (continued)	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. Bilogical 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
	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
	Black-footed ferret	Conservation concern	Federal protection status
	Black-footed ferret	Population size	Count of adult ferrets
	Black-footed ferret	Habitat quality	Black-tailed prairie dog colony acreage
	American bison	Herd size and composition	Herd size
	American bison	Herd size and composition	Population structure
	American bison	Landscape size and use	Landscape available to bison
	American bison	Landscape size and use	Human footprint
	American bison	Landscape size and use	Management of movements
	American bison	Ecological interactions	Natural selection
	American bison	Ecological interactions	Interaction with suite of native vertebrates
	American bison	Ecological interactions	Interaction with ecosystem processes

Table 3.1 (continued). Natural Resource Condition Assessment Framework for Badlands NP.

Context	Resource	Indicator	Measure
III. Bilogical Integrity (continued)	American bison	Geography	Representation
	American bison	Health and genetics	Presence and management of disease
	American bison	Health and genetics	Genetic diversity
	American bison	Health and genetics	Genetic integrity
	Swift fox	Population viability	Population growth rate
	Bats	Bat species status (11 species assessed individually)	Population growth rate
	Bats	Bat species status (11 species assessed individually)	Level of conservation concern
	Bats	Exposure to White-nose Syndrome	Presence, absence, or proximity
	Rocky mountain bighorn sheep	Population viability	Population growth rate
		Population size	Minimum population count
	Bobcat	Population viability	Population growth rate
	Mule deer	Population viability	Population growth rate
	Herpetofauna	Reptile and amphibian status (17 species assessed individually)	Population growth rate
	Herpetofauna	Reptile and amphibian status (17 species assessed individually)	Level of conservation concern
	Herpetofauna	Exposure to chytrid fungus	Presence, absence, or proximity
	Invertebrate pollinators	Diversity	Shannon index
	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 Badlands NP 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 3.1), 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 Badlands NP or as near the park 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 Badlands NP. 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). 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. Indicator symbols used to indicate 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 3.3).

Table 3.3. 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) 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). 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

Heinz Center (The H. John Heinz III Center for Science, Economics, and the Environment). 2008. Measuring the Lands, Waters, and Living Resources of the United States. Washington, D.C. Island Press.

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 and trends, 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 USC § 1–4) that established the National Park Service (NPS) and other park units, such as Badlands National Park (Figure 4.1.1).

Figure 4.1.1. Big Badlands Overlook at sunset at Badlands National Park. This view is likely similar to those that native tribes and settlers experienced in the 1800s. Photo by Rick Flohr, Artist in Residence (2008); image courtesy of Badlands NP.

The NPS prioritizes conserving scenery for the enjoyment of visitors and current and future generations (16 USC § 1–4). Scenic park resources are protected from impairment, which is any change that harms the integrity of the park unit (NPS 2006a). The 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 resources within a park unit encompass the visible areas from all locations within the park. 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.

Regional Context

At Badlands NP, rich fossil deposits, a long human history of Native Americans and homesteaders, the largest undisturbed mixed grass prairie in the U.S., and striking visual displays of deposition and erosion in the Badlands formations, are important aspects of the visitor experience (NPS 2016a). These park features combine to create a unique visual setting in a remote, natural environment (Figure 4.1.2).

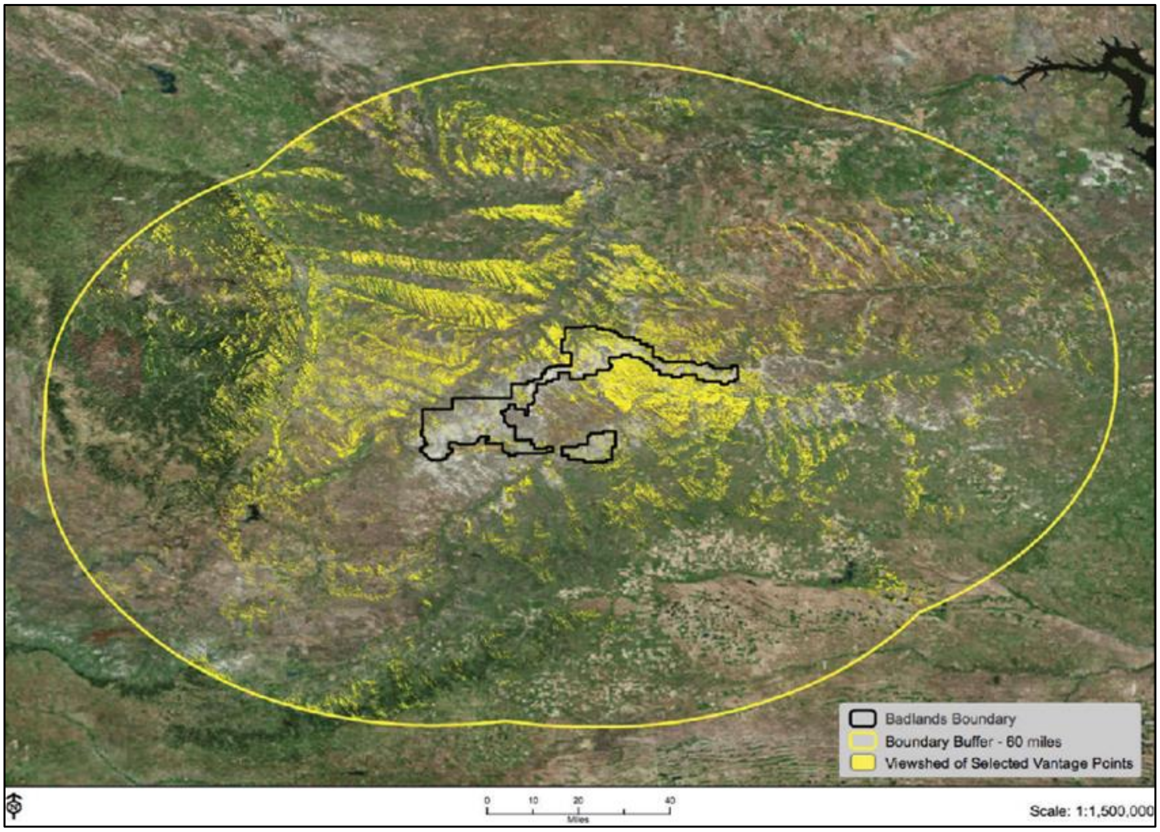


Figure 4.1.2. Viewshed of all areas visible from one or more vantage points at Badlands NP used in the digital viewshed assessment. Map created by WyGISC (2016) from Landsat Imagery.

The long history of conservation in the Badlands of South Dakota and the largely undisturbed and undeveloped landscape surrounding the park has ensured that the area continues to offer visitors an outstanding visual experience. Native Americans and early settlers would have been likely to encounter a similar environment to that existing in the Badlands today.

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.

The Badlands of South Dakota were first recognized for national significance in 1929 when congress authorized the creation of Badlands National Monument. This initial authorization stated the purpose of the monument to “preserve the scenic and scientific values of a portion of the White River Badlands and to make them accessible for public enjoyment and inspiration” (NPS 2006b). The scenic qualities and importance of the White River Badlands were further supported in the 1938 establishment of Badlands National Monument and the subsequent re-designation of the monument as a National Park in 1978. Today a main purpose of the park continues to be management that protects and preserves the landforms and scenery of the White River Badlands (NPS 2006b).

4.1.3. Methods

We assessed viewshed condition within Badlands NP using a combination of quantitative GIS analyses and an approach used for assessing visual resource indicators developed by the NPS Air Resources Division (NPS-ARD) for Visual Resource Inventories (VRI) (M. Meyers, personal communication, 3 March 2016).

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 direction 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 material for Badlands NP (NPS 2016a) planning documents (NPS 2006b), topographic maps, and geotagged photographs on Google Earth.

From these candidate vantage points, we then identified 15 points that were most likely to be of high importance to the park. We used all of these vantage points for the digital viewshed analysis (see below). To complete the VRI analyses in a timely manner, we further limited the vantage point selection for that process to five points representative of the most-visited areas in Badlands NP (vantage points 1 [Big Badlands Overlook], 2 [Cliff Shelf Trail], 7 [Ancient Hunters Overlook], 8 [Pinnacles Overlook], and 12 [Burns Basin Overlook]; 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 Badlands National Park. 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.

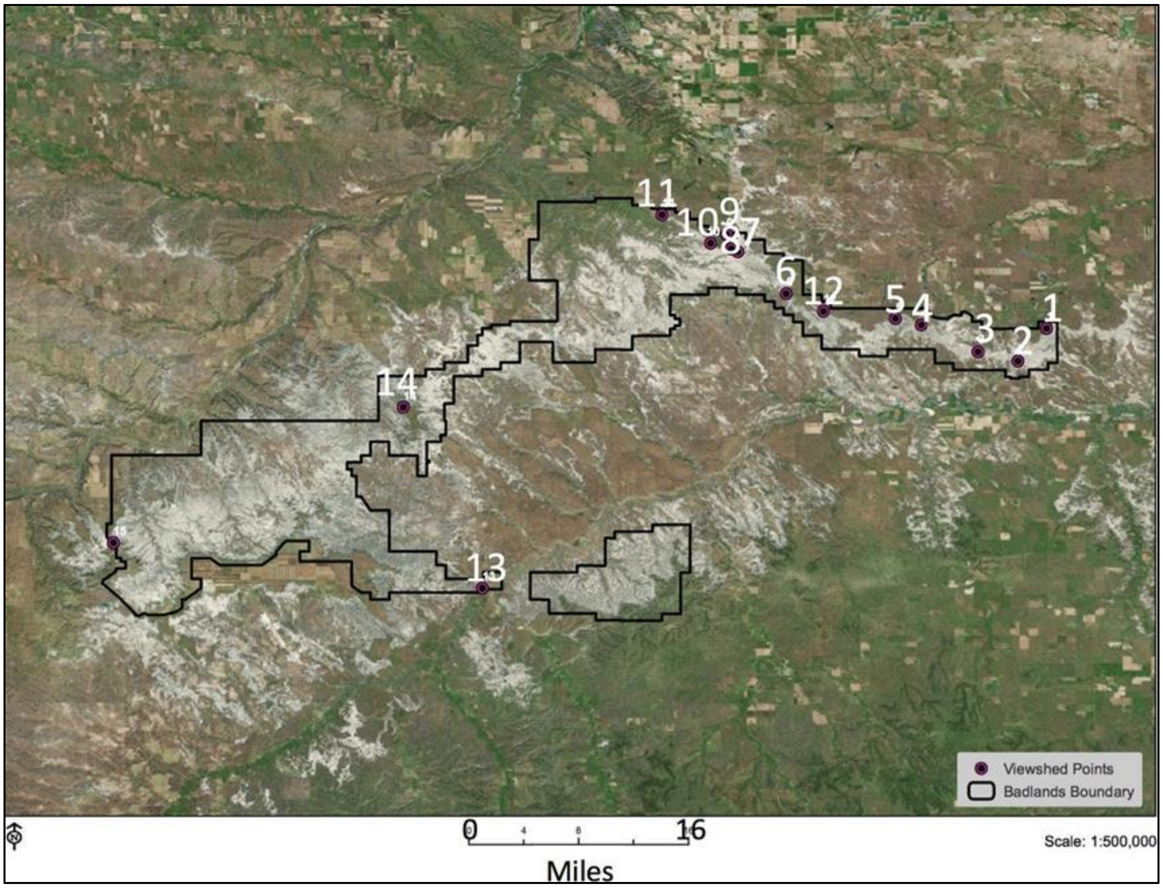


Figure 4.1.3. Vantage points used in the digital viewshed analysis for Badlands NP. For the Visual Resource Inventory, only vantage points vantage points: 1 (Big Badlands Overlook), 2 (CliffShelf Trail), 7 Ancient Hunters Overlook), 8 (Pinnacles Overlook), and 12 (BurnsBasin Overlook) were used. Map 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 point’s 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.

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.

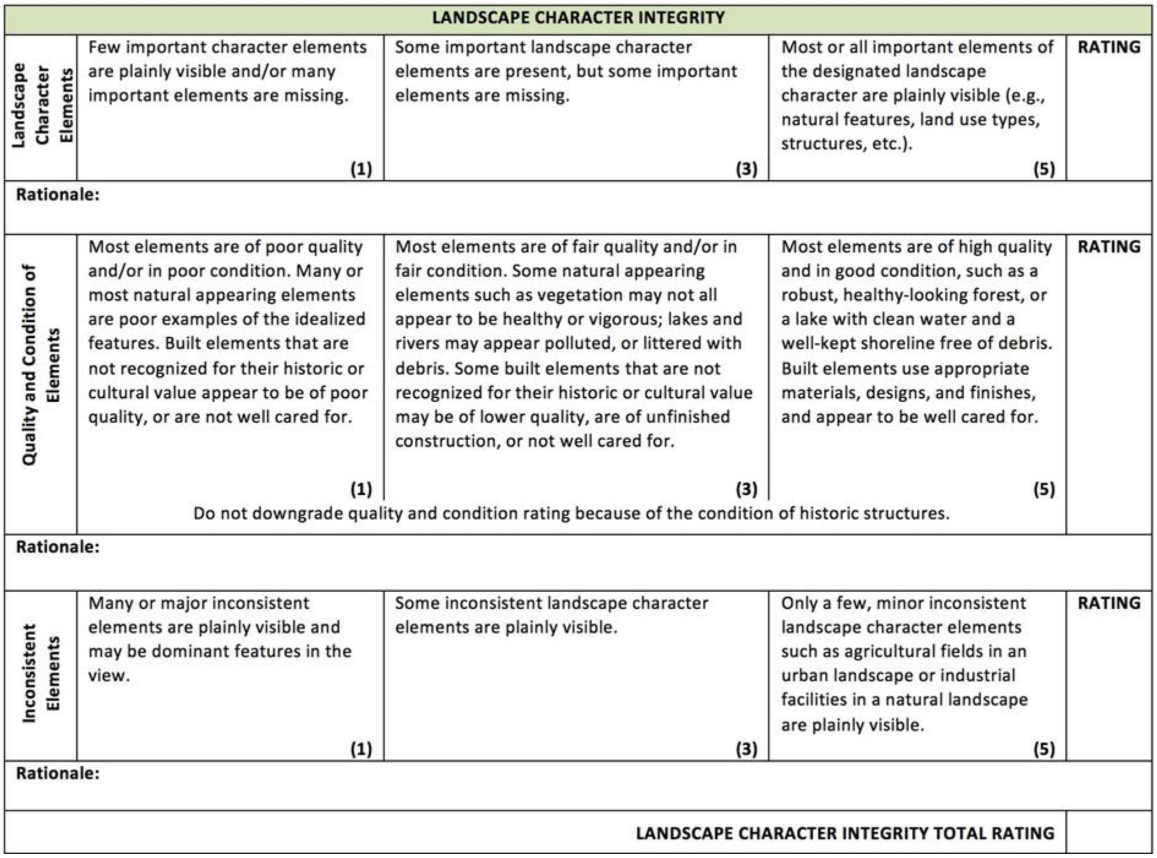
Indicator: Scenic Quality

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 presence of important landscape 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 onsite 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.



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 2015b).

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 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.*

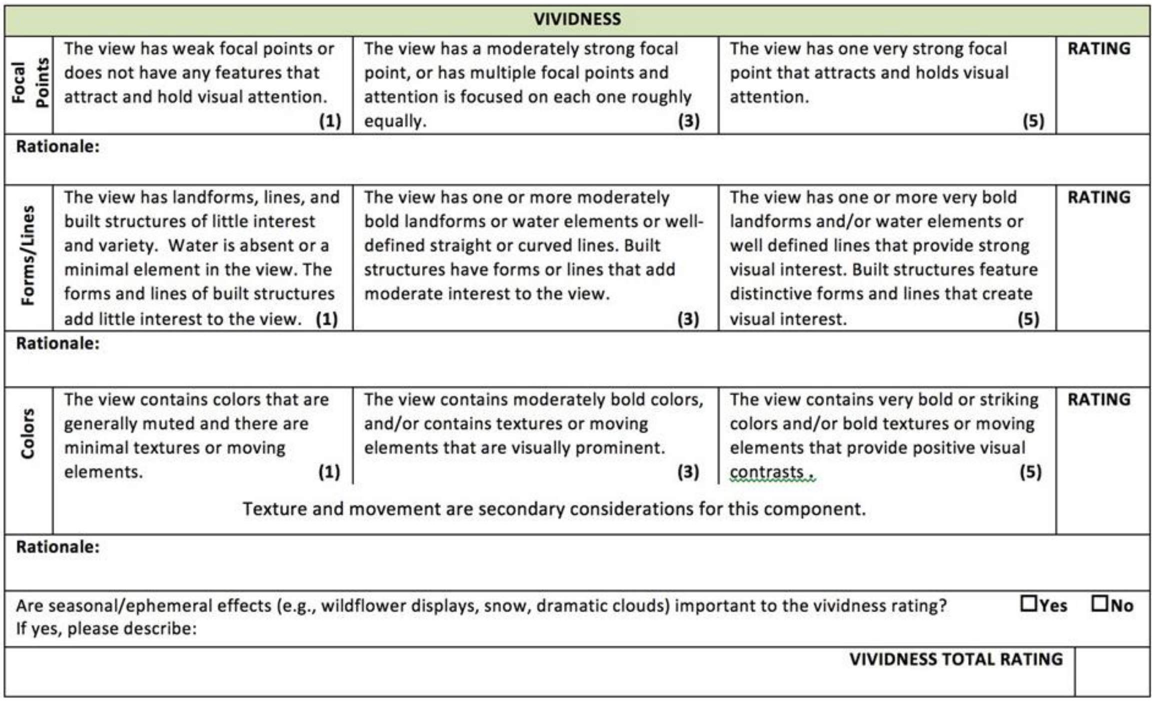
Table 4.1.1. Viewshed condition categories for the landscape character integrity of the view.

Resource condition		Character integrity rating
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 onsite 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 2015b).

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.*

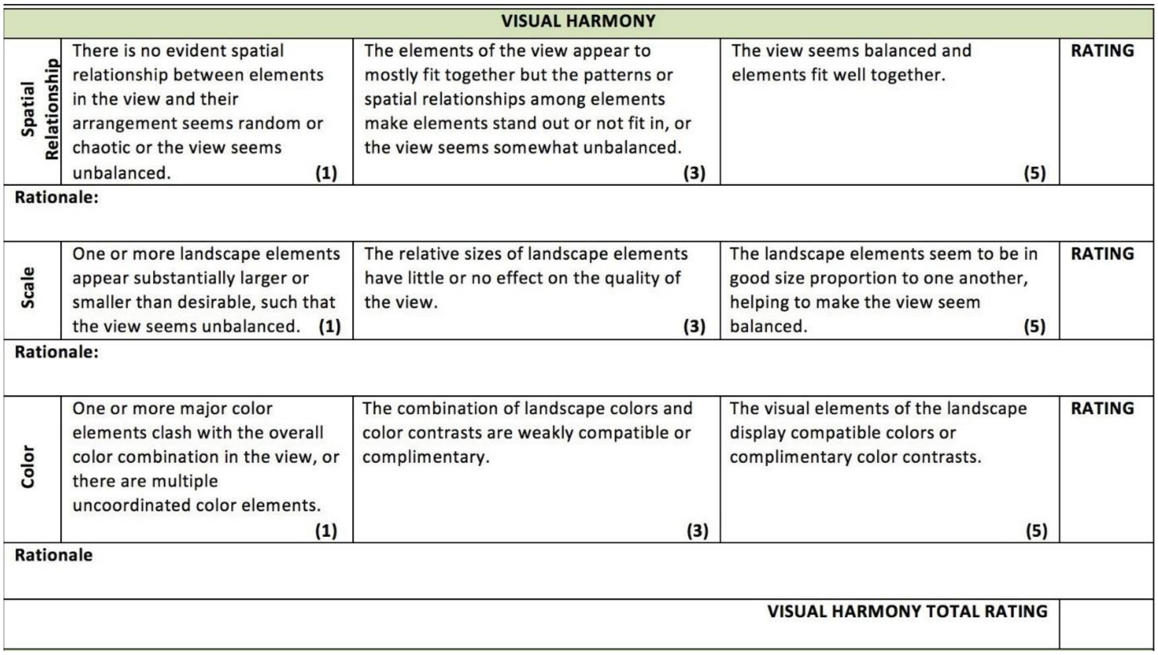
Table 4.1.2. Viewshed condition categories for the vividness of the view.

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 scores 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 onsite 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.



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 2015b).

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*.

Table 4.1.3. Viewshed condition categories for the visual harmony of the view.

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 good, 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).

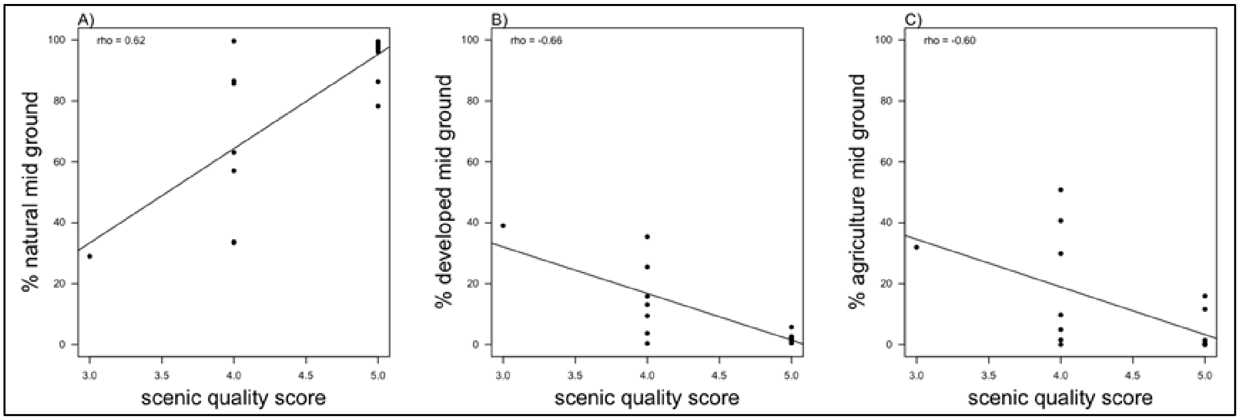


Figure 4.1.7. Relationships between scenic quality score and land cover. Rho is the correlation between scenic quality score and the percentage of each ground cover type.

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 > 75% 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 Badlands NP, 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 2013a, 2013b, 2013c, 2013d, 2013e). 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 2015b). 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 (see Chapter 3, Methods). 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 Conditions, Confidence, and Trends

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 Badlands NP 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.

		Vantage point ratings					
Measure	**Components**	**Big Badlands (vantage point 1)**	**Cliff Shelf Trail (vantage point 2)**	**Ancient Hunters (vantage point 7)**	**Pinnacles (vantage point 8)**	**Burns Basin (vantage point 12)**	**Park average**
Landscape character integrity	Landscape character elements	4	5	5	5	5	4.8
	Quality and condition of elements	4	5	5	5	5	4.8
	Inconsistent elements	3	5	5	5	5	4.6
	Total	**11**	**15**	**15**	**15**	**15**	**14.2**
Vividness	Focal points	4	3	3	4	4	3.6
	Forms/lines	5	5	5	5	5	5
	Colors	5	4	5	5	5	4.8
	Total	**14**	**12**	**13**	**14**	**14**	**13.4**
Visual harmony	Spatial relationship	4	5	5	5	5	4.8
	Scale	5	5	5	5	5	5
	Color	4	5	5	5	5	4.8
	Total	**13**	**15**	**15**	**15**	**15**	**14.6**

Confidence

Scenic quality data were not available from full VRI assessments conducted within the park. We conducted remote assessments using geo-tagged photographs, digitally stitched panoramas, and gigapans available from Badlands NP (NPS 2016b). The confidence rating was *Medium.*

Trend

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

<u>Land Cover Content</u>

●

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

Condition

Land cover content percentages for natural cover, developed cover and agricultural cover at mid-ground distances were 98.51, 1.41, and 0.08 respectively (Figure 4.1.8). Each of these measurements placed land cover content in the *Resource in Good Condition* category.

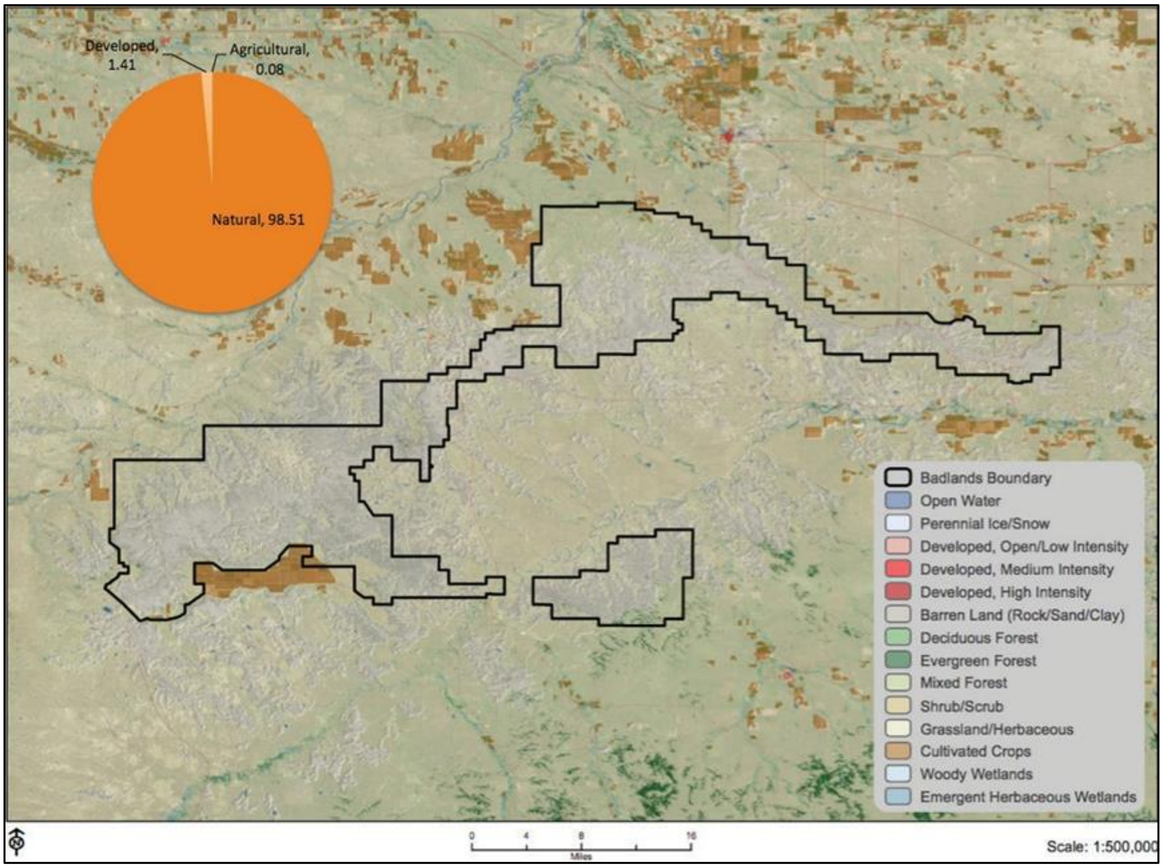


Figure 4.1.8. Mid-ground land cover content. Natural cover includes barren land, deciduous forest, evergreen forest, mixed forest, shrub/scrub, grassland/herbaceous, woody wetlands, and emergent herbaceous wetlands. Agricultural cover includes cultivated crops. Developed land includes developed with open/low intensity, medium intensity, and high intensity. Map created by WyGISC (2016) from Landsat Imagery.

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

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		🟢

The overall viewshed condition was determined by the average of the indicator conditions. We summarized the condition, confidence, and trend for each indicator, and assigned condition points (Table 4.1.9). Scenic quality at Badlands NP was placed in the *Resource in Good Condition* category and scored 100 points. Land cover content was placed in the *Resource in Good Condition* category and scored 100 points. The total score for overall viewshed condition was 100 points, which placed Badlands NP in the *Resource in Good Condition* category.

Table 4.1.9. Summary of viewshed indicators and measures.

Indicator	Measure	Condition	Confidence	Trend	Condition Rationale
Scenic quality	Landscape character integrity	Resource in good condition	Medium	Not available	The average landscape character integrity score from five different viewpoints in Badlands NP was 14.2; this placed landscape character integrity in the Resource in Good Condition category. Panoramic images were available for most sites, so confidence was Medium. Trend was Not Available.
	Vividness	Resource in good condition	Medium	Not available	The average vividness score from five different viewpoints in Badlands NP was 13.4; this placed landscape character integrity in the Resource in Good Condition category. Panoramic images were available for most sites, so confidence was Medium. Trend was Not Available.

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

Indicator	Measure	Condition	Confidence	Trend	Condition Rationale
Scenic quality (continued)	Visual harmony	Resource in good condition	Medium	Not available	The visual harmony score from five different viewpoints in Badlands NP was 14.6; this placed landscape character integrity in the Resource in Good Condition category. Panoramic images were available for most sites, so confidence was Medium. Trend was Not Available.
Land cover content	Mid-ground percent natural cover	Resource in good condition	High	Not available	Average 2011 mid-ground natural land cover visible from the five different Badlands NP viewpoints comprised 98.51% of the viewed landscape; this placed mid-ground natural land cover in the Resource in Good Condition 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	Resource in good condition	High	Not available	Average 2011 mid-ground developed land cover visible from the five different Badlands NP viewpoints comprised 1.41% of the viewed landscape; this placed mid-ground developed land cover in the Resource in Good Condition category. The GIS analysis of land cover used the most recent NLCD data so confidence was High. Trend was Not Available.
	Mid-ground percent agricultural cover	Resource in good condition	High	Not available	Average 2011 mid-ground agricultural land cover visible from the five different Badlands NP viewpoints comprised 0.08% of the viewed landscape; this placed mid-ground agricultural land cover in the Resource in Good Condition 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 that 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 U.S. Forest Service's resource management plan (USDA 2009a) and Pennington County planning documents. The U.S. Forest Service has a recent revision of the management plan for the Buffalo Gap National Grassland adjacent to Badlands NP (USDA 2009b). Pennington County dictates zoning regulations for the lands surrounding Badlands NP (Pennington County South Dakota 2003, 2014). Zoning regulations dictate the pattern and type of development occurring within the viewshed of Badlands NP.

Based on the unpublished developmental guidance of the NPS-ARD (Meyer 2016), we evaluated the level of viewshed vulnerability at Badlands NP, 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 Badlands NP viewshed is low to medium. The majority of land within the Badlands NP viewshed is protected through zoning restrictions or forest service management decisions. Primary considerations are forest service areas designated as rangeland with broad resource emphasis. These areas have few limitations for potential resource development (USDA 2009c).

The potential magnitude of visual change is low to medium. Changes to the viewshed are unlikely, but the potential for increased surface developments would be highly noticeable and counter to the primary purpose of protecting the scenic resource value of Badlands NP.

Constraints to mitigation are very low. Both the county and cities surrounding Badlands NP value the presence of the park, but decisions that may affect the views can come from the management plan of the surrounding Buffalo Gap National Grassland.

4.1.6. Data Gaps

The views of and from Badlands NP 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 is available, but an expanded and continued collection 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 Badlands NP. 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 land cover types and developments affect park goals for viewsheds.

Acknowledgments

- Mark Meyer (NPS)
- Bill Gribb (UW)

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Google Earth. 2013b. Badlands National Park: Big Badlands Overlook. 43°47’08”N, 101°54’05”W. Eye altitude: Ground level view.

Google Earth. 2013c. Badlands National Park: Burns Basin Overlook. 43°48’14”N, 102°08’12”W. Eye altitude: Ground level view.

Google Earth. 2013d. Badlands National Park: Cliff Shelf Trail. 43°45’02”N, 101°55’53”W. Eye altitude: Ground level view.

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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 2012b), 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 2012c), and migrating birds requiring starry skies for navigation.

The NPS is dedicated to the protection and preservation of the natural nightscapes, those areas existing in the absence of human-caused light at night, within the parks (NPS 2012d). 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) to 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 nightscapes 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 nightscapes are crucial to the integrity of park settings. Dark skies and natural nightscapes 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.

<u>Regional Context</u>

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). For now, however, some of the darkest skies in the lower 48 states surround Badlands NP (Figure 4.2.1).

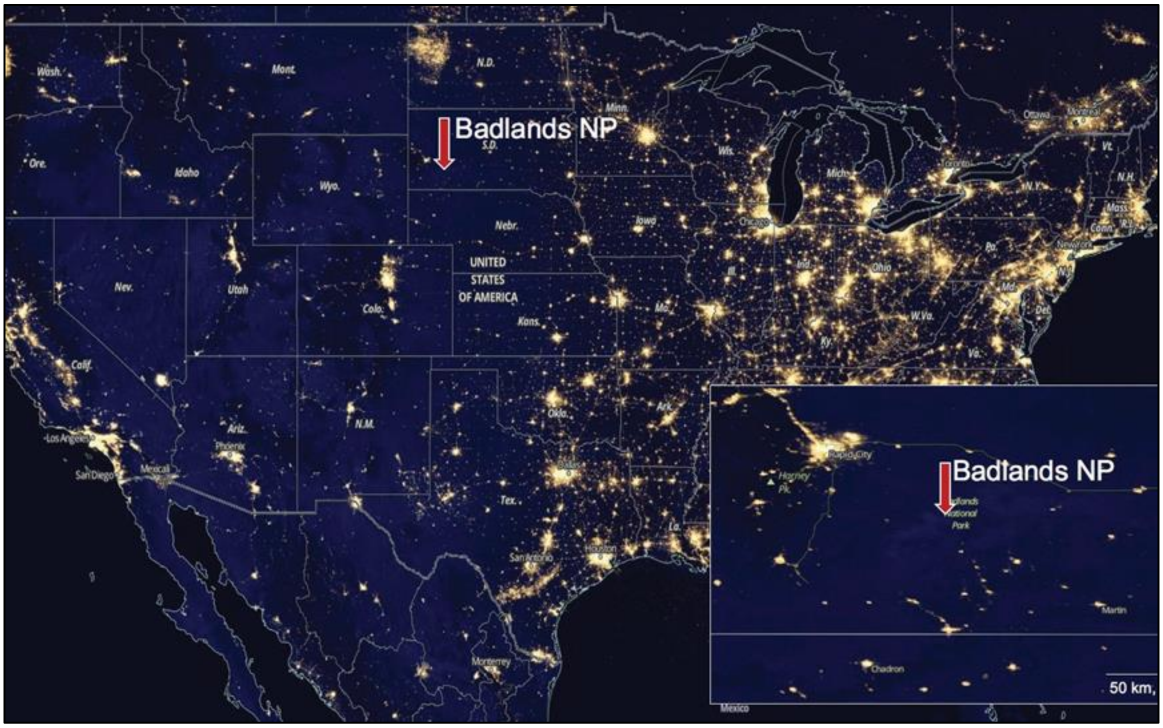

Figure 4.2.1. Satellite image of Badlands NP and the lower 48 states at night in 2012. Map generated at https://worldview.earthdata.nasa.gov using Earth at Night 2012 base layer from NASA Earth Observatory.

Clear, dark night skies are a valuable natural resource at Badlands NP. An astronomy program has been conducted during the summer months at Badlands NP since 2006. These programs begin nightly after the evening ranger programs, weather permitting, and offer visitors the opportunity to view night sky objects through telescopes. Rangers leading the program help to locate constellations, stars, planets, and other objects (Figure 4.2.2). In early July, 2016, the park successfully completed its 5th Annual Astronomy Festival. The 2016 three-day festival included telescope viewing of the sky each night, planetarium shows, model rocket building and launching workshops, and guest speakers. The annual festival and the nightly sky events have been very successful (C. Schroll, personal communication, 31 July 2016).

Figure 4.2.2. Big Dipper asterism in the constellation Ursa Major above badlands formation in Badlands NP. Photo by Larry McAfee, NPS.

4.2.2. Night Sky 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 NPS 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 nightscapes 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. Nightscapes 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 Badlands NP.

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 assessing 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 4.2.3). 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).

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 (Figure 4.2.3.). 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 4.2.1. 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

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 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.	Zodical 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/sub-urban 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
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

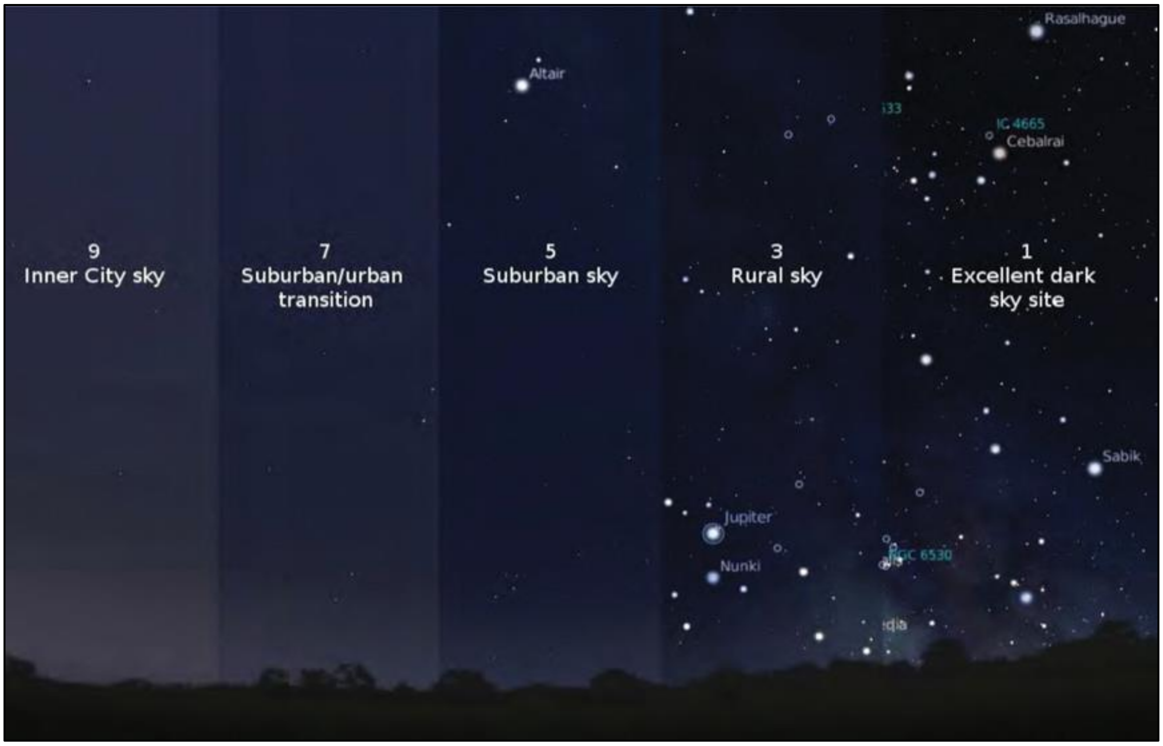

Figure 4.2.3. Bortle Dark Sky composite image. Image from Struthers et al. (2014), generated from Stellarium (https://www.stellarium.org).

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

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 assigned 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 synthetic Sky Quality Meter (SQM)

Resource condition		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 of 60–79 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 Sky Quality Index (SQI).

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

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 nightscape, 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 nightscapes 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 Badlands NP, 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 data collected by NPS Natural Sounds and Night Skies Division. Data collection took place on July 19, 2006, June 3, 2011, and June 5, 2011; we used the most recent data, those collected on June 5, 2011. Where multiple samples were taken, we used the average in this assessment. Data were collected on site at Badlands NP and included values for Bortle Class, Synthetic Sky Quality Meter (SQM), Sky Quality Index, and Anthropogenic Light Ratio (ALR).

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 (see Chapter 3, Methods 3.2.2).

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 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

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 4.2.6).

Table 4.2.6. Summary of night sky indicators and measures.

Indicator	Measure	Condition	Confidence	Trend	Condition Rationale
Night sky quality	Bortle Dark Sky class	Resource in good condition	High	Not available	Bortle Dark Sky Class was 3, which placed the condition of this measure in the category, *Resource in Good Condition*. Monitoring was conducted on site but not frequently enough to identify a trend, so confidence was High and trend was *Not Available*.
	Synthetic Sky Quality Meter (SQM)	Resource in good condition	High	Not available	Average synthetic SQM was 21.49, which placed the condition of this measure in the category, *Resource in Good Condition*. Monitoring was conducted on site but not frequently enough to identify a trend, so confidence was *High* and trend was *Not Available*.
	Sky Quality Index (SQI)	Resource in good condition	High	Not available	Sky Quality Index was 94.55, which placed the condition of this measure in the category, *Resource in Good Condition*. Monitoring was conducted on site but not frequently enough to identify a trend, so confidence was *High* and trend was *Not Available*.
Natural light environment	Anthropogenic Light Ratio (ALR)	Resource in good condition	High	Not available	Anthropogenic Light Ratio was 0.125, which placed the condition of this measure in the category *Resource in Good Condition*. Monitoring was conducted on site but not frequently enough to identify a trend, so confidence was *High* and trend was *Not Available*.

4.2.4. Night Sky Conditions, Confidence, and Trends

Night Sky Quality

●
Condition: Resource in Good Condition
Confidence: High
Trend: Not Available

Condition

The Bortle Dark Sky Class of 3, average Sky Quality Index of 94.55, and average Synthetic SQM or 21.49 all placed the condition of Night Sky Quality at Badlands NP in the category, *Resource in Good Condition*.

Confidence

Night Sky Quality data were collected by the NPS Natural Sounds and Night Skies Division conducted on site at Badlands NP, so confidence was *High*.

Trend

Data were not available for the minimum three years, so trend was *Not Available*.

Natural Light Environment

●
Condition: Resource in Good Condition
Confidence: High
Trend: Not Available

Condition

The average ALR rating of 0.125 at Badlands NP was in the category *Resource in Good Condition*. Anthropogenic Light Ratio was the only measure of the indicator, Natural Light Environment, so this indicator was in the category, *Resource in Good Condition*.

Confidence

Natural Light Environment data were collected by the NPS Natural Sounds and Night Skies Division conducted on site at Badlands NP, so confidence was *High*.

Trend

Data were not available for the minimum three years, so trend was *Not Available*.

Night Sky Overall Condition

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)	🟢
Natural light environment	• Sky Quality Index (SQI) • Anthropogenic Light Ratio (ALR)	🟢
Overall condition for all indicators and measures		🟢

Condition

The average score for all measures was 100, which placed the condition of night skies at Badlands NP in the category, *Resource in Good Condition*.

Confidence

All data were collected by the NPS Natural Sounds and Night Skies Division conducted on site at Badlands NP, so confidence was *High*.

Trend

Data were not available for the minimum three years, so trend was *Not Available*.

4.2.5. Stressors

Badlands NP night sky experts identified that light from the small nearby town of Interior SD, two miles away, could be a source of light pollution in the park (C. Schroll, personal communication, 31 July 2016).

4.2.6. Data Gaps

The most recent data were collected in 2011, and no subsequent sampling has been conducted since. The only previous data available were collected in 2006. We were consequently unable to identify a trend in night sky condition. Annual or biennial (every two years) sampling of night sky conditions at Badlands NP would improve the ability of managers to maintain optimal night sky conditions.

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4.3. Soundscape/Acoustic Environment

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 Badlands NP and reorganized several subsections herein to follow the structure that we used for the other NRCA natural resource sections.

Lightning strikes over Badlands National Park. Photo by Larry McAfee, NPS.

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

Badlands NP is surrounded by vast areas of prairie and badlands formation, with some agricultural development bordering the park unit. Primary sources of non-natural sounds within the park include automobile traffic, visitor conversations and associated acoustics, maintenance operations, and air traffic passing overhead. Industrial activities and noise from business and heavily populated residential areas are unlikely to affect the acoustic environment in Badlands NP. The closest town with population > 10,000 is Rapid City, SD (population ~70,900), about 60 kilometers (37 miles) to the northwest.

4.3.2. Soundscape/Acoustic Environment 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 (Saunders 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 (Table 4.3.1.) 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

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, 100m above ground level	Yukon-Charley Rivers NP
126	Cannon fire at 150m	Vicksburg NMP

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)
- Vehicles
- Generators
- Watercraft
- Grounds care (lawn mowers, leaf blowers)
- Human voices

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 L90 across all sites and hours of the day of 21.8 dBA (between 20 and 800 Hz). L90 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, land cover, 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, Mennitt et al. 2013).

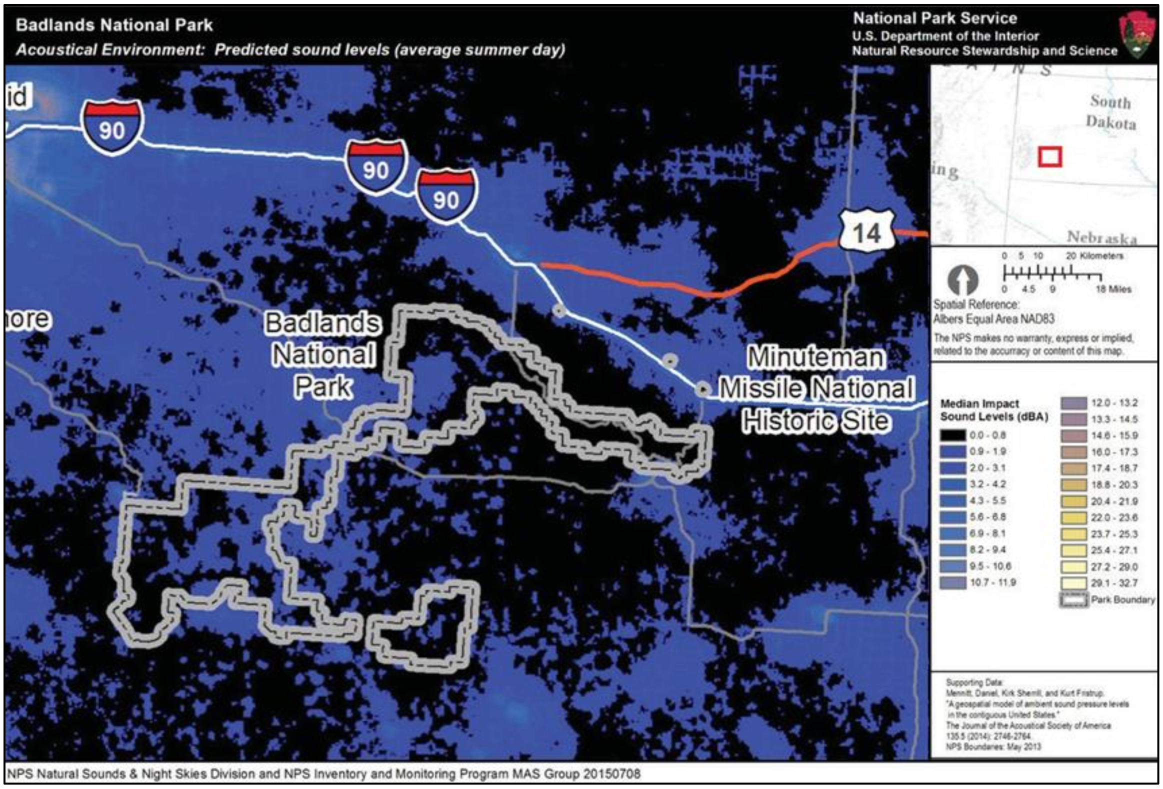

Figure 4.3.1. Modeled L_{50} dBA impact levels in Badlands National Park (NPS 2013).

Indicators and Measures

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, whereas 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 are applied to units that have at least 90% of the park property outside an urban Area. We used non-urban threshold to identify condition of anthropogenic impact in Badlands NP. 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 *Warrants Moderate Concern* and *Warrants Significant Concern* 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 park; units in urban areas may seek to preserve or restore low ambient sound levels to offer respite for visitors.

Table 4.3.2. Soundscape/acoustic environment condition categories for anthropogenic impact. Badlands NP is a non-urban park, so condition was evaluated using the non-urban criteria.

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 Badlands NP, and discussed sound condition with Badlands NP managers to identify any additional concerns about soundscape.

Quantifying Soundscape/Acoustic Environment Condition, Confidence, and Trend

Indicator Condition

To quantify soundscape condition and trend, we used assessment criteria developed by the NPS Natural Sounds and Night Skies Division (Turina et al. 2013) and the experience of full-time management within the park.

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 which 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.

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 do not differentiate between ambient natural and ambient existing sounds, or when expert opinion did not agree with modeled soundscape data. We assigned *Low* confidence ratings when acoustic data were unavailable.

Overall Soundscape/Acoustic Environment 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/Acoustic Environment Conditions, Confidence, and Trends

Soundscape/Acoustic Environment Overall Condition

Table 4.3.3. Soundscape/acoustic environment overall condition.

Indicators	**Measures**	**Condition**
Anthropogenic impact	• L_{50} dBA impact • Qualitative assessment	🟡

Condition

The L_{50} dBA impact level at Badlands NP was 0.6, which indicated a good condition, but park managers expressed concern that the modeled data did not capture the high noise levels present in the park during parts of the summer, particularly associated with motorcycle rallies and helicopter tours. We placed overall condition for Badlands NP in the category, *Warrants Moderate Concern*.

Confidence

We used methods developed by NPS NSNSD to assess soundscape condition, and used data supplied by the division to complete the assessment. Data were not collected during an onsite inventory, and expert opinion disagreed with the condition given by the modeled soundscape. The confidence was *Medium*.

Trend

Acoustic data for Badlands NP were insufficient to calculate a trend. Trend was *Not Available*.

4.3.5. Stressors

In the summer, motorcycle traffic to and from rallies create serious noise issues in the park. Additionally, helicopter tours create noise pollution. A common source of noise in national parks is transportation (e.g., airplanes, 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 km/yr (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).

4.3.6. Data Gaps

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.

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4.4. Air Quality

4.4.1. Background and Importance

Most visitors expect clean air and clear views in parks. However, air pollution can sometimes affect Badlands NP. 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 NPS Organic Act (16 USC § 1 1916) and the Clean Air Act (CAA; 42 USC § 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.

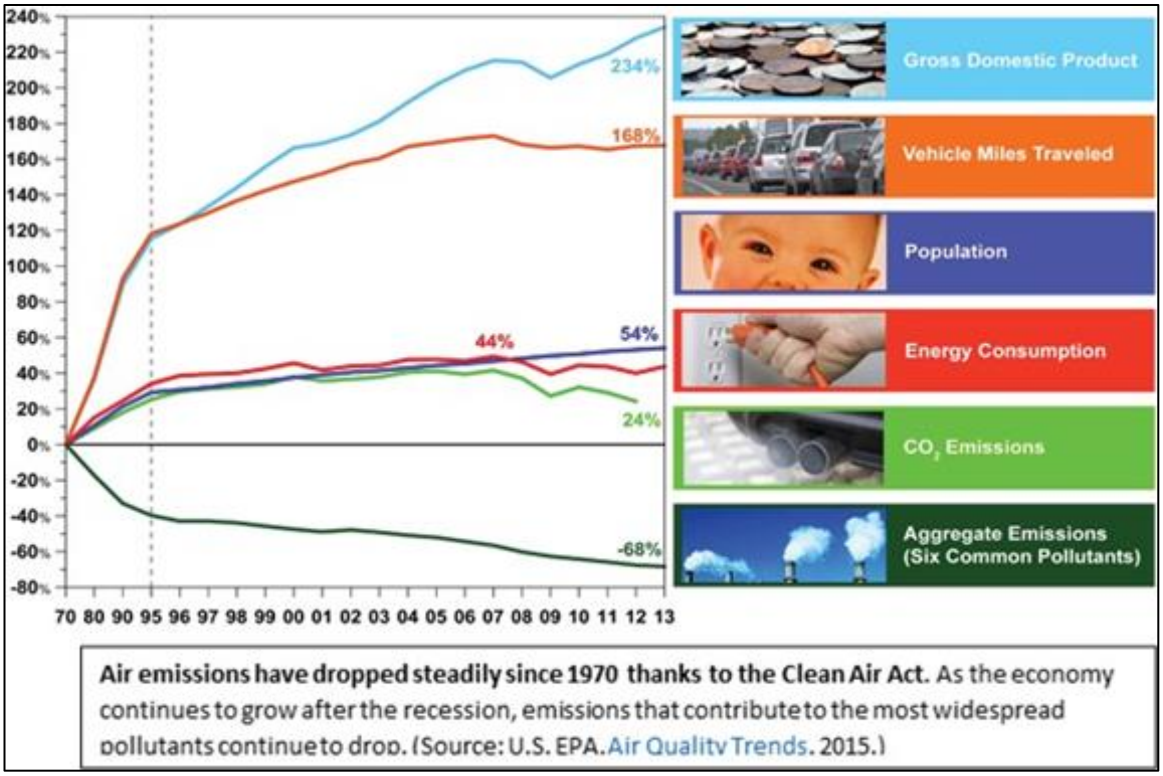
The Great Plains province is plateau-like, with some isolated mountains and lowlands throughout. Photo by Sara Feldt, NPS (2011).

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 USC § 7401 et seq. 1970). Park units greater than 6,000 acres in area, including Badlands National Park, are Class I 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).



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 https://www.epa.gov/air-trends).

The American Lung Association compiles a State of the Air report for each state, and assigns grades for air quality by county. Badlands NP spans three counties in South Dakota: Jackson, Pennington, and Oglala Lakota. Jackson County received the best grade (A) for overall air quality, ozone, and particle pollution. The other counties comprising Badlands NP did not have enough monitoring data from 2013–2015 to assign a grade for ozone pollution or particle pollution (ALA 2015). While few South Dakota counties had sufficient data for the ALA to assign an overall air quality grade, the existing data indicated generally high quality air.

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. Air Quality 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

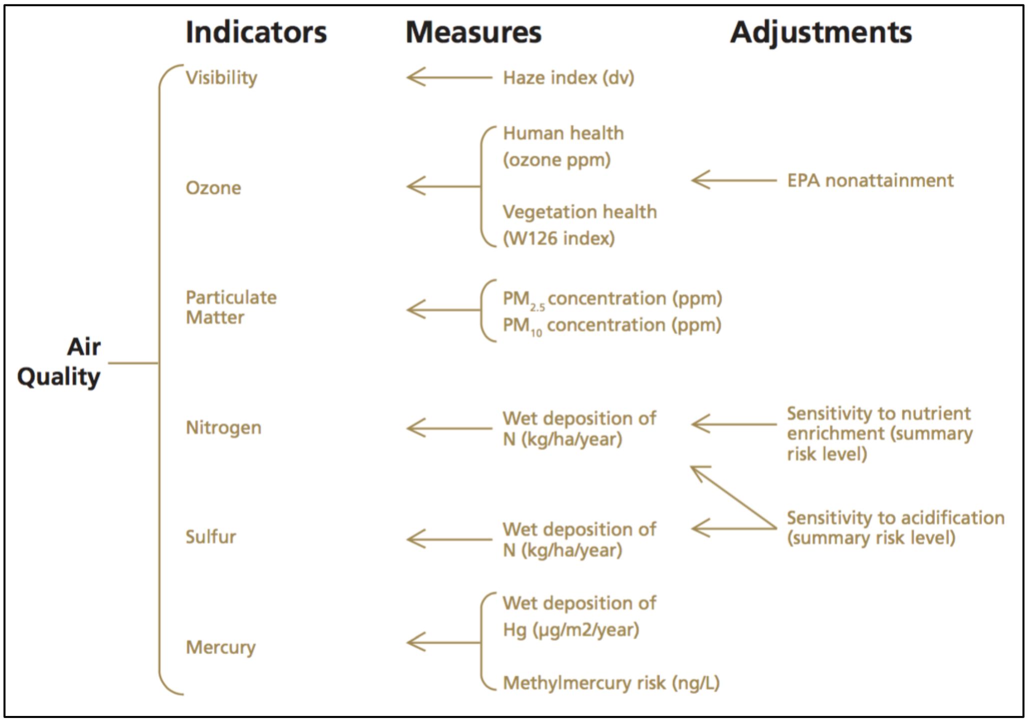


Figure 4.4.2. Schematic of the factors considered in air quality condition assessment.

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 2014, 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 on Lichens and Air Quality) 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 (NPS-ARD 2015a).

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.

There are a number of lichens at Badlands National Park 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 Badlands NP with known level of sensitivity. S = sensitive, I = intermediate sensitivity T = tolerant.

Species	Sensitivity	Species	Sensitivity
Ochrolechia androgyna	S	*Physcia aipolia*	I
Caloplaca flavorubescens	S	*Physconia detersa*	I
Candelaria concolor	S-I	*Caloplaca holocarpa*	I
Cladonia fimbriata	S-I	*Xanthoria candelaria*	I

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

Species	Sensitivity	Species	Sensitivity
Usnea hirta	S-I	*Xanthoria polycarpa*	I
Caloplaca cerina	S-I	*Parmelia sulcata*	I-T
Candelariella vitellina	I	*Phaeophyscia nigricans*	I-T
Lecanora chlarotera	I	*Lecanora dispersa*	T
Hyperphyscia adglutinata	I	*Lecanora hagenii*	T
Phaeophyscia orbicularis	I	*Lecanora muralis*	T
Physcia adscendens	I	–	–

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.

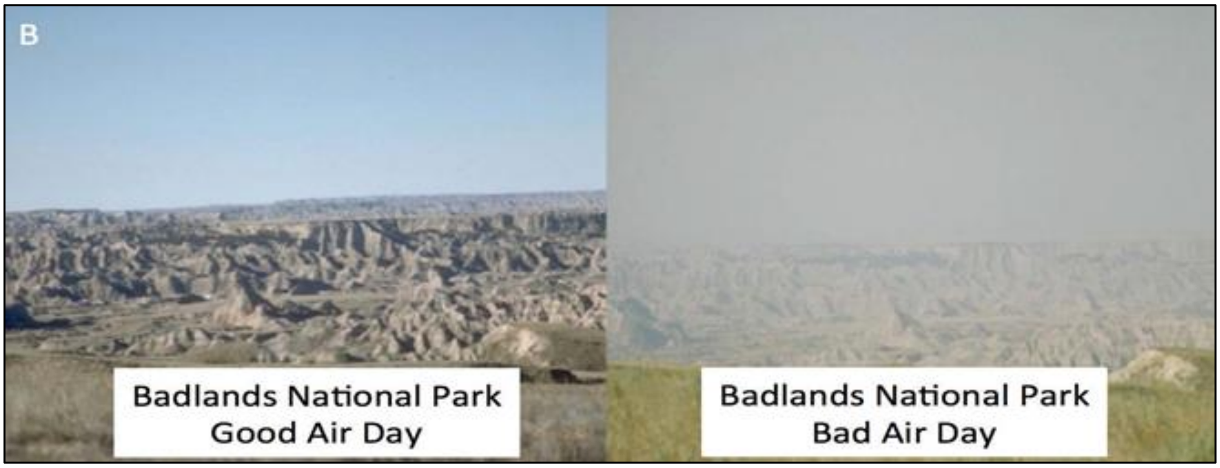


Figure 4.4.3. Photo representation of air quality in Badlands NP for a good air and bad air day. Haze can reduce visibility at Badlands National Park and may be accompanied by an increased risk to human and environmental health. Fires and dust storms can contribute to poor air quality days, such as this one at Badlands NP. Photo courtesy of NPS-ARD (https://www.nature.nps.gov/air/).

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.

The 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 Badlands NP 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 condition (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 primarily on NPS-ARD air quality trends (2004–2013) and conditions (2009–2013; NPS-ARD 2015b), with reference to additional studies and data where relevant.

A visibility condition estimate of less than two deciviews above estimated natural conditions indicates that air quality is in *Good Condition*, estimates ranging from two to eight deciviews 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 on-site Badlands NP IMPROVE monitoring site (IMPROVE site ID: BADL1).

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).

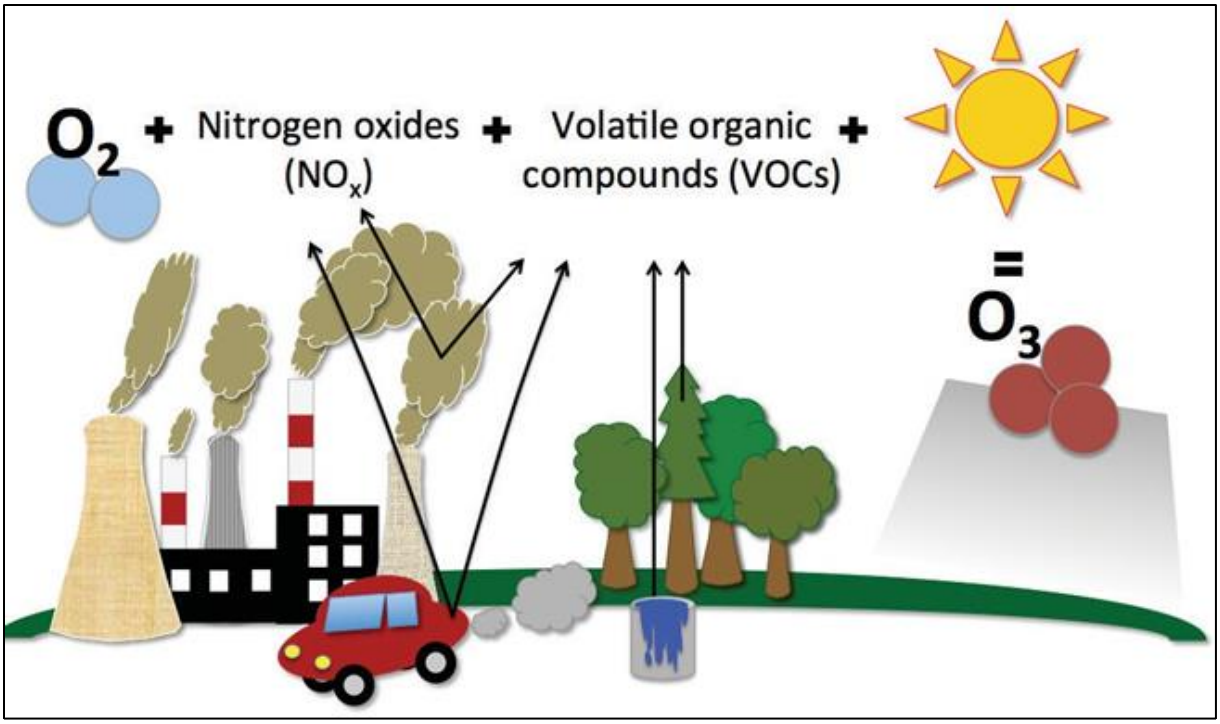


Figure 4.4.4. Graphic illustrating ozone (O_3) production (Dibner 2017). Ozone is formed when oxygen (O_2) combines with nitrogen oxides (NO_x) and volatile organic compounds (VOCs) in the presence of sunlight (EPA 2014, Dibner 2017). Fuel combustion from vehicles, power plants, and industrial operations produces NO_x 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.

While VOCs are produced naturally by some plants and soil microbes (Insam and Seewald 2010), additional VOCs are emitted from chemical solvents and during fuel combustion (EPA 2015b). Nitrogen oxides are produced by burning fossil fuels, and the largest sources of NOx 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).

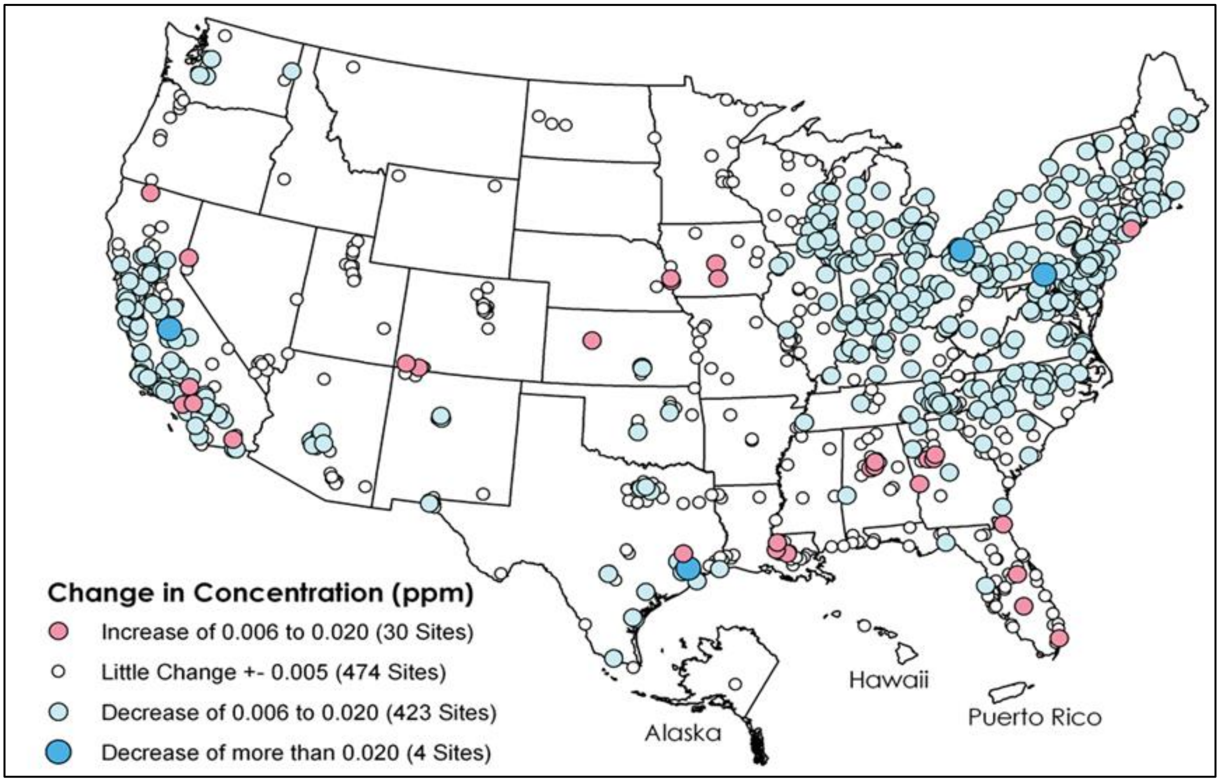


Figure 4.4.5. Change in ozone concentrations from 2001 to 2007 (EPA 2008).

Measure of Ozone: Human Health – Ozoe Concentration

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 Badlands NP 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 concentration (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 plant damage as a result of 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 Badlands NP 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 (Stölzel et al. 2007, EPA 2009). 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 µg/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 1988–2015 at the Badlands NP Visitor Center. 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.

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

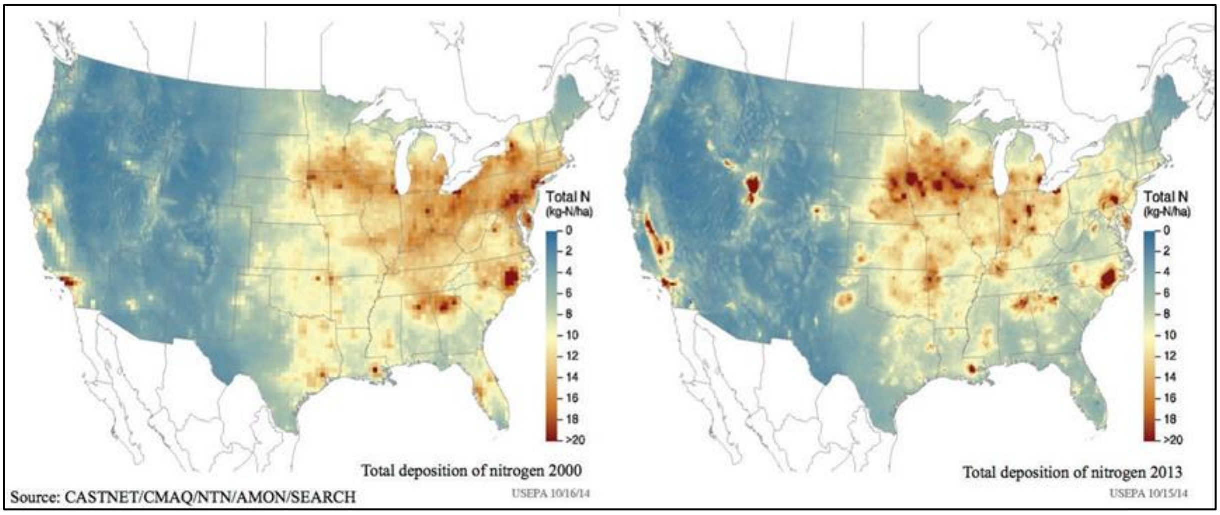
The standard for PM$_{10}$ is 150 g/m^3 for 24-hours (not to be exceeded more than once per year over 3 years).

Coarse particulate matter (PM$_{10}$) data were collected from 1988–2015 at the Badlands NP Visitor Center. We evaluated these 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 nitrogen deposition has decreased in some parts of the United States and increased in others.

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 Badlands NP.

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 condition (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

If Badlands NP 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/year; Table 4.4.6).

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 Badlands NP.

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 4.4.6).

Condition Adjustments

If Badlands NP 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 *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-caused sources 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	🟩	🟩	🟩	🟨	🟨
Low	🟩	🟩	🟨	🟨	🟨
Moderate	🟩	🟨	🟨	🟨	🟥
High	🟨	🟨	🟨	🟥	🟥
Very high	🟨	🟨	🟥	🟥	🟥

Note: Condition is represented in the following manner; green = good, yellow = moderate, red = 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

Indicator Condition

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. Air quality overall 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: Unchanging

Condition

The Haze Index for 2009–2013 was 5.4 dv, which placed visibility in Badlands NP in the *Warrants Moderate Concern* category.

To improve visibility, it is important to understand which pollutants have the greatest contributions to haze. Light extinction is used to calculate the contributions of individual pollutants to haze. Visibility impairment primarily results from small particles in the atmosphere that include natural particles from dust and wildfires and anthropogenic sources from organic compounds, NO_x and SO_2. The contributions made by different classes of particles to haze on the clearest days and haziest days are shown in Figures 4.4.8 and 4.4.9 from data collected at the Badlands NP IMPROVE monitoring location (NPS-ARD 2015b).

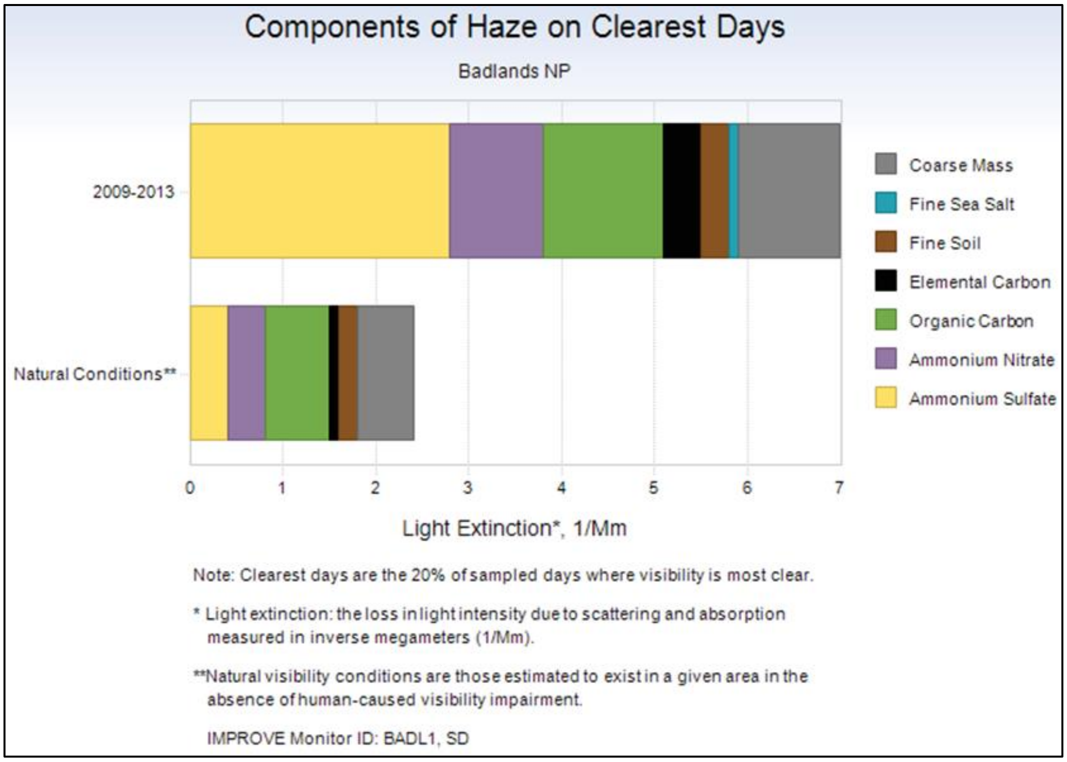


Figure 4.4.8. Components of haze on haziest days at Badlands NP for 2009 to 2013.

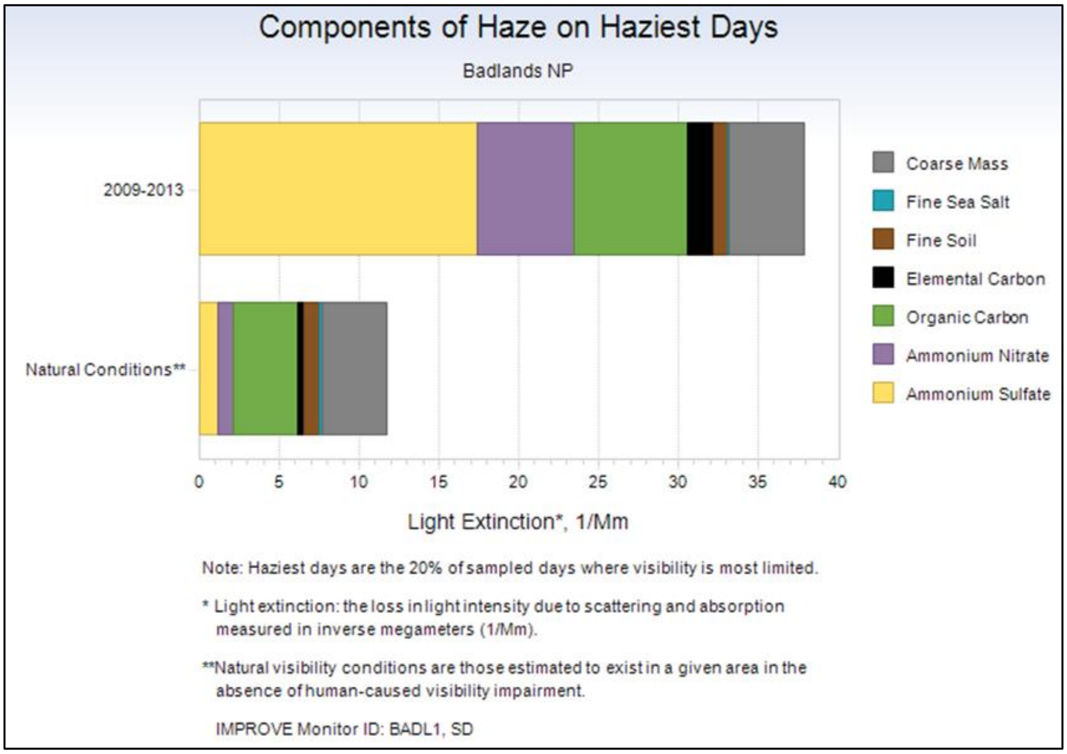
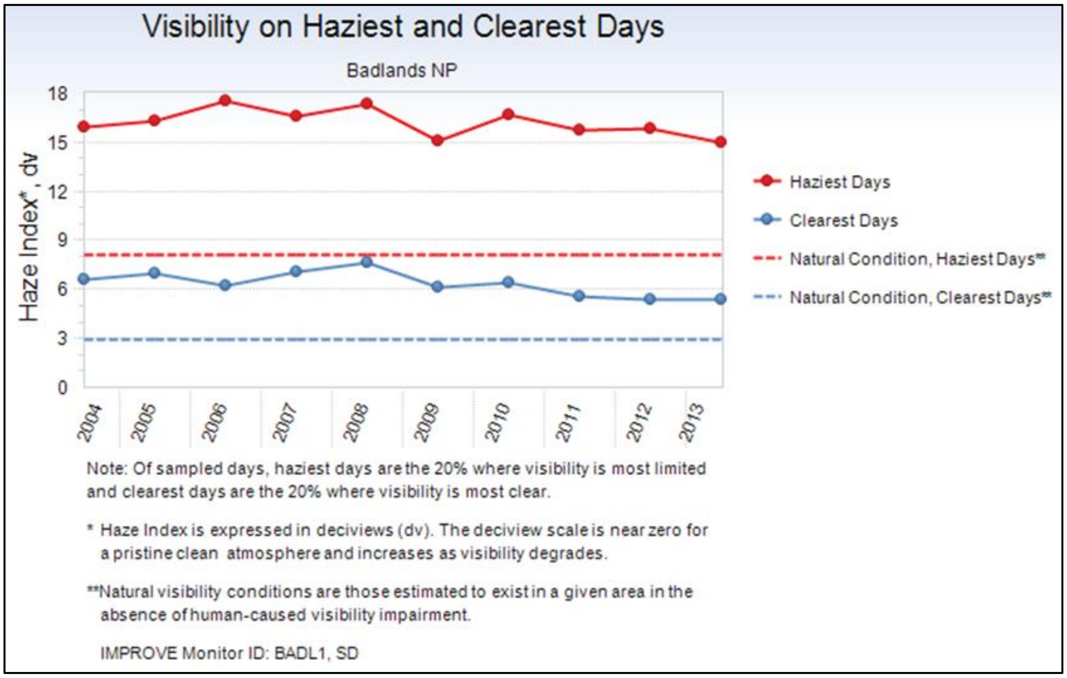


Figure 4.4.9. Components of haze on clearest days at Badlands NP for 2009 to 2013.

The primary visibility impairing pollutants on both the clearest and haziest days from 2009–2013 (Figure 4.4.10) were ammonium sulfate, ammonium nitrate, coarse mass, and organic carbon (NPS-ARD 2015b). Ammonium sulfate originates mainly from coal-fired power plants and industrial facilities; coarse mass consists of wind-blown dust; ammonium nitrate originates from emissions from vehicles and coal-fired power plants; while organic carbon originates primarily from combustion of fossil fuels and vegetation. Note that ammonia from sources such as fertilizer and animal feed operations contributes to the formation of sulfates and nitrates that exist in the atmosphere as ammonium sulfate and ammonium nitrate.



Note: Of sampled days, haziest days are the 20% where visibility is most limited and clearest days are the 20% where visibility is most clear.

* Haze Index is expressed in deciviews (dv). The deciview scale is near zero for a pristine clean atmosphere and increases as visibility degrades.

**Natural visibility conditions are those estimated to exist in a given area in the absence of human-caused visibility impairment.

IMPROVE Monitor ID: BADL1, SD

Figure 4.4.10. Visibility measured in haze index on haziest and clearest days for 2004 to 2013.

Confidence

Visibility was calculated from monitors on site in Badlands NP, so the confidence was *High*.

Trend

Visibility data were collected for at least 10 years on site at Badlands NP, which meant that a trend calculation could be completed. For 2004–2013, the trend in visibility at Badlands NP remained relatively unchanged (no statistically significant trend) on the 20% clearest days and 20% haziest days (IMPROVE Monitor ID: BADL1, SD). The overall visibility trend was *Unchanging* at Badlands NP (NPS-ARD 2015b).

Ozone

●

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

Human health condition: The calculated ground-level ozone from 2009–2013 was 58.9 ppb, which placed the human health measure of ozone pollution at Badlands NP in the *Resource in Good Condition* category.

Vegetation health condition: The W126 value for Badlands NP was 5.0 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 Badlands (Kohut 2004). Ozone-sensitive plants were present (Table 4.4.11), but observed levels of ozone were unlikely to damage plants.

Table 4.4.11. Ozone-sensitive plants at Badlands National Park.

Family	Common Name	Scientific Name
Asteraceae	Yarrow	*Achillea millefolium*
	Goldenrod	*Solidago canadensis*
Apocynaceae	Dogbane	*Apocynum*
Oleaceae	Green ash	*Fraxinus pennsylvanica*
Salicacaceae	Coyote willow	*Salix exigua*
Pinaceae	Ponderosa pine	*Pinus ponderosa*
Rosaceae	American plum	*Prunus americana*
	Chokecherry	*Prunus virginiana*
Anacardiaceae	Fragrant sumac	*Rhus aromatic*
Sapindaceae	Boxelder	*Acer negundo*

Confidence

Ozone levels were calculated from interpolated data collected at distant a monitoring stations, so the confidence was *Medium* (NPS-ARD 2015b).

Trend

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

Particulate Matter

Condition: Warrants Moderate Concern
Confidence: High
Trend: Unchanging

Condition

Badlands NP is located in Jackson, Pennington, and Oglala Lakota counties, South Dakota, that meet the 2012 and 2006 $PM_{2.5}$ standards and 1987 PM_{10} standard. For this reason, the counties are EPA-designated "attainment" areas for particulate matter.

The measured 3-year average (2013–2015) of the 98th percentile 24-hour $PM_{2.5}$ concentration was 16 $\mu g/m^3$, which falls in the *Warrants Moderate Concern* category. The measured 3-year average (2013–2015) of 2nd maximum 24-hour PM_{10} concentration was 36 $\mu g/m^3$ and falls into the *Resource in Good Condition* category. The overall particular matter condition falls into the *Warrants Moderate Concern* category.

Confidence

The particulate matter condition was calculated from on-site monitors in Badlands National Park, so the confidence was *High*.

Trend

Particulate matter data were collected for at least 10 years on site at Badlands NP (AQS Site ID: 46071001), which meant that a trend calculation could be completed. For 2004–2013, the trend of the 98th percentile 24-hour $PM_{2.5}$ concentration was *Unchanging* and was also *Unchanging* for the 2nd maximum 24-hour PM_{10} concentration. The overall particulate matter trend was *Unchanging* at Badlands NP (K. Taylor, personal communication, 26 May 2016).

Nitrogen Deposition

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

Condition

The total nitrogen deposition from 2009–2013 was 3.1 kilograms/hectare, placing total nitrogen wet deposition pollution at Badlands NP in the *Warrants Significant Concern* category (NPS-ARD 2015b).

Ecosystems in the park were rated as having high sensitivity to nutrient-enrichment effects relative to all Inventory & Monitoring parks (Sullivan et al. 2011a; Sullivan et al. 2011b). In addition to assessing wet deposition levels, critical loads can also be a useful tool in determining the extent of deposition impacts (i.e., nutrient enrichment) to monument resources. A critical load is defined as a level of deposition below which harmful effects to the ecosystem are not expected. For the Badlands NP, Pardo et al. (2011) suggested following critical load ranges for total nitrogen deposition in the Northwestern Forested Mountains ecoregion:

- 5.0–25.0 kg/ha/yr to protect herbaceous vegetation
- 12.0 kg/ha/yr to protect mycorrhizal fungi

To maintain the highest level of protection in the park, the minimum of the critical load ranges (5.0 kg/ha/yr) is an appropriate management goal.

The estimated maximum 2010–2012 average for total nitrogen deposition was 4.5 kg/ha/yr in the Great Plains ecoregion (NPS-ARD 2014) of Badlands NP. Therefore, the total nitrogen deposition level in the park is below but approaching the minimum ecosystem critical loads for some park vegetation communities, suggesting that herbaceous vegetation is at risk for harmful effects if nitrogen deposition levels increase in the future.

Confidence

None of the monitoring stations for wet deposition were on site in Badlands NP 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 50 kilometers east in Jackson County, South Dakota. The maximum distance allowed for calculating a trend in wet N deposition is 16 kilommeters away from a park unit, so trend was *Not Available* (NPS-ARD 2013).

Sulfur Deposition

●

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

Condition

The total sulfur deposition from 2009–2013 was 0.9 kilograms/hectare, which placed total sulfur wet deposition pollution at Badlands NP in the *Resource in Good Condition* category (NPS-ARD 2015b). Furthermore, ecosystems in the park were rated as having moderate sensitivity to acidification effects relative to all Inventory & Monitoring parks (Sullivan et al. 2011c; Sullivan et al. 2011d)

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 sulfur wet deposition was approximately 50 kilometers away in Jackson County, SD (NADP 2014). The maximum distance allowed for calculating a trend in wet sulfur deposition is 16 kilometers away from a park unit so trend was *Not Available* (NPS-ARD 2013).

Mercury Deposition

●

Condition: Warrants Significant 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 2011–2013 estimated wet mercury deposition is medium at the park, ranging from 5.8 to 6.5 $\mu g/m^2/yr$ (NPS-ARD 2016). The predicted methylmercury concentration in park surface waters is very high, ranging from 0.05 to 0.51 ng/L (USGS 2015). Wet deposition and predicted methylmercury ratings were combined to determine the *Warrants Significant Concern* condition.

Confidence

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

Trend

The closest monitoring site for mercury wet deposition was over 160 kilometers away in Eagle Butte, South Dakota (NADP 2014). The maximum distance allowed for calculating a trend in wet mercury deposition is 16 kilometers away from a park unit so trend was *Not Available* (NPS-ARD 2013).

Air Quality Overall Condition

Table 4.4.12. 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 (µg/m^2/year) • Methylmercury risk	🔴
Overall condition for all indicators and measures		🟡

The overall air quality condition was determined by the average of the indicator conditions. We summarized the condition, confidence, and trend for each indicator, and assigned condition points as specified by NPS-ARD (Table 4.4.13; NPS-ARD 2015a). The total score for overall air quality condition was 57 points, which placed Badlands National Park in the *Warrants Moderate Concern* category.

Table 4.4.13. Summary of air quality indicators and measures.

Indicator	Measure	Condition	Confidence	Trend	Condition Rationale
Visibility	Haze index (dv)	Warrants moderate concern	High	Unchanging	Visibility from 2009–2013 was 5.4 dv; this value placed visibility in the *Warrants Moderate Concern* category. Particulate matter ($PM_{2.5}$ and PM_{10}) concentrations were within the range for compliance with NAAQS, so the condition held. Data came from a monitoring location on site at BADL; confidence was *High* and trend was *Unchanging*.
Ozone	Human health (ozone concentration)	Resource in good condition	Medium	Not available	Ozone from 2009–2013 was 58.9 ppb; this value placed ozone pollution in the *Resource in Good Condition* 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)	Resource in good condition	Medium	Not available	The biologically relevant W126 value was 5.0 ppm-hrs, which placed vegetation health condition in the *Resource in Good Condition* category. Risk of foliar damage was *Low*.
Particulate matter	$PM_{2.5}$	Warrants moderate concern	High	Not available	$PM_{2.5}$ for 2013-2015 was 16 ug/m^3; this valued placed $PM_{2.5}$ in the *Warrants Moderate Concern* category. Data were collected on-site for *High* confidence, and trend was *Not Available*.
	PM_{10}	Resource in good condition	High	Not available	PM_{10} for 2013-2015 was 36 ug/m^3; this valued placed PM_{10} in the *Good Condition* category. Data were collected on-site for *High* confidence, and trend was *Not Available*.
Nitrogen deposition	Wet deposition N (kg/ha/yr)	Warrants significant concern	Medium	Not available	Total wet deposition of N from 2009–2013 was 3.1 kg/ha/yr; this value placed total N wet deposition pollution in the *Warrants Significant Concern* category. Risk of acidification was *Moderate* and risk of nutrient enrichment was *High*, but N was already in the category warranting the most concern. There were no monitoring data available from on site or nearby; confidence was *Medium* and trend was *Not Available.*

Table 4.4.13 (continued). Summary of air quality indicators and measures.

Indicator	Measure	Condition	Confidence	Trend	Condition Rationale
Sulfur deposition	Wet deposition S (kg/ha/yr)	Resource in good condition	Medium	Not available	Total average wet deposition level from 2009–2013 was 0.9 kg/ha S; total S wet deposition was in the *Resource in Good Condition* category. Risk of acidification was *Moderate*, so the category did not need to be adjusted. There were no monitoring data available from on site or nearby; confidence was *Medium* and trend was *Not Available*.
Mercury deposition	Wet deposition (µg/m^2/yr) and Methylmercury rating	Warrants significant concern	Low	Not available	Combined wet deposition and methylmercury ratings placed mercury deposition in the *Warrants Significant Concern* category. There was no on-site monitoring, so confidence was *Low* and trend was *Not Available*.

Confidence

Confidence was *High* for visibility and particulate matter, *Low* for mercury, and *Medium* for all other indicators. The score for overall confidence was 57 points, which met the criteria for *Medium* confidence in overall air quality.

Trend

Trend data were *Not Available* for all but two indicators, so overall trend for air quality was *Not Available*.

4.4.5. Stressors

Potential air quality stressors include industrial operations in Rapid City, South Dakota, approximately 70 kilometers to the northwest, automotive activity on local roads and Interstate 90 to the north, smoke from fires during the summer months, and coal-fired power plants approximately 220 kilometers away near Gillette, Wyoming (EIA 2015). Agricultural activity in the area could also contribute to poor air quality in Badlands NP, increasing particulate matter and deposition of nitrogen and sulfur (EPA 2016b).

Badlands NP is located just outside of three major oil and gas basins. The Powder River Basin (PBR) is the closest, located just to the west and northwest of the Badlands NP in eastern Wyoming, southwestern South Dakota and southeastern Montana. The Denver-Julesburg is located to the south of Badlands NP in north eastern Colorado, and the Williston Basin is located to the north of Badlands NP 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). Table 4.4.13 shows a summary of air quality conditions.

4.4.6. Data Gaps

Most of the available air quality data for Badlands National Park 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 Badlands NP over time.

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- Ksienya Taylor (NPS)

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4.5. Water Quality

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. The water quality of streams, rivers, wetlands, ponds, lakes, and other water bodies determines their suitability for these various uses (Boyd 2015). Indicative of the importance of water in park units, the National Park Service (NPS) identified water quality as a core natural resource (NPS 2009) to include in its nationwide ecosystem monitoring program (Fancy and Bennetts 2012).

Badlands National Park, South Dakota. Photo by Cathy Bell, NPS (2012).

The Clean Water Act (33 USC § 1251 et seq 1972) provides a general structure for surface water quality regulation in the U.S., and NPS places a high priority on improving and protecting water quality in park units (NPS 1999). The 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 square kilometers of upstream land (Seaber et al. 1987). This drainage basin continues to be affected by the construction of dams, levees, reservoirs, and canals for agricultural, industrial, and infrastructural activities since the 19th century (Buie 1980, Brown et al. 2011).

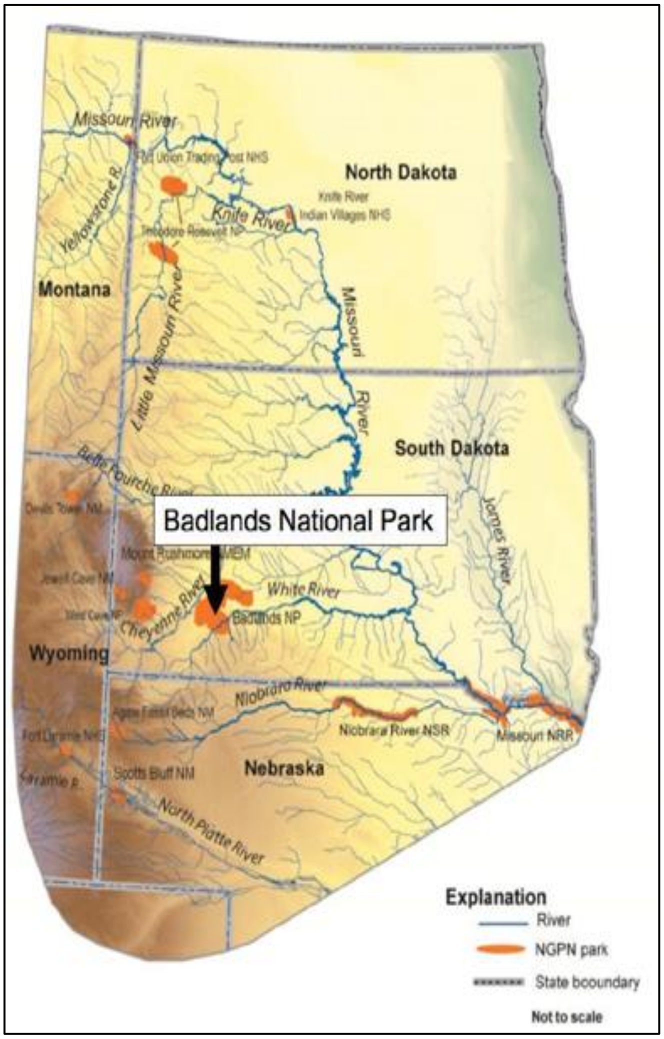

Figure 4.5.1. Tributaries and rivers in NGPN park units with Badlands NP location (Wilson et al. 2014).

Badlands National Park is located in the Bad, Middle Cheyenne-Elk, Middle Cheyenne-Spring, Upper White, and Middle White River drainage basins. Each of these rivers flow east into the Missouri River, though only White River runs through the park. Other water resources within the park are limited, consisting primarily of intermittent streams—Battle, Cedar, Palmer, and Sage Creeks, ephemeral water bodies, and constructed impoundments (Wilson et al. 2014). The top water quality priority at the Badlands NP is the Civilian Conservation Corps (CCC) Springs, an artificial stock pond (Wilson et al. 2014), and Sage Creek has also received monitoring attention (L. Trondstad, personal communication, 20 January 2016).

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 objectives, 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 2014) 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 CFR §131.5 1998). 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 Civilian Conservation Corps (CCC) Springs in Badlands NP is the highest priority for NGPN for water quality in the park, though it is lower priority than rivers and tributaries in the NPS network (Wilson et al. 2014). This impoundment, as well as the other stock ponds in the park have designated beneficial use for stock watering. Sage Creek, a stream in the boundary of Badlands NP has a beneficial use designation for fish and wildlife propagation, recreation, and stock watering, as well as for irrigation waters (Administrative Rules of South Dakota 2015). The White River, flows along the periphery of the park. This river has the beneficial use designations assigned to Sage Creek, plus the stricter beneficial use designation of limited contact recreation and warmwater semipermanent fish life propagation.

Surface waters in South Dakota are regulated to water quality standards consistent with their designation (Administrative Rules of South Dakota 2015, P. Snyder, personal communication, 15 August 2016). We assessed water quality based on NGPN monitoring protocol and specific indicator parameters. The standards for these parameters are:

- **pH:** 6.5–9.0 (White River); 6.0–9.5 (Sage Creek and stock ponds)
- **Dissolved oxygen (DO):** ≥ 5 mg/L (White River); not applicable to Sage Creek and stock ponds.

- **Temperature:** ≤ 32°C (White River); not applicable to Sage Creek and stock ponds.
- **Specific Conductivity:** 7,000 umhos/cm @ 25°C daily maximum (stock ponds); 4,375 umhos/cm @ 25°C daily for Sage Creek to meet the irrigation use designation; not applicable to White River.
- ***Escherichia coli* (*E. coli*):** < 630 cfu/100 mL (average) or < 1,178 cfu/100 mL (daily maximum) (White River); not applicable to Sage Creek and stock ponds.
- **Streamflow:** Streamflow is the amount of water that flows in a river or stream, eventually reaching the ocean. 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 the rivers and Sage Creek, numeric water quality standards shall apply at all times except during low flow. Low flow is defined as either the minimum 7-day average low flow that can be expected to occur once in every five years or 1.0 cubic foot per second, whichever is greater (Administrative Rules of South Dakota 2015).

4.5.3. Methods

Indicators and Measures

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 South Dakota Department of Environment and Natural Resources (Administrative Rules of South Dakota 2015) and/or identified as key indicators by NPS (Wilson et al. 2014). The National Park Service 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 biological indicators gives a more robust assessment of overall health of the aquatic environment. The NGPN protocol for surface water monitoring incorporates a suite of advanced 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. We considered all indicators and measurements in the context of streamflow, as flow rates determine the applicability of water quality standards.

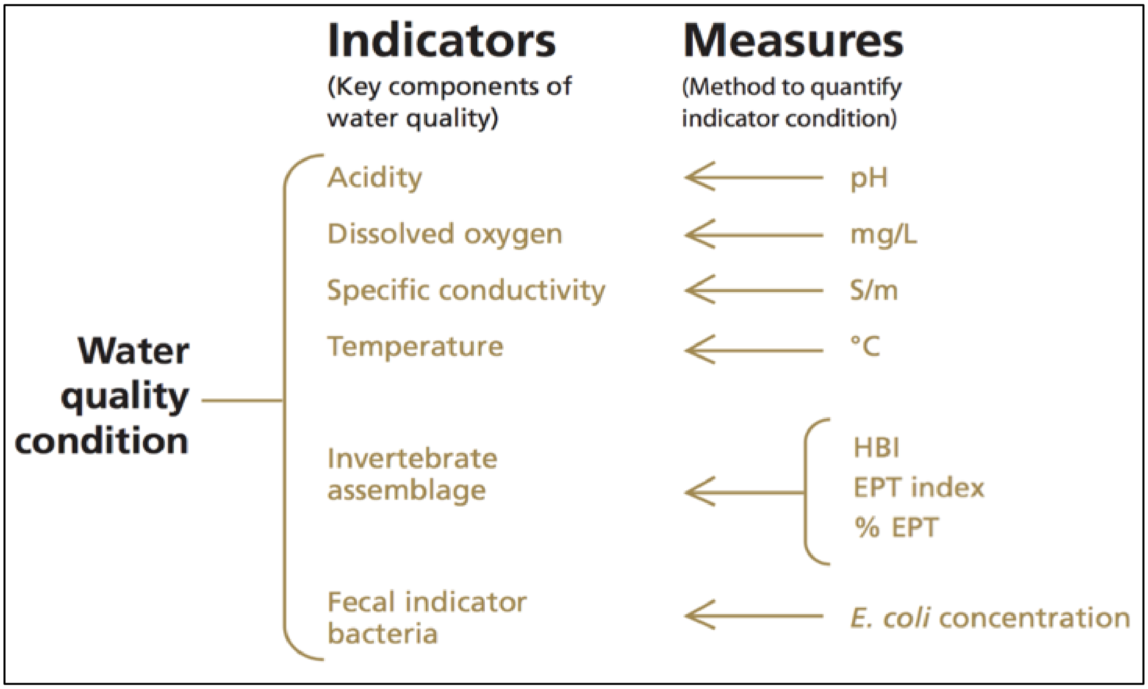

Figure 4.5.2. Schematic of the factors considered in water quality condition assessment.

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 Badlands NP and focused on the most recent data available for each indicator. To assign a condition to each water quality indicator, we used measurements specified by South Dakota DENR (Administrative Rules of South Dakota 2015), EPA, and expert opinion for indicators not regulated federally or by South Dakota DENR. 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*; category was determined by the proportion of samples that were outside the range of allowed values (Table 4.5.1). Ideally, samples would have been collected consistently over time at set monitoring locations, and would have allowed us to assign a category based on the proportion of those samples that exceeded Nebraska standards for water quality.

Table 4.5.1. 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) when data from multiple sampling events were available.

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.

All water bodies that were identified as impaired for one or more designated uses (South Dakota DENR 2016, EPA 2016) according to South Dakota water quality standards and/or the Clean Water Act, were given the worst condition associated with that water body. We assigned all waters with *Impaired* status the condition, *Warrants Significant Concern*, all waters with a *Threatened* status as *Warrants Moderate Concern*, and all Good waters as *Resource in Good Condition* (Table 4.5.2).

Table 4.5.2. Example of water quality assessment table with impaired status for the designated beneficial uses, agricultural and recreation. This water body would receive the overall condition, *Warrants Significant Concern*.

Designated use	Designated use group	Status
Fish and wildlife propagation, recreation, and stock watering waters	Aquatic life harvesting	Good
Irrigation waters	Agricultural	Impaired
Limited contact recreation waters	Recreation	Impaired
Warm water semi-permanent fish life propagation waters	Aquatic life harvesting	Good

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.

Core Indicators and Measures

Indicator: Acidity

Most streams are naturally neutral; they are neither very acidic nor alkaline. 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 4.5.3). 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).

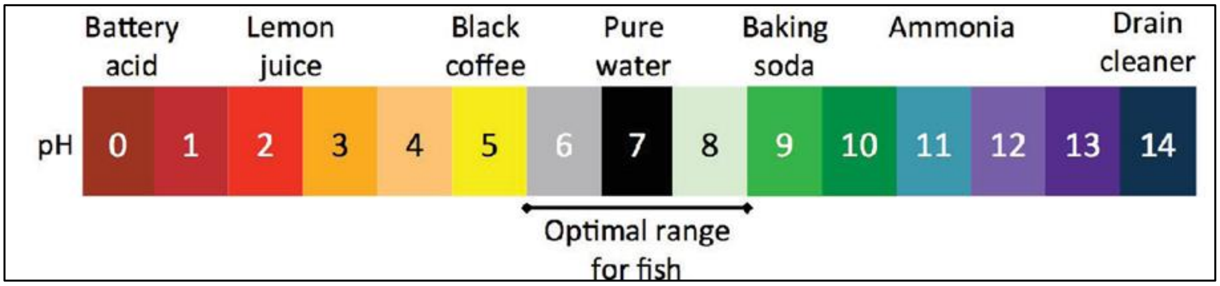

Figure 4.5.3. pH scale. Low and high pH waters are limiting for aquatic life; fish survive best at pH of 5–9.

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 scale of 0 (most acidic) to 14 (most alkaline), where 7.0 is neutral.

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 milligrams/liter 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 into algae blooms that can temporarily increase dissolved oxygen. 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).

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 grown 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: 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 of a water body, its physical structure, the clarity of the water (Paaijmans et al. 2008), and flow rates or circulation 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.

Biological Indicators and Measures

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 *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. Background data and EPT criteria have not yet been developed for Badlands NP (P. Snyder, personal communication, 16 August 2016), so we assigned condition to this measure based on background data for EPT numbers in the nearest assessment to Badlands NP, an assessment of Nebraska streams with numeric criteria specific to the northernmost part of Nebraska—the Northwestern Great Plains (Bazata 2011, 2013). 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 *Good Condition* to values above the 75th percentile of streams (Table 4.5.5). Because these criteria are not specific to Badlands National Park or the water bodies considered in this assessment, they are accompanied by a low confidence rating. When site-specific criteria are available, they may be compared to the data we present here.

Table 4.5.5. Water quality condition categories for Ephemeroptera, Plecoptera, and Trichoptera (EPT) index (Bazata 2011, 2013).

Resource condition		EPT index
Warrants significant concern	🔴	< 3
Warrants moderate concern	🟡	3 – 5
Resource in good condition	🟢	> 5

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 2015a). Condition ranges were not available for proportion of EPT for South Dakota, so we used the nearest assessment to Badlands NP, an assessment of Nebraska streams with numeric criteria specific to the northernmost part of Nebraska—the Northwestern Great Plains (Bazata 2011, 2013) and assigned condition based on these ranges (Table 4.5.6). Because these criteria are not specific to Badlands National Park or the water bodies considered in this assessment, they are accompanied by a low confidence rating. When site-specific criteria are available, they may be compared to the data we present here.

Table 4.5.6. Water quality condition categories for proportion of Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa (Bazata 2011, 2013).

Resource condition		Proportion EPT taxa
Warrants significant concern	🔴	< 0.11
Warrants moderate concern	🟡	0.11 – 0.17
Resource in good condition	🟢	> 0.17

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.

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

Concentration of *E. coli* (number of bacteria per unit volume) is regulated as 30-day averages and as single samples (Administrative Rules of South Dakota 2015). If we did not have the requisite number of samples to apply a 30-day mean, we used single sample standards to evaluate *E. coli* condition. We used a quartile approach to assign conditions (Table 4.5.7), such that concentrations up to the first quartile indicated *Good Condition*, the interquartile range indicated *Warrants Moderate Concern*, and concentrations above the third quartile indicated *Warrants Significant Concern*.

Table 4.5.7. Water quality condition categories for *Escherichia coli* (*E. coli*).

Resource condition		***E. coli* concentration (cfu/100 milliliters)**	***E. coli* concentration, 30-day average (cfu/100 milliliters)**
Warrants significant concern	🔴	884 ≤ x	473 ≤ x
Warrants moderate concern	🟡	295 < x < 884	158 < x < 473
Resource in good condition	🟢	0 < x ≤ 295	0 < x ≤ 158

Data Sources

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 Badlands NP. We conferred with experts to identify relevant monitoring data and reports for water quality at Badlands NP (P. Snyder, personal communication, 15 August 2016; L. Tronstad, personal communication, 20 January 2016). We identified several data sources within park boundaries: the 2016 integrated report for South Dakota surface water quality (South Dakota DENR 2016), unpublished data on water quality chemistry and biological indicators (L. Tronstad, personal communication, 20 January 2016), EPA waterbody reports (EPA 2016), and a thesis on water quality (Rust 2006). Core indicator data collected by Tronstad in 2015 were the most recent, therefore forming the basis of our evaluation of core indicators of water quality. For the biological components of the assessment, we used data collected by the State of South Dakota (SDDENR 2016) and Rust (2006).

Sampling locations that we considered for this assessment included 10 sampling points on Sage Creek (10 sampled by Rust [2006], one resampled by Tronstad [2016]), six stock ponds (four sampled by both Rust [2006] and Tronstad [2016] plus two additional locations sampled by Tronstad), and one sampling point on the White River (Figure 4.5.4).

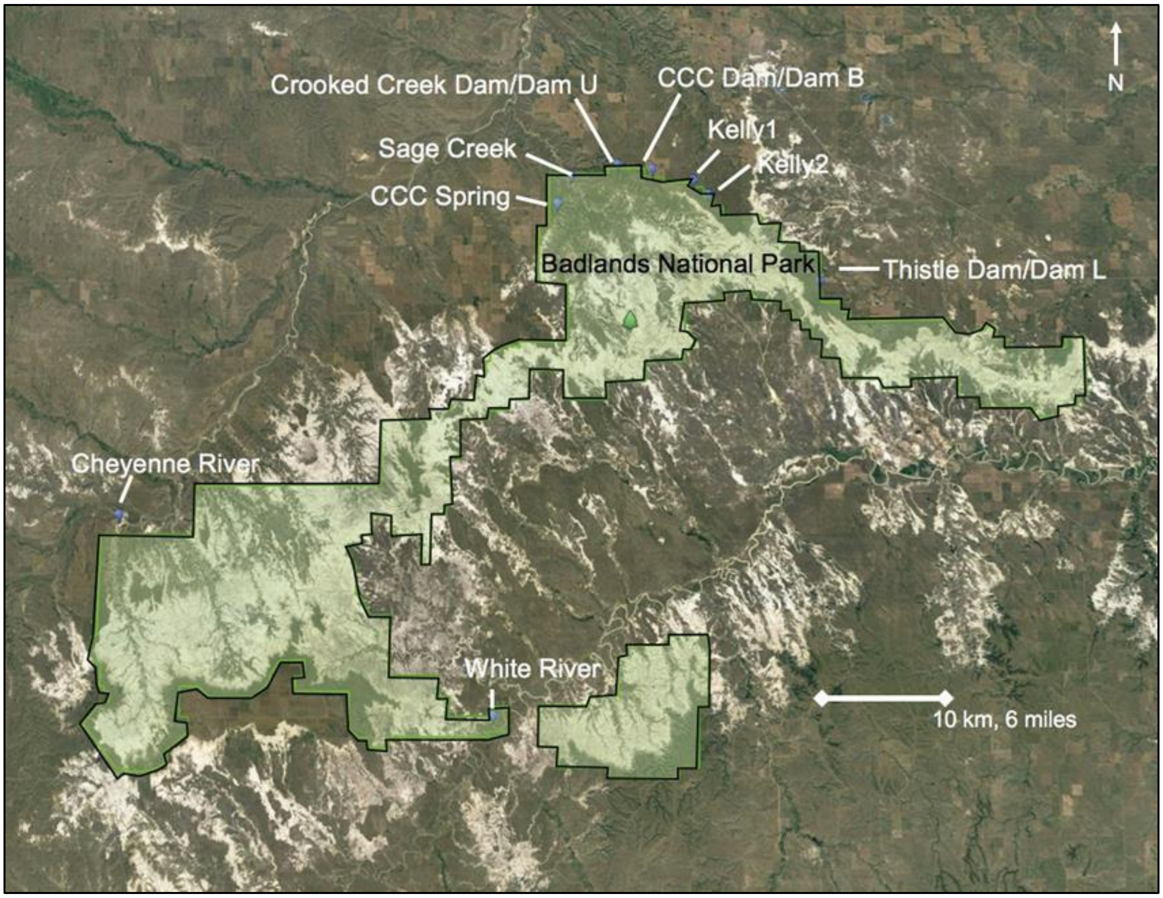

Figure 4.5.4. Water quality sampling locations in rivers, creeks, and stock ponds at Badlands NP (modified from Google Earth 2016).

Quantifying Water Quality Condition, Confidence, and Trend

Indicator Condition

To quantify water quality condition and trend, 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 deferred to data that were collected most recently and rigorously, where multiple sources existed. 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 monitoring location, monitoring frequency, and time since data collection. We gave a rating of *High* confidence for core indicators and fecal indicator bacteria when sampling efforts were on site, data were collected continuously over two years with the last year of sampling falling within two years of this assessment, and the data were collected using equipment and procedures consistent with published methods and South Dakota DENR standards. We gave a rating of *High* for invertebrate indicators of water quality when sampling efforts were on site and had been collected at least twice a year for at least two years, with the second year falling within three years of this assessment. We assigned a *Medium* confidence rating when sampling efforts were not repeated or data were not collected recently. We assigned *Low* confidence ratings when reference conditions were unavailable, data were not collected on site, data collection was not repeatable or methodical, or there were no data sources to support the condition.

Indicator Trend

Potential trend categories were *Improving*, *Unchanging*, or *Deteriorating*. To calculate a trend estimate for core indicators and fecal indicator bacteria, we sought water quality data that were collected at least five times 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. To calculate a trend for invertebrate indicators of water quality, we required at least three years of data in which samples had been collected at least twice at least as recent as three years prior to this assessment.

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 4.5.8).

Table 4.5.8. Summary of surface water quality indicators and measures.

Indicator	Measure	Condition	Confidence	Trend	Condition rationale
Acidity	pH	Resource in good condition	Medium	Not available	Acidity was within state standards during sampling period. Monitoring was not continuous for two years, so confidence was *Medium* and trend was *Not Available*.
Dissolved Oxygen (DO)	Milligrams/ liter	Resource in good condition	High	Not available	DO was within state standards during sampling period. Condition was based on state summary data so confidence was High but trend was *Not Available.*
Temperature	°Celsius	Resource in good condition	High	Not available	Temperature was within state standards during sampling period. Condition was based on state summary data so confidence was *High* but trend was *Not Available*.
Specific conductivity	Siemens/ meter	Resource in good condition	Medium	Not available	Specific conductivity was within state standards during sampling period. Monitoring was not continuous for two years, so confidence was *Medium* and trend was *Not Available.*
Invertebrate assemblage	• HBI • EPT index • Proportion EPT	Warrants significant concern	Low	Not available	The average score of conditions indicated by all measures was 33.3, which *Warrants Significant Concern*. Monitoring was repeated 2004–2005. No reference data for EPT measures were available. Confidence was *Low* and trend was *Not Available*.
Fecal indicator bacteria	*Escherichia coli* (*E. coli*) count of colony forming units/100 milliliters	Warrants significant concern	High	Not available	Fecal coliform count was a cause of impairment in the two large rivers considered in this assessment. Condition was based on state summary data so confidence was *High* but trend was *Not Available*.

4.5.4. Water Quality Conditions, Confidence, and Trends

The most recent core parameter data were collected in 2015 in Sage Creek and the stock ponds by Tronstad, and in 2015 by South Dakota DENR. Invertebrate data were most recently collected by Rust (2006) from Sage Creek and the stock ponds.

Acidity

●

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

Condition

To assign a condition to dissolved oxygen (DO) we referred to South Dakota DENR (2016) summary data. Specific values were not available for the White River, but these waters are assessed for water quality by South Dakota DENR and any water quality parameters outside of acceptable limits were reported; dissolved oxygen was not one of the causes for impairment in either river over the 12 years prior to this assessment. Dissolved oxygen criteria did not apply to the designated beneficial uses for the other water bodies in this assessment. The available information placed DO for Badlands NP in the *Resource in Good Condition* category.

Confidence

We interpreted dissolved oxygen condition based on the South Dakota DENR (2016) report that was itself based on data collected on site Badlands NP over 12 years. The confidence was *High*.

Trend

While the cause of impairment did not include dissolved oxygen for at least 12 years prior to this assessment, we were unable to identify an overall trend in DO concentration from the summary data. Trend was *Not Available*.

Dissolved Oxygen (DO)

●

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

Condition

To assign a condition to dissolved oxygen (DO) we referred to South Dakota DENR (2016) summary data. Specific values were not available for the White River, but these waters are assessed for water quality by South Dakota DENR and any water quality parameters outside of acceptable limits were reported; dissolved oxygen was not one of the causes for impairment in either river over the 12 years prior to this assessment. Dissolved oxygen criteria did not apply to the designated beneficial uses for the other water bodies in this assessment. The available information placed DO for Badlands NP in the *Resource in Good Condition* category.

Confidence

We interpreted dissolved oxygen condition based on the South Dakota DENR (2016) report that was itself based on data collected on site Badlands NP over 12 years. The confidence was *High*.

Trend

While the cause of impairment did not include dissolved oxygen for at least 12 years prior to this assessment, we were unable to identify an overall trend in DO concentration from the summary data. Trend was *Not Available*.

Temperature

🟢

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

Condition

To assign a condition to temperature we referred to South Dakota DENR (2016) summary data. Specific values were not available for the White River, but these waters are assessed for water quality by South Dakota DENR and any water quality parameters outside of acceptable limits were reported; temperature was not one of the causes for impairment in either river over 10 years prior to this assessment. Temperature criteria did not apply to the designated beneficial uses for the other water bodies in this assessment. The available information placed temperature for Badlands NP in the *Resource in Good Condition* category.

Confidence

We interpreted temperature condition based on the South Dakota DENR (2016) report that was itself based on data collected on site Badlands NP over 12 years. The confidence was *High*.

Trend

While the cause of impairment did not include temperature for at least 10 years prior to this assessment, we were unable to identify an overall trend in temperature from the summary data. Trend was *Not Available*.

Specific Conductivity

🟢

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

Condition

To assign a condition to specific conductivity we used data summarized by Tronstad (L. Tronstad, personal communication, 15 July 2016). Data collected at Sage Creek and the stock ponds were within the acceptable range for South Dakota water quality standards. Conductivity criteria did not apply to the designated beneficial uses for the White River. The condition of specific conductivity at Badlands National Park was *Resource in Good Condition*.

Confidence

Specific conductivity data were collected on site at Badlands NP recently but the sampling effort occurred during one sampling visit to each water body and was not repeated. The confidence was *Medium*.

Trend

Specific conductivity data were not collected continuously, so data were insufficient to identify a trend. Trend was *Not Available*.

Invertebrate Assemblage

🔴

Condition: Warrants Significant Concern
Confidence: Low
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 measures, we used the average condition indicated by each measure.

- **Hilsenhoff Biotic Index (HBI):** The average value of HBI was 6.83. This value indicated an HBI condition of *Resource in Good Condition* at Badlands NP.
- **EPT Index:** The average value of EPT index was 0.5. This value indicated an EPT condition of *Warrants Significant Concern* at Badlands NP.
- **Proportion EPT:** The average value for proportion EPT of total invertebrate samples was 0.015. This value indicated a proportion EPT condition of *Warrants Significant Concern* at Badlands NP.

The average of conditions indicated by all measures was 33, which placed the condition of macroinvertebrate assemblage at Badlands NP in the category, Warrants Significant Concern.

Confidence

Macroinvertebrate data were collected on site at multiple locations twice in 2004–2005. Macroinvertebrate condition reflects long-term environmental conditions, unlike the snapshot nature of chemical sampling, but to assign a *High* confidence rating, we required data that had been collected at least as recently as three years prior to this assessment. Additionally, reference values for EPT and EPT proportion were unavailable for this geographic region of South Dakota. Confidence was *Low*.

Trend

Data were insufficient to assign a trend. Trend was *Not Available*.

Fecal Indicator Bacteria (Fecal coliform)

●

Condition: Warrants Significant Concern
Confidence: High
Trend: Not AvailableCondition

To assign a condition to temperature, we referred to South Dakota DENR (2016) summary data. Specific values were not available for the White River, but these waters are assessed for water quality by South Dakota DENR and any water quality parameters outside of acceptable limits were reported; fecal coliform was one of the causes of impairment for both rivers for 10 years prior to and including this assessment. Fecal indicator criteria did not apply to the designated beneficial uses for the other water bodies in this assessment. The available information placed fecal indicator bacteria for Badlands NP in the *Warrants Significant Concern* category.

Confidence

We interpreted fecal indicator bacteria condition based on the South Dakota DENR (2016) report that was itself based on data collected on site Badlands NP over 12 years. The confidence was *High*.

Trend

While fecal coliform was a cause for impairment for at least 12 years prior to this assessment, we were unable to identify an overall trend in fecal from the summary data. Trend was *Not Available*.

Water Quality Overall Condition

Table 4.5.9. Water quality overall condition.

Indicators	**Measures**	**Condition**
Acidity	- pH	🟢
Dissolved oxygen	- mg/L	🟢
Temperature	- °C	🟢
Specific conductivity	- S/m	🟢
Invertebrate assemblage	- HBI - EPT index - % EPT	🔴
Fecal indicator bacteria	- *E. coli* concentration	🔴
Overall condition for all indicators and measures		🟡

Condition

Overall water quality condition was determined by the average of the indicator conditions. We summarized the condition, confidence, and trend for each indicator, and assigned condition points. The total score for overall water quality condition was 62.5 points, which placed water quality at Badlands NP in the *Warrants Moderate Concern* category.

Confidence

Confidence was *High* for dissolved oxygen, temperature, and fecal indicator bacteria, *Low* for Invertebrate assemblage and *Medium* for pH and specific conductivity. The score for overall confidence was 62.5 points, which met the criteria for *Medium* confidence in overall water quality.

Trend

Trend data were *Not Available* for any indicator, so overall trend for water quality was *Not Available*.

4.5.5. Stressors

Water quality at Badlands National Park was of medium concern. Heavy use of available water resources by livestock and agriculture upstream and bison within the park are the most likely causes of water quality impairment. Contamination from chemicals such as atrazine could have serious negative consequences for the park (Graymore et al. 2001). Agricultural activity upstream could contribute to chemical contamination, but so could weed control within the park. Atrazine has been detected in CCC spring within the park in the past, though not recently (USGS 2016).

Additionally, changes to upstream land use or management practices could have unanticipated consequences. Development of Bakken shale oil (P. Penoyer, personal communication, 7 July 2016) could pose a threat to water supply and water quality in the general region. A summary of current water quality conditions is found in Table 4.5.10.

Table 4.5.10. Summary of surface water quality indicators and measures.

Indicator	Measure	Condition	Confidence	Trend	Condition Rationale
Acidity	pH	Resource in good condition	Medium	Not available	Acidity was within state standards during sampling period. Monitoring was not continuous for two years, so confidence was *Medium* and trend was *Not Available.*
Dissolved Oxygen (DO)	Milligrams/liter	Resource in good condition	High	Not available	DO was within state standards during sampling period. Condition was based on state summary data so confidence was *High* but trend was *Not Available*.
Temperature	°Celsius	Resource in good condition	High	Not available	Temperature was within state standards during sampling period. Condition was based on state summary data so confidence was *High* but trend was *Not Available*.
Specific conductivity	Siemens/m	Resource in good condition	Medium	Not available	Specific conductivity was within state standards during sampling period. Monitoring was not continuous for two years, so confidence was *Medium* and trend was *Not Available*.

Table 4.5.10 (continued). Summary of surface water quality indicators and measures.

Indicator	Measure	Condition	Confidence	Trend	Condition Rationale
Invertebrate assemblage	• HBI • EPT index • Proportion EPT	Warrants significant concern	Low	Not available	The average score of conditions indicated by all measures was 33.3, which Warrants Significant Concern. Monitoring was repeated 2004–2005. No reference data for EPT measures were available. Confidence was *Low* and trend was *Not Available*.
Fecal indicator bacteria	*Escherichia coli* (*E. coli*) count of colony forming units/100 milliliters	*Warrants Significant Concern*	*High*	*Not Available*	Fecal coliform count was a cause of impairment in the two large rivers considered in this assessment. Condition was based on state summary data so confidence was *High* but trend was *Not Available*.

4.5.6. Data Gaps

Water quality data for core indicators at Badlands NP were limited to samples collected once in Sage Creek and the stock ponds in the last 10 years, and frequent sampling is required for any more detailed analysis of trend. Frequent sampling within the park for at least two years would improve assessment efforts to understand the water quality condition at Badlands NP. 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 Badlands NP will depend on the specific o

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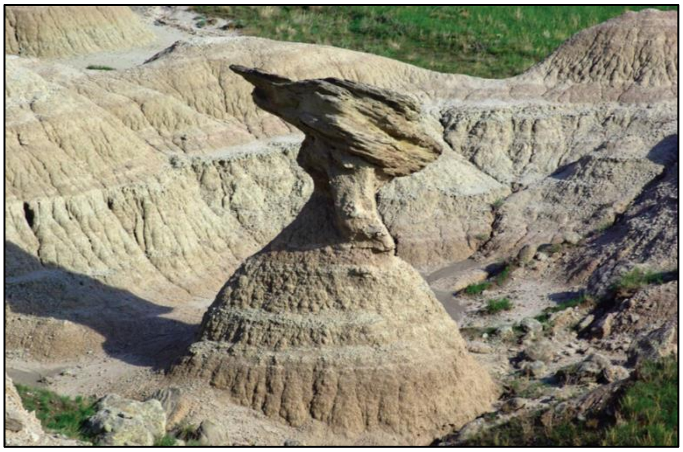
4.6. Geology

4.6.1. Background and Importance

Geological resources underlie and impact 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 highly friable and lead to slope instability. Modern river valleys in this region hold thick fluvial gravel deposits that overlie the sedimentary bedrock. In many areas these river gravels have had an impact on the history of human habitation, as buildings were historically placed near the river channels (Graham 2009).



Toadstool Rock at Norbeck Pass. Photo by Larry McAfee, NPS.

Geological hazards in the northern Great Plains area are mostly related to landslide 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 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 park to minimize uncharacteristic or dangerous mass wasting.

The Great Plains region has not been seismically active for millions of years, and earthquakes are uncommon in the area. Small earthquakes have occurred in the northern Laramie Range in Wyoming approximately 281 kilometers (175 miles) southwest of Badlands NP (Case 2002).

Regional Context

The rugged geology of Badlands National Park (NP) is a primary draw to the park for people from around the world (Figure 4.6.1). 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 Badlands NP are those of the Cretaceous Pierre Shale and the overlying Fox Hills Formation. These marine strata were deposited in the Cretaceous Interior Seaway as it covered much of the center of the continent. Their contained faunas mostly consist of invertebrate fossils such as bivalves and ammonites, as well as occasional fishes and marine reptiles. Based on the age of these fossils, the Western Interior Seaway persisted in the region until about 67 Ma (millions of years ago), just prior to the end-Cretaceous extinction (Benton et al. 2015).

After the retreat of the seaway, the region experienced a prolonged period of erosion and non-deposition. This resulted in an unconformity representing a hiatus of approximately 30 million years, with the formation of thick, distinctively-colored paleosols (fossil soils) on the exposed surfaces. Deposition recommenced in the late Eocene, approximately 37 Ma. The oldest rock units above the unconformity are (from oldest to youngest) the Chamberlain Pass Formation, the Chadron Formation, and the Brule Formation, all part of the widespread White River Group of Eocene–Oligocene age (~36–30 Ma; Benton et al. 2015).

Figure 4.6.1. Characteristic geology of Badlands NP. Photo by Cathy Bell, NPS.

The White River strata of the northern Great Plains are an important sequence of rocks, as they hold the best-preserved record of a climactic transition in the terrestrial rock record. 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).

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 volcaniclastics (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).

Because differential erosion across the region has removed some parts of the White River Group strata and left others in place, outcrops across the region preserve different segments of the EOT. The section of the White River Group exposed in Badlands NP, spanning the latest Eocene (37.1 Ma) to the early Oligocene (27.7 Ma), is one of the best-known parts of the sequence and it provides a great deal of information on this global climactic change (Benton et al. 2015).

The youngest strata that crop out in Badlands NP are the beds of the Sharps Formation, which overlies the White River Group strata. The Sharps Formation is usually classified as part of the

Arikaree Group of middle Oligocene age, although recent work may support assignment as an uppermost part of the White River Group based on lithological similarities (Benton et al. 2015).

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 USC 4321–4327); the Federal Land Policy and Management Act of 1976 (P.L. 94–579; 90 Stat. 27; 43 USC 1701–1782); and most recently the Omnibus Public Land Management Act of 2009 (PL 11–11, 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 NP depends on the condition of a single indicator, weathering/erosion; we considered weathering and erosion together because they work in tandem to break down and remove geologic material. Preservation of paleontological resources is also an issue of concern at Badlands NP (Graham 2008), and it is discussed in detail in the section on Paleontological Resources in this NRCA.

Indicator: Weathering and Erosion

Weathering and erosion together have been identified as an important geological resource issue within Badlands NP (Graham 2008; Benton et al. 2015). 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/erosion can be both natural and human-influenced.

The term “badlands” refers to regions of highly weathered and eroded land with sparse or no vegetation cover (Stoffer 2003). In badlands areas, the surface is dissected by gullies and ridges, which create a rugged topography that can be difficult to cross. “Badlands” (with a capital “B”), also called the Big Badlands and the White River Badlands, refers to the Badlands of western South Dakota including those protected within Badlands National Park (Benton et al. 2015).

In Badlands NP, weathering/erosion act together to impact geological resources. Weathering and erosion are gradually wearing away the surface of the Badlands, and they also cause mass wasting and resultant rockslides and landslides along trails and roads that are highly traveled by visitors. Mass wasting has significant impacts to visitor access to park resources as well as potential impacts to visitor safety (Stoffer 2003; Graham 2008; NPS 2015).

To assign a condition to this indicator, we used qualitative and quantitative information from ongoing and past weathering and erosion of bedrock within Badlands NP. The condition of weathering and erosion was also the overall geological resource condition.

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

Weathering caused by the actions of water is breaking down the rock that forms the Badlands. This weathered material is then removed from that surface by erosion via wind and water. Within the Badlands, much research has been done to quantify the amount of weathering and erosion that is occurring from natural processes.

Weathering and erosion are usually natural occurrences, and the unique topography and lack of vegetation that give Badlands NP its name are the direct result of this high rate of erosion (Benton et al. 2015). The strata are composed of easily eroded, poorly cemented rock, and much of the strata have high smectitic clay content. This type of clay shrinks and swells with water, and this shrink/swell behavior often results in a distinctive surface texture called "popcorn weathering." Vegetation tends to be sparse or nonexistent on these surfaces as it has a hard time gaining a foothold. This lack of vegetation in turn is a factor in increased rates of erosion (Benton et al. 2015).

Smectitic clays are often the result of the weathering of volcanic ash, and bentonite (a type of smectite) is specifically the result of the weathering of the glass shards in volcanic ash (Moore and Reynolds 1997). All of the strata exposed in the Badlands have some smectite, but it is found in higher concentrations in specific layers of the Cretaceous marine Pierre Shale as well as in parts of the Tertiary Chamberlain Pass and Chadron formations (Benton et al. 2015). As a result of its high smectite content, the Chadron Formation tends to weather into mounds with a popcorn surface texture as compared with the more cliff and spire-forming Brule Formation rocks whose contained volcanic ash was not altered to smectite to the same degree (Benton et al. 2015).

In many areas, geologists are not able to easily 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 is weathering and eroding 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 (Granger and Riebe 2014), and these types of studies have been done in Badlands NP (Leithauser et al. 2010).

Other less-technical methods of measuring weathering and erosion have also been used in the Badlands. In the 1950s, metal U.S. Geodetic Survey markers were emplaced flush with the ground surface in several places across the Badlands, and over the past 60+ years weathering and erosion have removed bedrock from around the markers. Thus, we can directly measure the amount of weathering and erosion that has occurred in this part of the Badlands since the markers were placed (Benton et al. 2015).

Recent work has focused on erosion rates that specifically impact fossil resources in Badlands NP. From 2010–2013, measurements of weathering and erosion of fossil-bearing strata and fossils at six sites 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 specific assessments of the current rates of weathering and erosion for strata within Badlands NP (Stetler 2014).

To determine whether current rates of weathering and erosion are consistent with historic natural conditions, we must have an estimate of what those conditions were. Erosion of the Badlands began approximately 660,000 years ago, when erosion began to dominate over deposition (Stamm et al. 2013). A combination of factors such as regional uplift or a reduction in regional base level, coupled with climate change, were likely triggers for this change to erosional conditions (Benton et al. 2015). Data are not available, however, for exactly how much weathering and erosion has occurred since then. Instead, we can use a qualitative measure based on the existence of the Badlands themselves to support the conclusion that extremely high rates of weathering and erosion are the historic natural conditions for this area over the past 660,000 years.

If there was no current weathering or erosion OR any current weathering and erosion was at a low level, we assigned the condition *Warrants Significant Concern*, meaning that the resource is behaving outside of historic natural conditions. If current weathering and erosion was moderate, we assigned the condition *Warrants Moderate Concern*, meaning that the resource is behaving somewhat outside of historic natural conditions. If current weathering and erosion has been occurring at a high rate, we assigned the highest level of condition, *Resource in Good Condition*, meaning that the resource is behaving within historic natural conditions (Table 4.6.1).

Table 4.6.1. Geologic resource condition categories for the amount of erosion.

Resource condition		Erosion
Warrants significant concern	🔴	Weathering and erosion significantly outside range of historic natural conditions.
Warrants moderate concern	🟡	Weathering and erosion somewhat outside range of historic natural conditions.
Resource in good condition	🟢	Weathering and erosion within range of historic natural conditions.

Measure of Weathering and Erosion: Qualitative Assessment of Anthropogenic Impact

While weathering and erosion are natural processes, they can also be exacerbated by human activities. The same properties of the bedrock at Badlands NP that allow it to weather and erode quickly also allow it to be impacted by the actions of humans.

In Badlands NP, visitors are causing erosion by hiking off trails and climbing hoodoos and other features. Several areas of heavy visitor use within the park are showing signs of human-caused erosion, including the Door and Window Trail complex, the butte behind the Cedar Pass Amphitheater and the buttes around the Fossil Exhibit Trail.

These examples of human-influenced erosion are important to note, and may result in a downgrading of the indicator condition for these select areas.

Quantitative measurements at established sampling points are critical for monitoring changes in erosion and weathering rates over time, but major changes may occur away from these points as well. In particular, abandoned infrastructure in locations susceptible to weathering and erosion could exacerbate naturally high erosion and weathering rates. We relied on expert opinion among park management to validate the indicator condition.

Data Sources

Much of the information summarized here was presented in a Geologic Resources Inventory Report prepared for the NPS (Graham 2008). Other sources of information include scientific papers and books that we identify throughout this assessment.

We used both quantitative and qualitative data on weathering and erosion at Badlands NP from scientific studies to assess indicator quality.

Quantifying Geological Resource Condition, Confidence, and Trend

Indicator Condition

To quantify geological resource condition and trend, we used quantitative and qualitative data, expert opinion, and reports of prior impacts to the resource, as described above.

Indicator Trend

Potential trend categories were *Improving*, *Unchanging*, or *Deteriorating*. Because of the long timescales that are involved in many geological 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 geological 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 Badlands this time period is 77 years (Graham 2008). 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 Geological 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 4.6.2).

Table 4.6.2. Summary of geological resource indicators and measures.

Indicator	Measure	Condition	Confidence	Trend	Condition rationale
Weathering/ erosion	Amount of weathering and erosion	Warrants moderate concern	Medium	Not available	Weathering and erosion of the rocks exposed at the surface of the Badlands are occurring at a very high rate of between 7.9 and 40 millimeters/year. This high rate of weathering and erosion is likely within historic natural conditions for the Badlands, but anthropogenic activity has led to exacerbated weathering and erosion in some locations. Condition was of *Moderate Concern*. Some on-site quantitative data were available, so confidence was *Medium*. Trend was *Not Available*.

4.6.4. Geological Resources Conditions, Confidence, and Trends

Weathering and Erosion

●

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

Condition

Because of the type of rock that crops out at Badlands National Park, weathering and erosion are major factors in the condition of geological resources. We used one measure of weathering and erosion to assess its condition: the amount of weathering and erosion occurring at the surface of the Badlands.

In 1950s, surveyors placed metal markers into rock outcrops in the Badlands, flush with the surface. Today, more than 60 years later, weathering and erosion have exposed these markers, and in some places they have even toppled over. Measurements of the amount of exposure of the survey markers demonstrates a rate of weathering and erosion of approximately 20 millimeters/year (Benton et al. 2015). In addition, 14C analyses done in Badlands NP using paleosols exposed in sod tables (low sod-covered mesas that are remnants of older floodplain surfaces) have given estimated rates of erosion of between 10–40 millimeters/year (Stoffer 2003; Leithauser et al. 2010).

In more recent research, six sites within the North Unit of Badlands NP were monitored for rates of weathering and erosion from 2010 to 2013. Various slope angles and directions were tested, as were different rock formations. Sediment movement was noted and measured after significant precipitation events, or monthly during the summer and bi-monthly for the rest of the year.

Precipitation data was also recorded for months when temperatures stayed above freezing. 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).

Based on these data, current weathering and erosion has been occurring at a high rate, and so we assigned the highest level of condition, *Resource in Good Condition*, meaning that the resource is behaving within historic natural conditions and awarded the measure 100 points (Table 4.6.1).

While erosion at the monitoring locations was within the natural range of variation, anthropogenic impact poses a substantial risk to geologic condition in other areas of the park. Buttes are so heavily trampled by visitor foot traffic that the shapes of the buttes have been significantly changed (R. Benton, personal communication, 27 June 2016). In June of 2015, several visitors were injured when a butte collapsed under their weight (NPS 2015). The actions of these visitors not only put their safety at risk, but also resulted in increasing the erosion to that butte.

In addition to direct erosion caused by visitors, human activities also cause increased erosion near roads. One example of this has been occurring around the Badlands Loop Road, which is the main highway that crosses the park. As the drainage system for the road has been repaired and replaced, culverts and waterlines have become abandoned and forgotten. These have then acted as conduits that bring water underneath the road and cause instability, accelerating the natural process of mass wasting (R. Benton, personal communication, 27 June 2016; R. Tupper 2016). Because the Badlands Loop Road is built on shrink/swell clays and active landslides, the NPS has invested over 5 million dollars just to keep the Cedar Pass portion of the road open for park visitors and farm to market traffic; future plans are to invest in other portions of the road for stabilization and safety (R. Benton, personal communication, 1 December 2016). Human activities and infrastructure maintenance issues reduced the condition to *Warrants Moderate Concern*.

Confidence

There were quantitative data available on the current rates of weathering and erosion of the surface of the Badlands, although there were no data available to quantitatively assess the historic natural conditions. We therefore we gave this measure a confidence rating of *Medium*.

Trend

Trend was *Not Available* for the measure of the amount of weathering and erosion, so trend was *Not Available* for the indicator of weathering and erosion.

Geological Resource Overall Condition

Table 4.6.3. Geological resources overall condition.

Indicators	Measures	Condition
Weathering and erosion	Amount of erosion	🟡

Condition

The overall geological resources condition was determined by the condition of weathering and erosion, as well as by anthropogenic impact. Together, the data and expert opinion placed the overall geological resource condition for Badlands National Park in the category, *Warrants Moderate Concern*

Confidence

Confidence was *Medium* for geological resources.

Trend

Trend was *Not Available*.

4.6.5. Stressors

Potential stressors to geological resources include the timing and amounts of precipitation events. As demonstrated by Stetler (2014), individual heavy precipitation events can significantly increase the rate of short-term weathering and erosion of fossil-bearing strata. 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 would in turn increase the impact of weathering and erosion on geological resources (Amberg et al. 2012).

A second stressor to geological resources is the possibility for future expansion of park infrastructure such as trails and roads into areas with a high potential for weathering and erosion. These types of expansions can increase the likelihood that visitors may cause weathering and erosion by walking off-trail in the newly accessible areas. Road and building construction may cause increased erosion by changing the ways that surface and groundwater moves, or by introducing water into areas where it was not found naturally.

4.6.6. Data Gaps

One data gap was recognized for geological resources at Badlands NP: the lack of data to determine the historical reference condition for erosion rates for the Badlands.

Acknowledgments

- Rachel Benton (NPS)

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4.7. Paleontological Resources

4.7.1. Background and Importance

Fossil at Badlands NP. Photo by NPS.

The principal mission of the National Park Service (NPS) 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. Fossils are known to occur in 260 NPS units and are the main resource showcased in 13 of those parks, including Badlands NP (NPS 2016). The fossil resources of Badlands NP include the richest accumulations of terrestrial vertebrate fossils of late Eocene and early Oligocene age in North America, if not the world (Benton et al. 2014).

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.

Fossil at Badlands National Park. Photo by Dakota McCoy, NPS (2013).

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.

Regional Context

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 Badlands National Park are those of the Cretaceous Pierre Shale and the overlying Fox Hills Formation. These marine strata were deposited by the Cretaceous Interior Seaway when it covered much of the center of the continent. Their contained faunas mostly consist of invertebrate fossils such as bivalves and ammonites, as well as occasional fishes and marine reptiles. Based on the age of these fossils, the Cretaceous Interior Seaway persisted in the region until about 67 Ma (millions of years ago), just prior to the end-Cretaceous extinction (Benton et al. 2015).

After the retreat of the seaway, the region experienced a period of erosion of existing sediments as well as non-deposition (Benton et al. 2015). This resulted in an unconformity representing a hiatus of approximately 30 million years, with the formation of thick, distinctively colored paleosols (fossil soils) on the exposed surfaces. Deposition recommenced in the late Eocene, approximately 37 Ma, with the Chamberlain Pass Formation, the middle Chadron Formation, and the overlying Brule Formation, all part of the widespread White River Group of Eocene–Oligocene age (~36–30 Ma; Benton et al. 2015).

The White River strata of the northern Great Plains are an important sequence of rocks, as they hold the best-preserved record of a climactic transition in the terrestrial rock record. 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).

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Because differential erosion across the region has removed some parts of the White River Group strata and left others in place, outcrops across the region preserve different segments of the EOT. The section of the White River Group exposed in Badlands NP, spanning the latest Eocene (37.1 Ma) to the early Oligocene (27.7 Ma), is one of the best-known parts of the sequence and it provides a great deal of information on this global climactic change (Benton et al. 2015).

The youngest strata that crop out in Badlands NP are the beds of the Sharps Formation, which overlies the White River Group strata. The Sharps Formation is usually classified as part of the Arikaree Group of middle Oligocene age, although recent work may support assignment as an uppermost part of the White River Group based on lithological similarities (Benton et al. 2015).

The term “badlands” refers to regions of weathered and eroded land with sparse or no vegetation cover (Stoffer 2003). In badlands areas, the surface is dissected by gullies and ridges, which create a rugged topography that can be difficult to cross. “Badlands” (with a capital “B”), also called the Big Badlands and the White River Badlands, refers to the Badlands of western South Dakota including those protected within Badlands NP (Benton et al. 2015).

Badlands NP was established in large part to protect fossil resources (Graham 2008). Abundant and diverse flora and fauna are well known from the White River Badlands, and these fossils have played a large role in our understanding of the evolution and adaptation of plants and animals to climate change (Benton et al. 2015). Numerous vertebrate taxa as well as scarce plant fossils, petrified wood, and invertebrates have been described from these strata. While the mammalian fossils are the most well studied, fossils of bony fish, amphibians, turtles, squamates, crocodiles and alligators, and birds are also known from the Badlands (Benton et al. 2015).

Among the smaller mammalian fossils described from the Badlands are marsupials, insectivorous mammals, lagomorphs, and rodents. The carnivores include creodonts, nimravids (a group similar to but unrelated to modern felids), amphicyonids (often called “bear-dogs”), canids, bears, and mustelids. Ungulates are also well represented, with both artiodactyls (even-toed ungulates) and perissodactyls (odd-toed ungulates) known. Artiodactlys include both browsers and grazers, with differences in diet reflected in the dentition. Suids such as entelodonts (often called "hell-pigs") have been described in great detail, and several other suid families are known from the Badlands as well. Anthracotheres, a group of primitive artiodactyls that share similarities in habit and morphology with modern hippos, are known, as are oreodonts (small browsers that are ubiquitous in White River deposits), camels, and hypertragulids and leptomerycids (two groups of hornless ruminants). The perissodactyls are represented by tapirs, equids, rhinoceroses, and the giant brontotheres, which became extinct at the Eocene–Oligocene boundary (Benton et al. 2015).

4.7.2. Paleontological Resources Standards

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 USC 4321–4327); the Federal Land Policy and Management Act of 1976 (P.L. 94–579; 90 Stat. 2743; 43 USC 1701–1782); and most recently, the Omnibus Public Land Management Act of 2009 (PL 11–11, 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 in Badlands NP depends on the condition of a single indicator: fossil loss.

Indicator: Fossil Loss

As non-renewable resources, the loss of fossils from NPS 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 affect fossil resources (Press and Siever 2001; Benton et al. 2015). Weathering and erosion are important factors in the health of fossil resources at Badlands NP. Although weathering and erosion are primarily seen in a negative light, these natural processes are also important forces in liberating fossils from their enclosing rock. It should be remembered that without this exposure by weathering and erosion, fossils would not be available for collection and study. Poaching of fossils from park units is a human-caused impact that also results in the loss of fossil resources.

To assign a condition to this indicator, we used qualitative and quantitative 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: Amount of Weathering and Erosion of Rock (millimeters/year)

In Badlands NP, weathering and erosion act together to impact paleontological resources. Fossils are continually being exposed as a result of weathering and erosion, and this can result in physical degradation of the fossils, damage due to accidental or intentional breakage, and theft (Benton et al. 2015; Stetler 2014).

Weathering and erosion are occurring constantly at Badlands NP due to the nature of the rock that crops out in the area. The strata are composed of easily eroded, poorly cemented sedimentary rock. Much of the strata have high clay content, and many of the layers have a specific type of clay called smectite, which shrinks and swells with water. This shrink/swell behavior often results in a distinctive surface texture called "popcorn weathering," and vegetation tends to be sparse or nonexistent on these surfaces as it has difficulty establishing. This lack of vegetation, in turn, is a factor in increased rates of erosion (Benton et al. 2015).

Smectitic clays are often the result of the weathering of volcanic ash, and bentonite (a type of smectite) is specifically a product of the weathering of the glass shards in volcanic ash (Moore and Reynolds 1997). All of the strata exposed in the Badlands have some smectite, but it is found in higher concentrations in specific layers of the Cretaceous marine Pierre Shale as well as in parts of the Tertiary Chamberlain Pass and Chadron formations (Benton et al. 2015). As a result of its high smectite content, the Chadron Formation tends to weather into mounds with a popcorn surface texture as compared with the more cliff and spire-forming Brule Formation rocks whose contained volcanic ash was not altered to smectite to the same degree (Benton et al. 2015).

Weathering and erosion are natural occurrences, and the unique topography and lack of vegetation that give Badlands NP its name is the direct result of the high rate of erosion of the Badlands (Benton et al. 2015). Though weathering and erosion are responsible for the existence of the Badlands, they are also responsible for a great deal of damage to park resources such as roads, trails, and cultural and paleontological sites. Within the Badlands, some research has been done to quantify the amount of weathering and erosion that is occurring.

In many areas, geologists are not able to easily 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 is weathering and eroding 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 (Granger and Riebe 2014), and these types of studies have been done in Badlands NP (Leithauser et al. 2010).

Other less technical methods of measuring weathering and erosion have also been used in the Badlands. In the 1950s, metal U.S. Geodetic Survey markers were emplaced flush with the ground surface in several places across the Badlands, and over the past 60+ years weathering and erosion have removed bedrock from around the markers. Thus, we can directly measure the amount of weathering and erosion that has occurred in this part of the Badlands since the markers were placed (Benton et al. 2015).

Recent work has focused on erosion rates that specifically impact fossil resources in Badlands NP. 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.

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: Amount 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 on many forms. For example, the casual park visitor may pick up a piece of fossilized bone during a hike along a park trail. In an area such as the Badlands, where fossils can easily be seen along well-traveled trails, visitors may believe 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 NPS 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 2004–2014, 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.

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

<u>Data Sources</u>

Some of the information summarized here was presented in a Geologic Resources Inventory Report prepared for the NPS (Graham 2008). 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 Badlands this time period is 77 years (Graham 2009). 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 paleontologic resources indicators and measures.

Indicator	Measure	Condition	Confidence	Trend	Condition Rationale
Fossil loss	Amount of weathering and erosion	Warrants significant concern	High	Not available	Measured rates of weathering and erosion in Badlands NP were high, averaging from 7.9 to 40 millimeters/year. These rates have been demonstrated to be high enough to cause serious damage in a relatively short amount of time. This assessment placed amount of weathering and erosion in the *Warrants Significant Concern* category.
	Fossil poaching and vandalism	Warrants significant concern	High	Not available	Reports of fossil poaching and vandalism in Badlands NP 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

Fossil Loss

●

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

Condition

Because fossils are non-renewable resources, any factors that impact them have importance in the assessment of the resource condition. We used two measures of fossil loss to assess its condition: the amount of erosion occurring at the surface of the Badlands and thus potentially impacting fossils, and the occurrences of fossil poaching and vandalism within the park.

In the 1950s, surveyors placed metal markers into rock outcrops in the Badlands, flush with the surface. Today, more than 60 years later, weathering and erosion have exposed these markers, and in some places they have even toppled over. Measurements of the amount of exposure of the survey markers demonstrate a rate of weathering and erosion of approximately 20 millimeters/year (Benton et al. 2015). In addition, 14C analyses done in Badlands NP using paleosols exposed in sod tables (low sod-covered mesas that are remnants of older floodplain surfaces) have given estimated rates of erosion of between 10–40 millimeters/year (Stoffer 2003; Leithauser et al. 2010).

In more recent research, six sites within the North Unit of Badlands NP were monitored for rates of weathering and erosion from 2010 to 2013. Various slope angles and directions were tested, as were different rock formations. Sediment movement was noted and measured after significant precipitation events, or monthly during the summer and bi-monthly for the rest of the year. Precipitation data was also recorded for months when temperatures were above freezing. 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).

These data give us rates of erosion over at the past 60 years, and show the recent and current amount of weathering and erosion occurring within Badlands NP. Based on these data, the average rate of weathering and erosion in Badlands National Park ranges from 7.9 to 40 millimeters/year.

To understand the effects of weathering and erosion on fossil resources, we must look at the fossils themselves as well as the rock they are weathering from. Fossils can have varying levels of permineralization (a type of fossilization where minerals precipitate into pore spaces within a bone or piece of wood), which affects how quickly they degrade once they are exposed at the surface. Different skeletal elements will also respond to weathering at different rates. As a result, quantifying the levels at which weathering of fossils becomes significant is can be difficult.

The recent 18-month-long study by Stetler (2014) mentioned above measured the current rates of weathering and erosion of fossil-bearing strata within Badlands NP. This study also looked specifically at the rates that fossil bone degrades once it becomes exposed to the elements. The study looked at fossil localities in two different rock units: four localities in the Scenic Member of the Brule Formation, and one locality in the Peanut Peak Member of the Chadron Formation. The localities were scattered across the North Unit of the park in order to take into account climactic variation as well as differences in lithology.

At each of these five localities vertebrate fossils were found on the surface at the beginning of the study, and their positions and conditions were noted and photographed. Over the course of the study the amount of exposure of the fossils was recorded, as were the conditions of the fossils themselves (Stetler 2014).

This study found that, in some instances, fossils were completely destroyed within a single season. In other cases, fossils became more exposed as weathering and erosion proceeded but the fossils themselves experienced minimal damage. In general, larger fossils with denser bone such as intact turtle shells were damaged less by the weathering process than were smaller fossils such as limb bones and skulls of oreodonts and rodents (Stetler, 2014).

This study demonstrates that the rates of weathering and erosion measured in Badlands NP are high enough to cause damage to vertebrate fossils, especially smaller and more fragile fossils (Stetler, 2014).

Based on our classification of significant weathering and erosion as that which is occurring at a rate that negatively impacts fossil resources, we assigned a condition of *Warrants Significant Concern* for the measure of weathering and erosion of the Badland surface and awarded the measure 0 points.

Fossil poaching and vandalism occurrences was the second measure used to assess the condition of fossil loss. In Badlands NP between 2011 and 2014, one to three formal cases per year of fossil poaching were prosecuted (Benton et al. 2015). Many more fossils were undoubtedly removed illegally, and 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).

Badlands NP is extremely proactive in managing paleontological resources to lessen the impacts of fossil poaching and vandalism. A detailed fossil locality database is used to keep track of all localities known within the park, and this helps park paleontologists and law enforcement officers monitor areas that have a high risk of fossil poaching. In addition, Badlands NP utilizes a Visitor Site Report form that encourages visitors to report any fossils they might find within the park. These Site Reports allow visitors to participate in the preservation of fossil resources by bringing them to the attention of park paleontologists, with the hope that they will report a fossil site rather than collect illegally from the site. Badlands NP receives between 100 and 150 reports from visitors each year (Benton et al. 2014). Two incidents of fossil poaching have been recorded by law enforcement so far in 2016 (R. Benton, personal communication, 29 June 2016).

Even with the measures that are being taken to stop or mitigate fossil poaching and vandalism within Badlands NP, 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; as the average score of both measures was 0, this supports a condition of *Warrants Significant Concern* for the indicator of fossil loss.

Confidence

There were quantitative data available on the rates of weathering and erosion of the surface of the Badlands, and therefore we gave this measure a confidence rating of *High*.

There was also 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 *High*.

Trend

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

Paleontological Resource Overall Condition

Table 4.7.4. Paleontological resources overall condition.

Indicators	Measures	Condition
Fossil loss	- Amount of weathering and erosion - Fossil poaching and vandalism	🔴

Condition

The overall paleontological resources condition was determined by the condition of the single indicator, fossil loss. Fossil loss was given a condition of *Warrants Significant Concern*, which placed the overall paleontological resource condition for Badlands National Park in the category *Warrants Significant Concern*.

Confidence

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

Trend

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

4.7.5. Stressors

Potential stressors to paleontological resources include the timing and amounts of precipitation events. As demonstrated by Stetler (2014), individual heavy precipitation events can significantly increase the rate of short-term weathering and erosion of fossil-bearing strata. Climate change may result in an increase in the numbers of these extreme precipitation events for Badlands NP, and this would in turn increase the impact of weathering and erosion on fossil resources (Amberg et al. 2012).

A second stressor to paleontological resources is the possibility for future expansion of park infrastructure such as trails, roads, and buildings into areas with a high potential for fossil resources. These types of expansions can physically impact fossil resources, and they can also increase the likelihood that vertebrate fossils may be encountered by visitors in areas where there is no oversight of visitor activities.

A third stressor to paleontological resources in Badlands NP is any potential increases in general visitorship. An increase in the number of visitors can result in increases of incidents of fossil poaching and vandalism, as more visitors overall will come into contact will fossil resources.

4.7.6. Data Gaps

No data gaps were recognized for paleontologic resources at Badlands NP.

Acknowledgments

- Rachel Benton (NPS)

4.7.7. Literature Cited

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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 Badlands National Park*. The authors of the Badlands NP 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 in the Indicators and Measure section in 4.8.2 Methods.

Wildflower in Badlands National Park. Photo by Ty Karlovetz, NPS (2011).

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. 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 reality that there have been fundamental changes in the disturbance regimes, such as climate, fire, and large ungulate grazing, 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.

Badlands National Park (BADL) was established in 1939 as a National Monument and in 1978 became a National Park with a mission to protect and preserve 242,756 acres of rugged badlands, mixed-grass prairie, and rich fossil deposits. The vegetation is a mosaic of sparsely vegetated badlands, native mixed-grass prairie, woody draws, and exotic grasslands. Vegetation monitoring began at BADL in 1998 by the Northern Great Plains Fire Ecology Program (NGPFire; Wienk et al. 2011). The Northern Great Plains Inventory & Monitoring Program (NGPN) began vegetation monitoring at BADL in 2011 (Ashton et al. 2012). Vegetation monitoring protocols and plot locations were chosen to represent the entire park and to coordinate efforts with the Northern Great Plains Fire Ecology Program (FireEP). A total of 127 plots were established by NGPFire and NGPN in BADL and the combined sampling efforts began in 2011(Ashton et al. 2012). 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 BADL, we explore the following questions:

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

- How do trends in grassland condition relate to climate, fire history, and the presence of bison?
- What, if any, rare plants were found in BADL long-term monitoring plots?

4.8.2. Methods

Two different methods and protocols have been used to monitor long-term vegetation plots at BADL since 1997: the NGPN monitoring protocol (Symstad et al. 2012a, b) and the Fire Monitoring Handbook (NPS 2003). All monitoring plots discussed in this paper are located in the north unit of BADL. Below, we briefly describe both 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).

NGPN and NGPFire Monitoring Plots 2011-2015

The NGPN and NGPFire implemented a survey to monitor plant community structure and composition in BADL using a spatially balanced probability design (Generalized Random Tessellation Stratified [GRTS]; Stevens and Olsen 2003, 2004). Using a GRTS design, NGPN selected 100 randomly located sites within BADL to become Plant Community Monitoring plots (PCM plots; Figure 4.8.2). The NGPN visits 20 PCM plots every year using a rotating sampling scheme where 10 sites were visited in the previous year and 10 sites are new visits. After 5 years (2011-2015), 50 PCM plots were visited at least twice during mid-June. With the current sampling scheme, it will take the NGPN 20 years to monitor all 100 plots. 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 using the same GRTS sampling schema focused in active burn units (Fire FPCM plots). From 2011-2015, 32 FPCM plots were established. A total of 84 plots were established by NGPFire and NGPN from 2011-2015.

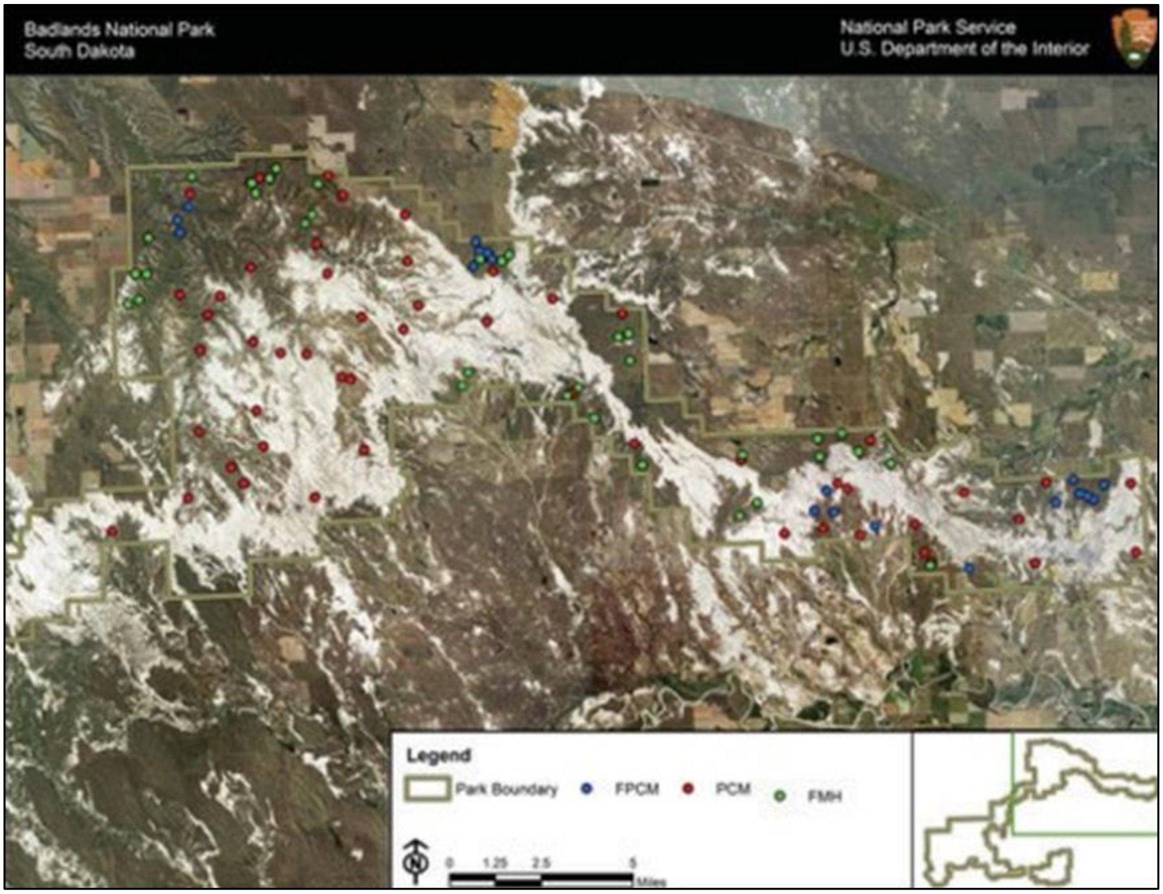

Figure 4.8.1. Map of Badlands National Park plant community monitoring plots, 1998-2015 (Ashton and Davis 2016). Data has been collected from 127 monitoring plots in the park. PCM plots (red) were established by the Northern Great Plains Inventory & Monitoring Program (NGPN) and FPCM plots (blue) were established by the Fire Effects Program (NGPFire) between 2011 and 2015. Additional 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 4.8.3). Data on ground cover, herb-layer height ≤ 2 meter, and plant cover were collected on two 50 meter transects (the long sides of the plot) using a point-intercept method (Figure 4.8.4). 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. 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 20 NGPN 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).

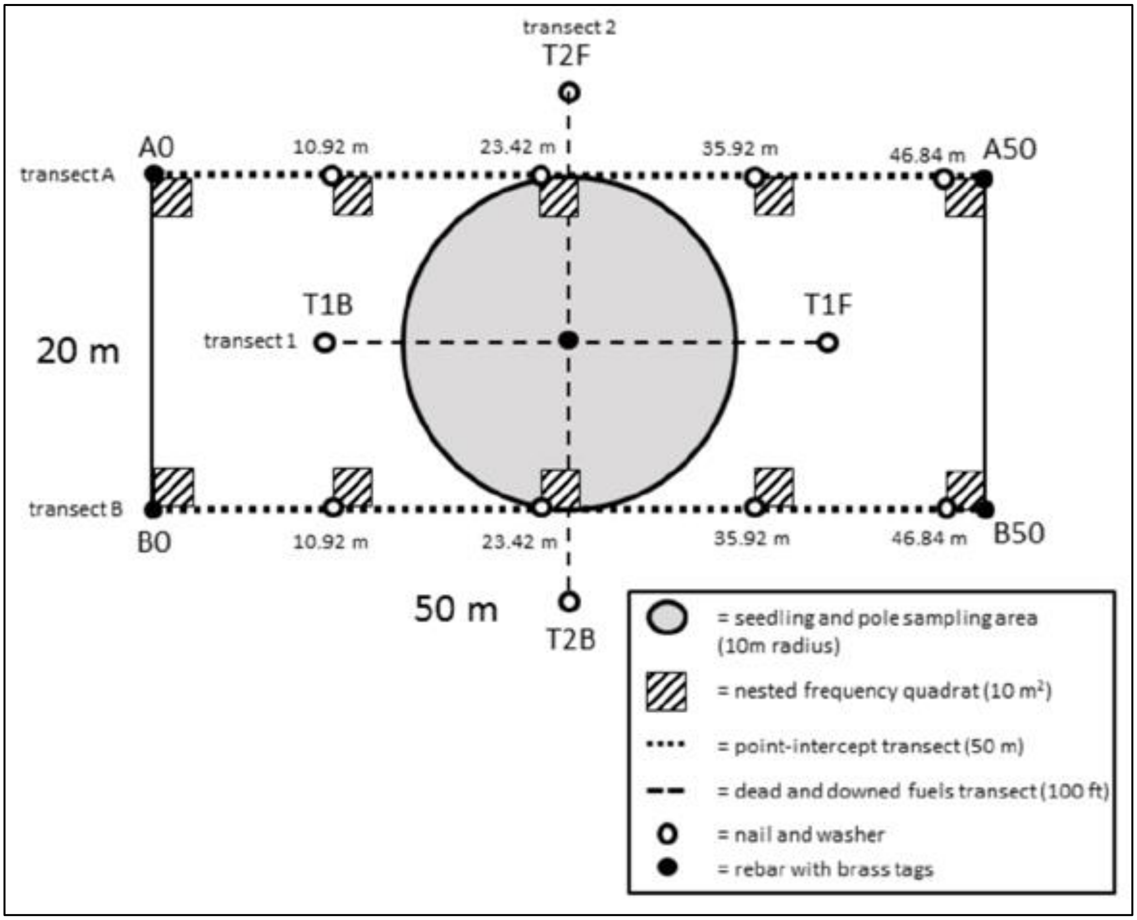

Figure 4.8.2. Long-term monitoring plot layout used for sampling vegetation in Badlands National Park (Ashton and Davis 2016).

Figure 4.8.3. Images of the Northern Great Plains Inventory & Monitoring vegetation crew using point-intercept (left and center panel) and quadrats (right panel) to document plant diversity and abundance (Ashton and Davis 2016).

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 4.8.3). Six PCM plots had trees close enough to the plot to warrant searching for seedlings, but we found seedlings in only one plot. BADL_PCM_0106 had 11 narrowleaf willow (*Salix exigua*) seedlings in 2015.

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). 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 Badlands National Park as part of the early detection and rapid response program within the Northern Great Plains Network.

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

* Species of management concern to Badlands National Park.

Table 4.8.1 (continued). Exotic species surveyed for at Badlands National Park as part of the early detection and rapid response program within the Northern Great Plains Network.

Scientific name	Common name
Salvia aethiopis	Mediterranean sage
Ventenata dubia	African wiregrass
*Eleagnus angustifolia**	Russian olive
*Euphorbia esula**	Leafy spurge
*Falcaria vulgaris**	Sickleweed
*Poa bulbosa**	Bulbous bluegrass
*Potentilla recta**	Sulphur cinquefoil
*Rhaponticum repens**	Russian knapweed
*Sideritis montana**	Mountain ironwort
*Tamarix spp.**	Tamarisk
*Tanacetum vulgare**	Common tansy
*Thymelaea passerine**	Spurge flax

* Species of management concern to Badlands National Park.

Other Monitoring Plots (1997-2015)

In 1997, NGPFire began monitoring plots within BADL 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 was collected along the two 50 meter sides. For each live tree with a DBH > 15 centimeters located within the 0.1 hectare plot, the species and DBH were recorded. The densities of smaller trees ($2.54 \leq \text{DBH} \leq 15$ 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. A total of 43 plots were monitored using these methods. Hereafter, we refer to these plots as Fire Monitoring Handbook (FMH) plots. These FMH plots are being retired after 10 years of monitoring is completed (e.g., the rebar will be removed).

Indicators and Measures

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 Badlands NP 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: 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).

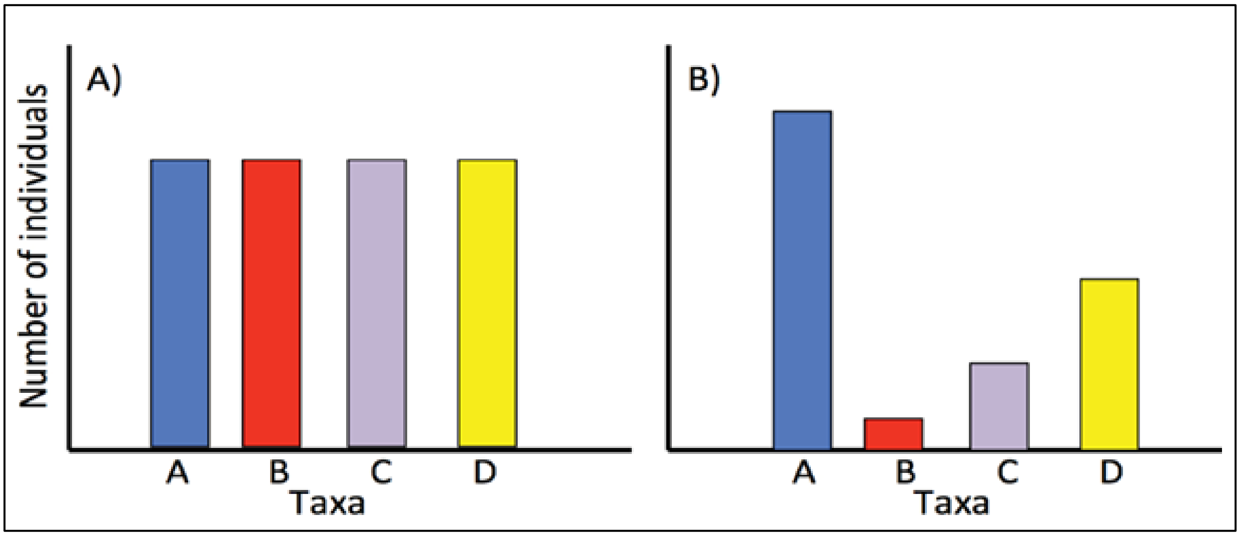

Figure 4.8.4. Illustration for describing taxa evenness. Taxa evenness is high if individuals are A) distributed similarly among taxa, and low if B) distributed unequally among taxa.

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 Badlands National Park 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 (see Figure 4.8.10; F1, 551 = 36.5, P < 0.0001). The presence of annual bromes in mixed grass prairie is associated with decreased productivity and altered nutrient cycling (Ogle et al. 2003).

Data Management and Analysis

We used FFI (FEAT/FIREMON Integrated; http://frames.gov/ffi/) as the primary software. 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). Most often, linear mixed models were used to test for significant responses where plot was considered a random factor.

Plant life forms (e.g., shrub, forb) were based on definitions from the USDA Plants Database (USDA-NRCS 2015). When only a plant genus was confirmed, the plant life form was assigned only when all species in that genus were the same life form. If any species present in the park within that genus is exotic, the genus was classified as exotic for analyses. The conservation status ranks of plant species in Nebraska is determined by the South Dakota Natural Heritage Program (SDNHP). For the purpose of this report, a species was considered rare if its conservation status rank was S1, S2, or S3 (Table 4.8.2). Definitions of state and global species conservation status ranks. 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/conservatio-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 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 J' 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. 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 Interior 2 NE, SD, US weather station were downloaded from NOAA's online database (NOAA 2015). A fire history map was compiled for BADL and cross-referenced with plot locations. For each plot visit, we determined the number of years since it burned and the number of recorded fires.

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 of the study 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 (See section on Indicators and Measures of Vegetation). 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 data. When this is the case, we refer to these as "To be determined", or TBD, and estimate condition based on our professional judgment.

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 confidence based on the results presented by Ashton and Davis (2016). The symbols used here indicate condition, confidence, and trend are likewise the same described in Chapter 3.

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

Status & Trends in Community Composition and Structure of BADL Prairies

There are 634 plant species on the BADL species list and we found 357 plant species in monitoring plots from 1998-2015 at BADL (Appendix A). Graminoids, which includes grasses, sedges, and rushes, accounted for most of the vegetative cover at BADL, but forbs, shrubs, and subshrubs (defined as a low-growing shrub usually under 0.5 meter) were also present (Figure 4.8.5). We found 76 exotic plant species at BADL, all of which were forbs or graminoids. Exotic graminoids were particularly abundant (Figure 4.8.5). The shrubs and subshrubs were all native species. We did not find any targeted exotic plants (Table 4.8.2).

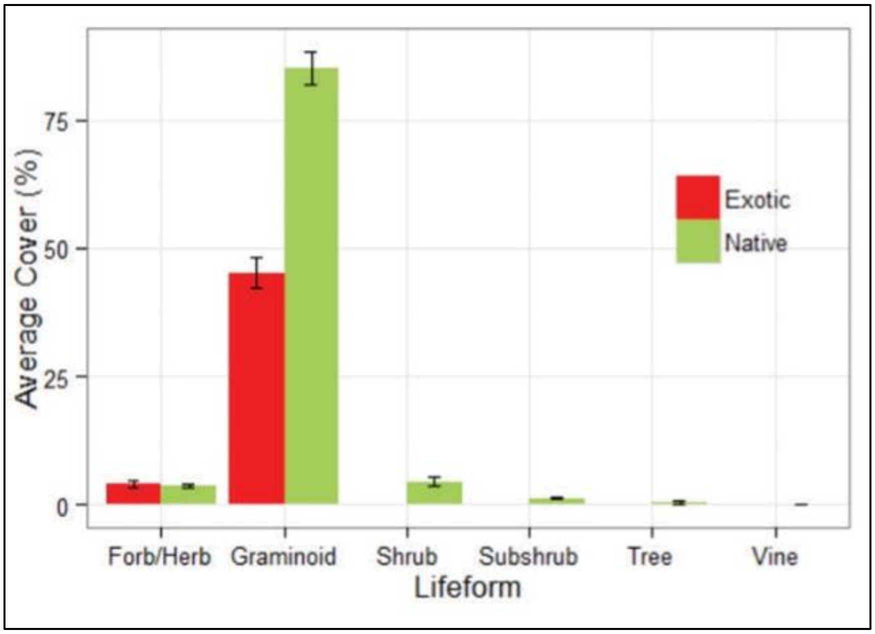

Figure 4.8.5. Average cover of native (green) and exotic (red) plants recorded in monitoring plots in Badlands National Park (1998-2015) (Ashton and Davis 2016). Absolute cover can be greater than 100% because the point-intercept methods records layers of overlapping vegetation.

Western wheatgrass (*Pascopyrum smithii*) was the most abundant native grass and averaged over 40% absolute cover (Figure 4.8.6). Japanese brome (*Bromus japonicus*), Kentucky bluegrass (*Poa pratensis*), and yellow sweet clover (*Melilotus officinalis*) were the most pervasive exotics at BADL. The relative cover of these and other exotic plant species has remained high since 1998, averaging 32.5 ± 1.1 % (mean ± one standard error; Figure 4.8.7). In more recent years, 2011-2015, cover was 28.8± 1.5 % but this decline is not statistically significant. Exotic species are widespread across the entire park (Figure 4.8.8). Maps of Kentucky bluegrass, Japanese brome, and yellow sweet clover are provided in Appendix B.

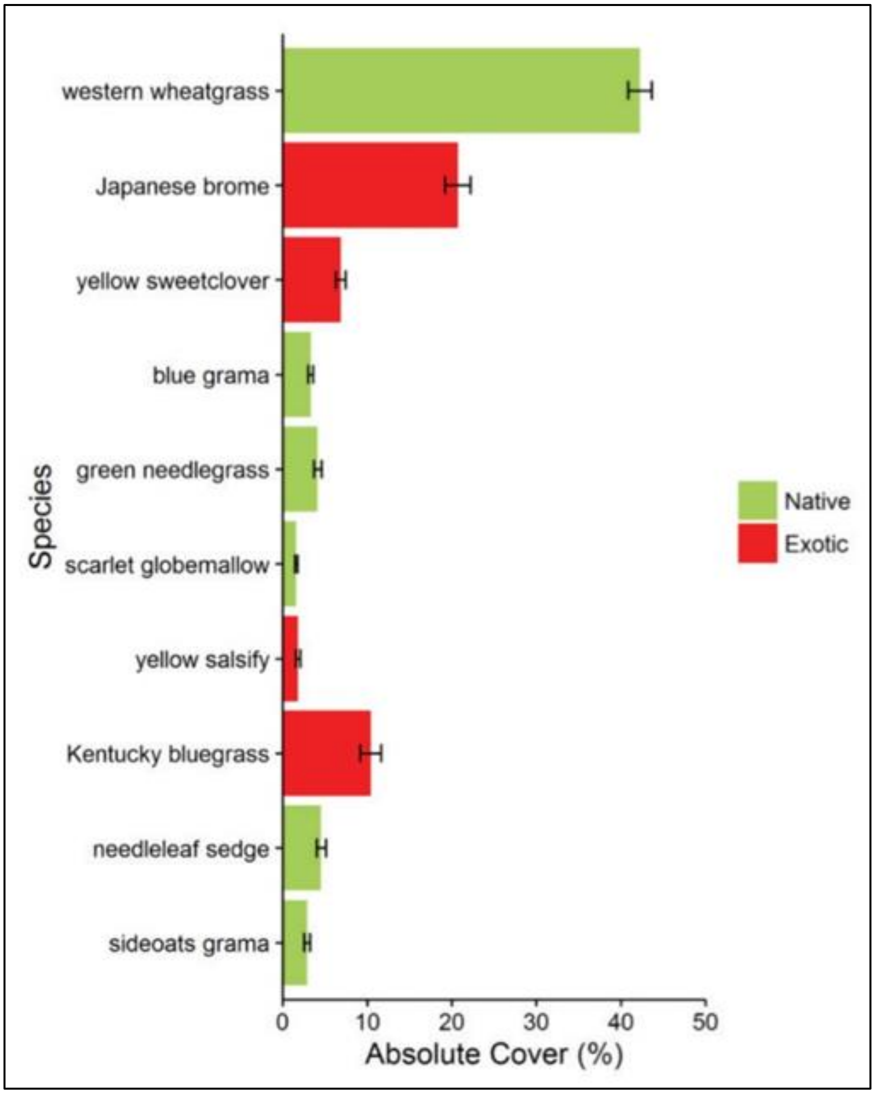

Figure 4.8.6. The average absolute cover of the 10 most common native (green) and exotic (red) plants recorded at Badlands National Park (1998-2015) (Ashton and Davis 2016). Bars represent means ± one standard error.

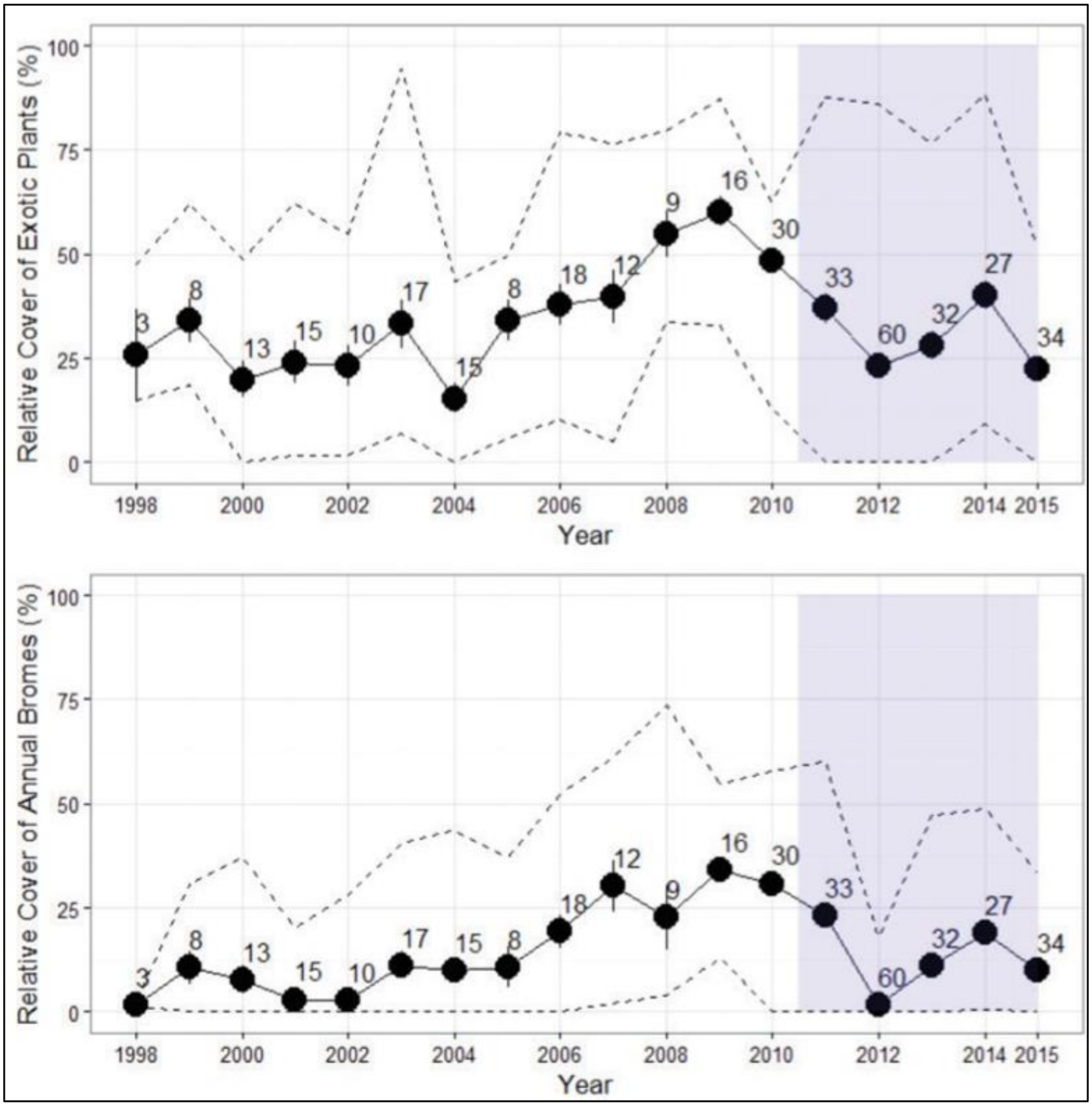

Figure 4.8.7. Trends in the relative cover of exotic plants (top) and annual bromes (bottom) in Badlands National Park from 1998 to 2015 (Ashton and Davis 2016). Points represent mean ± one standard error and sample size is to the right of the point. Years with fewer than 3 monitoring plots were excluded 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.

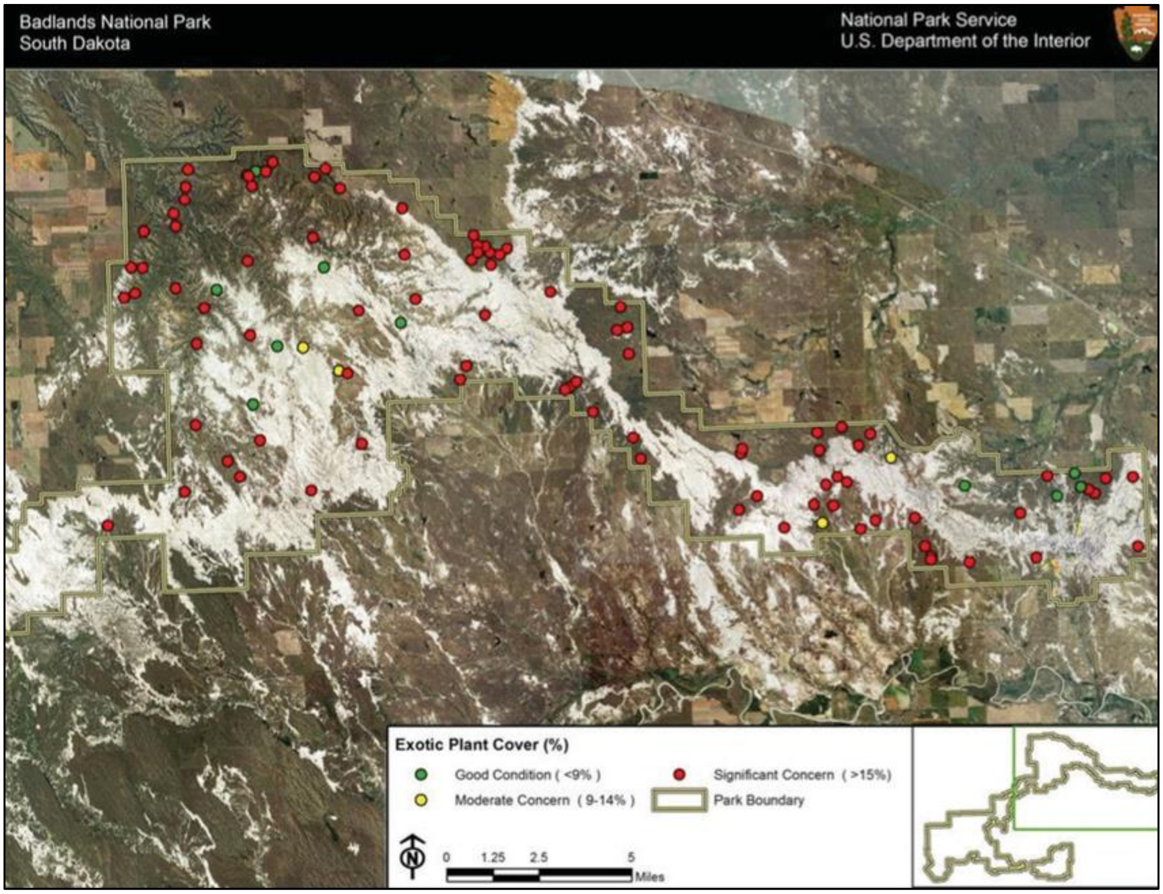

Figure 4.8.8. Map of exotic plant cover in Badlands National Park (Ashton and Davis 2016). Colors indicate the percent cover of exotic plants at a site averaged across all site visits.

Japanese brome, the most abundant exotic plant in BADL, is an Eurasian annual grass that has been a part of the Northern Great Plains landscape for more than a century, but its 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). While the cover of Japanese brome has varied over time in BADL (Figure 4.8.7) there is no evidence that it has been increasing. From 1998-2015, the average relative cover of annual bromes was 14.3 ± 0.8 % and the average for the last 5 years was 11.1 ± 1.0 %. Data from parks across the Northern Great Plains show that increasing annual brome relative cover is associated with reduced native species richness (Figure 4.8.9). Reducing the cover of annual bromes presents a major challenge for the park, as it has for the past 15 years.

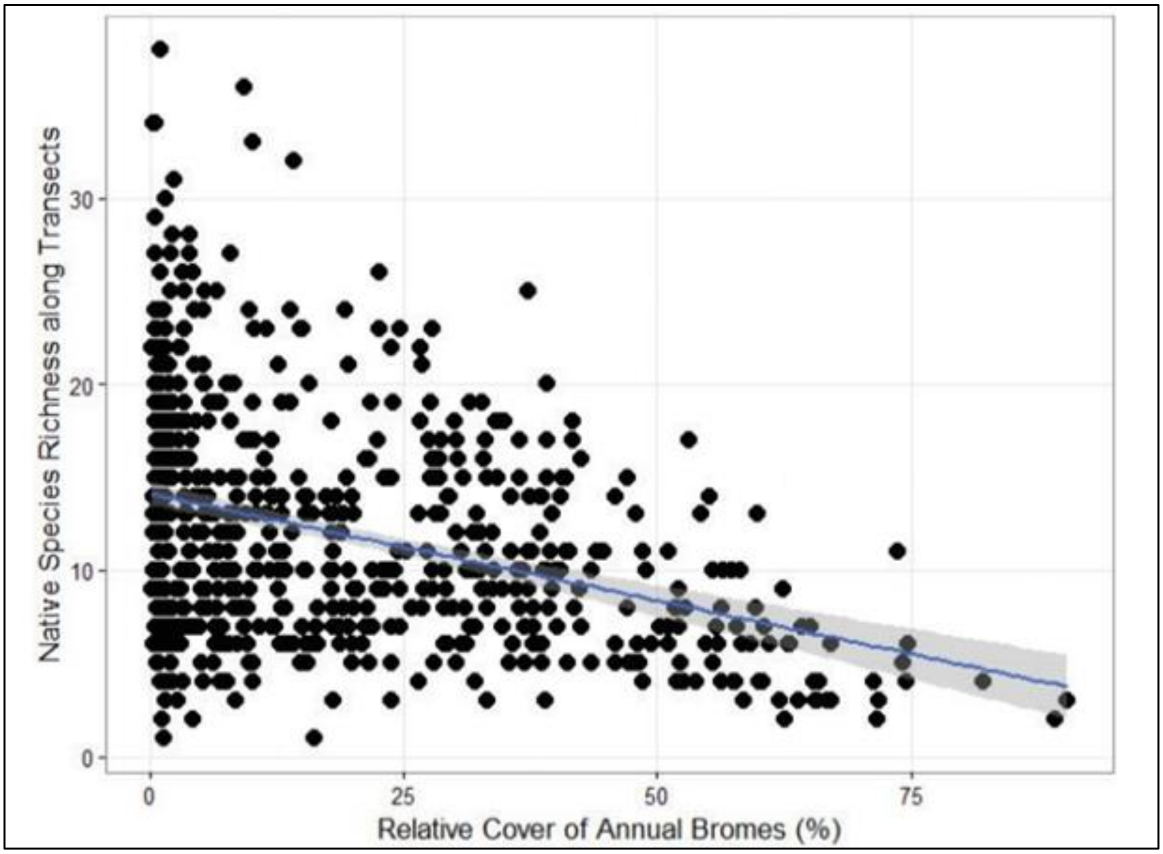

Figure 4.8.9. The relationship between native species richness and the relative cover of annual bromes in long-term monitoring plots in national park units of the Northern Great Plain (1998-2015) (Ashton and Davis 2016).

Species Richness, Diversity, and Evenness

One of the ways for the NPS to measure how effectively the mission of "preserving ecological integrity" is being accomplished is to examine trends in native plant diversity and evenness within their 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 Badlands National Park from 1998 to 2015. Values represent means ± one standard error.

Richness category	Point-Intercept (1988-2011; N = 127)	1m^2 Quadrats (2011-2015; N = 93)	10m^2 Quadrats (2011-2015; N = 93)
Species richness	14.7 ± 0.4	8.5 ± 0.4	14.2 ± 0.5
Native species richness	10.6 ± 0.4	6.1 ± 0.3	10.4 ± 0.4
Exotic species richness	4.3 ± 0.2	2.5 ±0.2	3.8 ± 0.2
Granimoid species richness	7.0 ± 0.3	3.1 ± 0.2	4.5 ± 0.2
Forb species richness	7.2 ± 0.2	5.2 ± 0.3	9.0 ± 0.4

While there was some variation across sites, the plots we visited in BADL tended to have a moderate 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 dog disturbance, and weather fluctuations (Symstad and Jonas 2011). In BADL, 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 that can vary so much spatially and temporally, 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 vary between 3 and 15 species per square meter over the course of 30 years (Symstad and Jonas 2014). Compared to this, the BADL average of 6 native species per square meter (Table 4.8.3) is within the natural range. However, native species richness is spatially variable. Some sites, such as PCM_0027, are on sparsely vegetated badlands and average only 1.6 native species per square meter (Figure 4.8.10). One of the most diverse plots, PCM_0018, is on a ridge north of the Sage Creek Rim Road. It has a mix of native shrub and grassland habitat and averages 14 species per square meter (Figure 4.8.10).

Figure 4.8.10. Photographs of long-term monitoring plots PCM_0027 and PCM_0018. PCM_0027 (left) has low plant diversity because it is in unvegetated badlands. Plot PCM_0018 (right) is a prairie site and has a large diversity of native plant species.

We did not find any trends over time in species richness or evenness (Figure 4.8.11). Native diversity in 1 meter^2 quadrats was fairly similar from 2011-2015; it ranged from a low in 2012 of 4.7 ± 0.54 (a drought year) to a high of 6.8 ± 0.56 in 2014 (a wet year). We have a longer record of native richness from point-intercept data (Figure 4.8.11; top). From 1998-2015, we recorded an average between 5 and 12 native species. There was no trend in Peilou’s Index of Evenness, J’, which measures how even abundances are across taxa (Figure 4.8.11). A large variation in richness and evenness across sites within the park and from year-to-year contribute to a large range of values (dashed lines in Figure 4.8.11) and makes detecting long-term trends difficult.

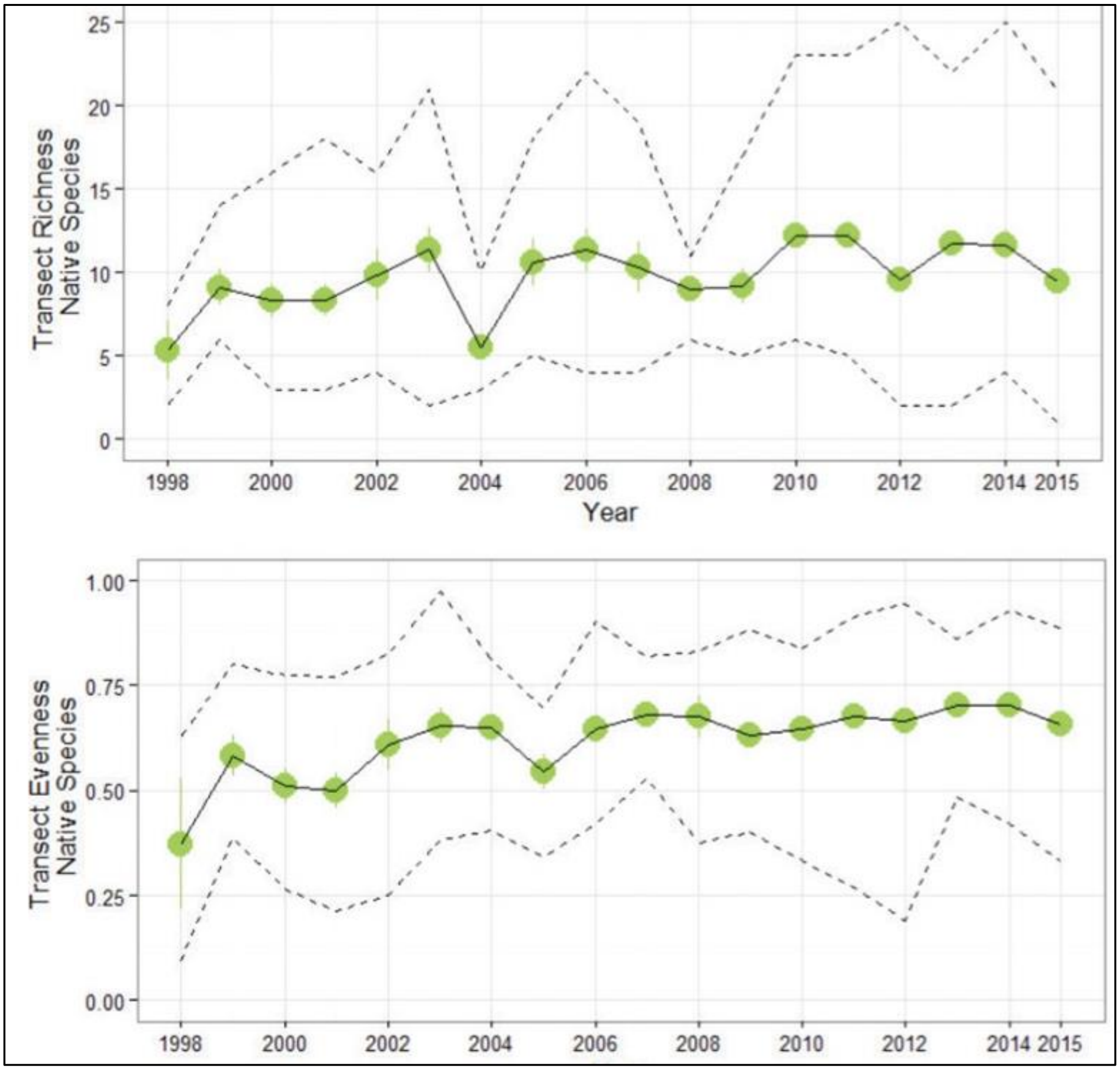

Figure 4.8.11. Trends in native species richness and evenness in Badlands National Park, 1998-2015 (Ashton and Davis 2016). Data are means ± one standard error. The dashed line indicates the maximum and minimum values for each year.

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.

Disturbance from grazing, prairie dogs, fire, and humans affects plant community structure and composition in mixed-grass prairie. We measured the approximate area affected by natural and human disturbances at each site we visited from 2011 to 2015 by surveying the area for ~ 5 minutes at the end of the plot visit. The most common disturbances were the trails, wallows, and the grazing impacts of bison. Soil disturbance from small mammals (e.g., gophers, these excluded prairie dogs) and disturbance from erosion and flooding were also common. We found no correlation with total disturbance, small or large animal disturbance and native richness or exotic cover. Disturbances are patchy in BADL making it difficult to detect trends because they are not found in all plots. As more monitoring data are collected in future years, we may be able to better explore the statistical relationship between these metrics and disturbance.

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

Climate

The 30-year normal temperatures at a nearby weather station, Interior3 NE, South Dakota and ranged from average minimum monthly temperatures in January of 15.6° F to maximum monthly July temperatures of 91.2° F (based on 1980-2010). The 30-year normal annual precipitation totals 18.5 inches. Annual precipitation at BADL in 1998-2015 was variable and ranged between 11.0 and 27.1 inches, in 2002 and 1998, respectively. There were dry years in the early to mid-2000s and in 2012 (Figure 4.8.12). Last year, 2013, and 1998 were 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).

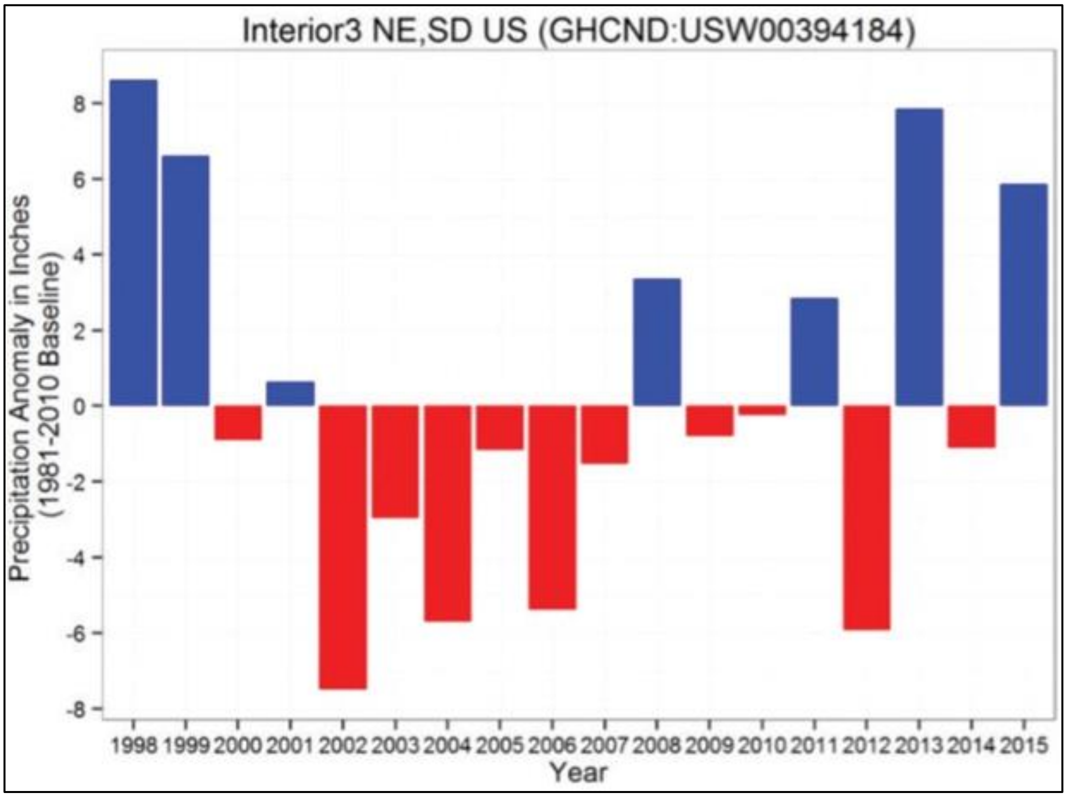

Figure 4.8.12. The total annual precipitation anomaly from 1998-2015 for Badlands National Park (Ashton and Davis 2016). Positive values (blue) represent years wetter than and negative values (red) are drier than the 1981-2010 normal. The anomaly is measured in inches and based on data from a nearby weather station.

We found that the relative cover of exotic species declines in response to increasing average annual maximum temperatures (F, 232 = 35.0, P < 0.001) but it does not respond to changes in precipitation or minimum temperatures. Native richness and plant height decreased in 2012, an extremely hot and dry year. However, when 2012 was excluded, there was not a statistically significant relationship between climate and native richness or height. Continued monitoring and a longer time series of vegetation data and climate will allow us to determine whether the response to the 2012 drought is typical.

Fire History

Historically, fire was a common disturbance in Northern Great Plains grasslands, with natural fire return intervals of 8-25 years (Wienk et al. 2007). Natural fires have been suppressed for most of the last century, but the use of prescribed burning to mitigate the effects of the absence of natural fires has increased over time since its start at Wind Cave National Park in 1973 (Wienk et al. 2011). As of 2015, there is a mosaic of recently burned and unburned areas in BADL (Figure 4.8.13).

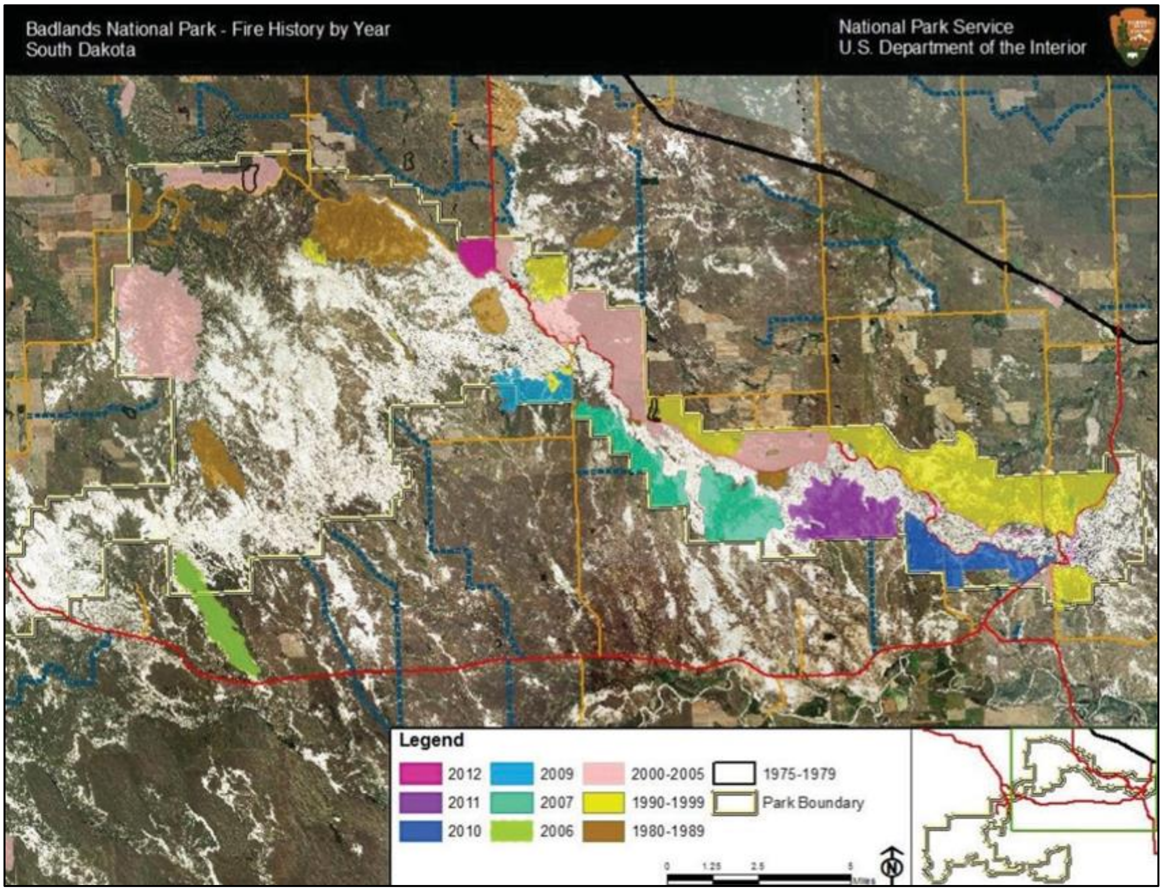

Figure 4.8.13. Map of recent fire history at Badlands National Park (Ashton and Davis 2016).

The effects of specific prescribed burns on vegetation and fuel loads and more details about fires at BADL can be found in past NGPFire annual reports (see https://www.nps.gov/ngpfire/docs.htm). Here, we were interested in determining the relationship between fire history and vegetation. We compared three vegetation metrics, native species richness and relative cover of all exotic plants and annual brome, 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-1975).

We found no relationship between native richness and years since fire (Figure 4.8.14; F1, 192 = 2.9, *P* = 0.089) or the relative cover of exotic species and years since fire (F1, 192 = 2.4, *P* = 0.12). Annual bromes, however, did respond to fire. Plots that had not burned in many years had a higher cover of annual bromes than sites that burned more recently (F1, 192 = 7.6, *P* = 0.006). This suggests that prescribed fire can benefit the mixed-grass prairie in BADL, but the reduction in annual brome cover may be short-lived.

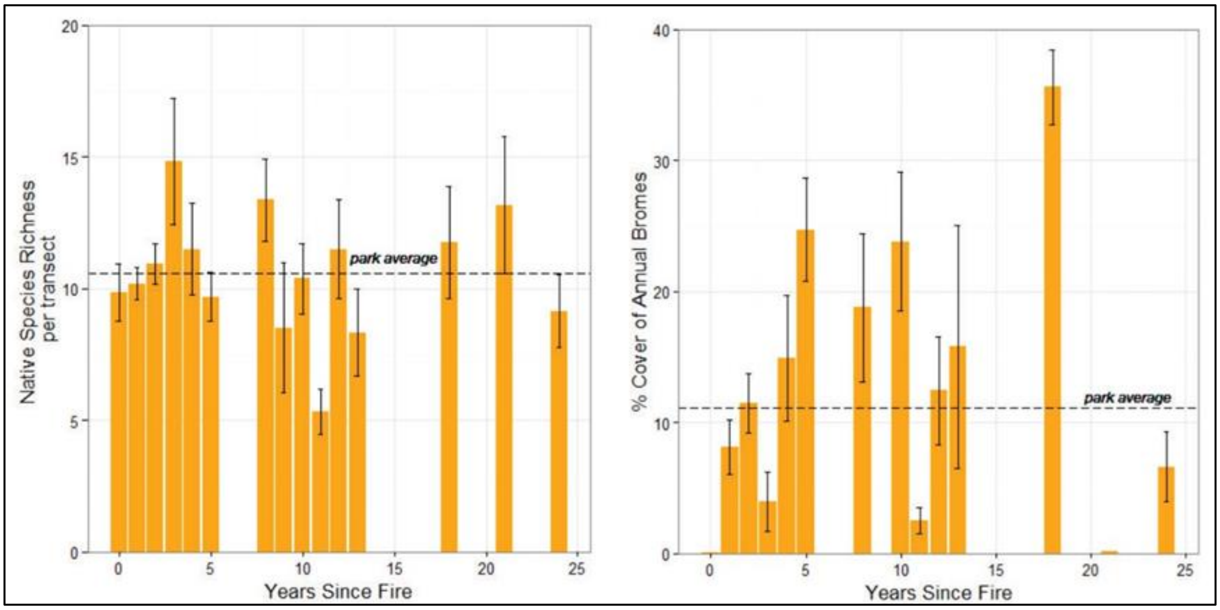

Figure 4.8.14. Native species richness (left panel) and relative percent cover of annual bromes (right panel) across plots with different fire histories (Ashton and Davis 2016). Observations vary between plots that have recently burned (0 years since fire) and plots that had burned 24 years previously (24 years since fire). Bars represent means ± one standard error and sample sizes range from 4 to 45 plots. The dashed line indicates the average native species richness and relative percent cover of exotic species of all plots in the park.

The best approach to reducing exotic species abundance in BADL will likely include burning; however there may also be a need for 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.

Bison

Bison were reintroduced to BADL in 1963 and the park now manages for a population of approximately 700 animals (Licht in press). Bison can influence the productivity and diversity of mixed-grass prairie through grazing and the creation of bison wallows, both of which limit the cover of dominant grass species (Collins and Barber 1986). In BADL, there is some evidence that bison have only a small effect on mixed-grass prairie communities, especially when compared to prairie dog, because they are in relatively low density (Fahnestock and Detling 2002). It is estimated that bison probably consume about 12% of plant productivity in a normal precipitation year (Licht in press). We used the monitoring data from 1998 to 2015 to compare species richness and exotic species cover between areas in BADL of similar ecological site types with and without bison (Figure 4.8.15). We focused on 3 of the most ecological site types found in and out of the bison pasture; these included clay pan and two loamy soils (Figure 4.8.15).

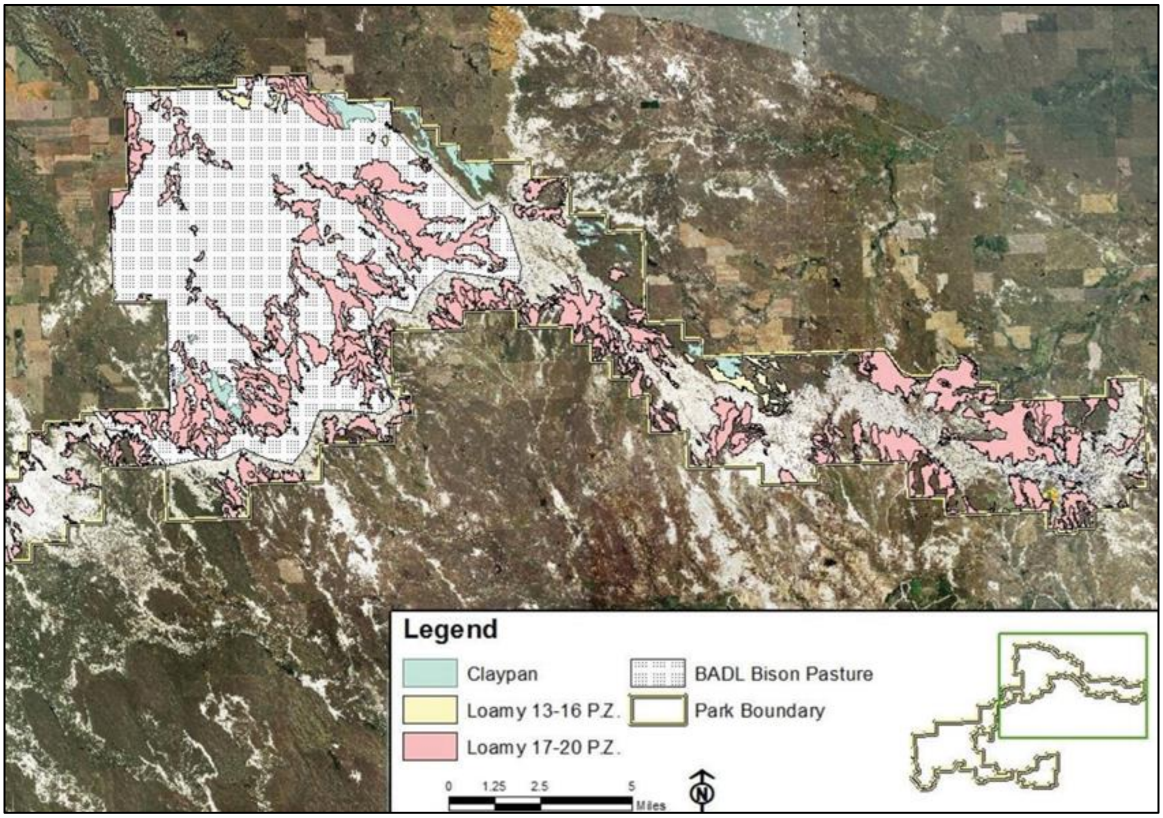

Figure 4.8.15. A map of the common ecological site types in and outside of bison pasture in Badlands National Park (Ashton and Davis 2016). The ecological site types are from the Web Soil Survey (NRCS 2015) and the bison pasture was estimated by D. Licht (personal communication).

We found that native plant diversity was higher in plots within the bison pasture areas (F1, 107 = 14.2, P < 0.001) and this pattern was consistent across ecological site types (Table 4.8.4). Total exotic cover and annual brome cover varied across ecological site types, but not with the presence of bison (F1, 107 = 1.1, *P* = 0.29, F1, 107 = 0.4, *P* = 0.55). This pattern of increased plant diversity in mixed-grass prairie grazed by bison is consistent with a past studies on the role of disturbance in maintaining grasslands (e.g., Collins and Barber 1986). Other factors could also influence this pattern including differences in past land-use history, wilderness management (the wilderness and bison boundary are similar), or slight differences in climate. With future monitoring we will increase our sample of plots within the park and our confidence in the assessment of grassland condition in and outside of the bison pasture.

Table 4.8.4. Average native species richness of plots within and outside the bison pasture at Badlands National Park.

	No bison present			Bison pasture		
Soil ecological site name	**# of plots**	**# of plot visits**	**Native richness (mean ± se)**	**# of plots**	**# of plot visits**	**Native richness (mean ± se)**
Claypan	3	6	11.3 ± 1.1	4	7	16.3 ± 1.5
Loamy 13-16 P.Z.	2	6	8.1 ± 1.2	2	6	13.2 ± 2.5
Loamy 17-20 P.Z.	27	88	9.9 ± 0.4	10	16	11.9 ± 1.0
All soil types	85	218	9.6 ± 0.3	42	87	12.2 ± 0.5

Rare Plants

While repeating rare plant surveys and locating rare species is not the focus of NGPN plant community monitoring, we identified one rare plant species in BADL from 1998 to 2015. Barr's milkvetch (*Astragalus barrii,* S3), was observed in a single vegetation monitoring plot at BADL (Table 4.8.5). Barr's milkvetch was observed at a single point in 2014 and at two points in 2015, and all occurrences were within the same plot. This species is a regional endemic, with a range limited to South Dakota, Wyoming, Nebraska, and Montana (Figure 4.8.16. Barr's milkvetch (*Astragalus barrii*, S3), a rare species observed at Badlands National Park. Left: Barr's milkvetch as observed by NGPN staff; Upper right: global distribution map; Lower right: in full bloom. Due to this limited range, it is also classified as a globally vulnerable species (G3).

Table 4.8.5. Rare species occurrence in Badlands National Park from 1998-2015 (Ashton and Davis 2016). Status ranks are based on the South Dakota Natural Heritage Program's 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	**Common name**	**Status rank**	**Plot count**	**Mean cover (%)**
Astragalus barrii	Barr's milkvetch	S3	1	< 0.01

Figure 4.8.16. Barr's milkvetch (*Astragalus barrii*, S3), a rare species observed at Badlands National Park. Left: Barr's milkvetch as observed by NGPN staff; Upper right: global distribution map; Lower right: in full bloom.

While several vegetation community mapping projects have been completed for BADL, there are limited floristic diversity and rare species surveys available for the park, and we recommend a park-wide survey be done when funds are available. A full rare plant survey will be more likely to accurately quantify the status of rare plants found in BADL and better document locations of rare species in areas of BADL with no NGPN monitoring plots. Any future construction efforts that could disturb native vegetation (e.g., trail building), should avoid damaging species considered rare in South Dakota.

4.8.4. Conclusion

The Northern Great Plains Inventory & Monitoring Program and Fire Effects Program have been monitoring vegetation in Badlands National Park for over 18 years. While methods have changed slightly, this report summarizes data from over 127 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 4.8.6) that summarizes the current status and trends in a few key vegetation metrics.

Table 4.8.6. Summary of vegetation indicators and methods. Current values are based on data from 2011-2015 and trends are based on data from 1998-2015.

Indicator	Measures	Current value (mean ± se)	Reference condition data and source	Condition/ trend	Condition rationale
Upland plant community structure and composition	Native species richness (1m^2 quadrats)	6.1 ± 0.3 species	3-15 species	🟢 ↔	BADL plays a vital role in protecting and managing one of the largest remnants of native mixed-grass prairie in the region. The park is characterized by moderate native species richness that falls within a natural range of variability (Symstad and Jonas 2014).
	Evenness (point-intercept transects)	0.68 ± 0.01	To be determined	🟢 ↔	There has been no trend in native richness over time. In general, the sites in BADL had a high cover of exotic species. Only one of the sites visited in 2014 had less than 10% relative cover of exotic species. Yellow sweet clover and annual bromes present a large challenge to managers of BADL, and more research on effective management strategies in mixed-grass prairie is greatly needed.
Exotic plant early detection and management	Relative cover of exotic species	28.8 ± 1.5%	< 10% cover	🔴 ↔	Many areas of BADL have a high cover of exotic species. Annual bromes, Kentucky bluegrass, and yellow sweet clover present the largest challenge to BADL. Exotic cover has remained high over the entire monitoring period.
	Annual brome cover	11.1 ± 1.0%	< 10% cover	🟡 ↔	More research on effective management strategies of annual bromes and other exotic species in the mixed-grass prairie is greatly needed.

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

BADL plays a vital role in protecting and managing some of the largest remnants of native mixed-grass prairie in the area. Most sites within the park have a number of native grass and forb species that is well within the natural range of variability for northern mixed-grass prairie. We found no significant trends in native species richness or evenness from 1998-2015, but both are threatened by the increasing cover of exotic species (Table 4.8.6). Annual bromes, Kentucky bluegrass, and yellow sweet clover are the most abundant exotic plant species in BADL. Continued control efforts will be necessary to maintain native prairie within BADL.

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

The large variability in the climate of BADL has made it difficult to discern strong patterns linking temperature, precipitation, and plant community structure (e.g., exotic cover, diversity). However, we did find that the relative cover of exotic species declined in response to increasing average annual maximum temperatures. Continued monitoring and a longer time series of vegetation data and climate will allow us to determine if hotter conditions continue to favor native species.

BADL has been using prescribed burning as a management tool since the 1980s. There was no difference in native diversity or exotic cover among plots that had burned recently and those that had not burned for over 10 or 25 years. However, those that had not burned in many years had a higher cover of annual bromes than sites that burned more recently. Ongoing adaptive management programs and research will provide better guidance to the park on whether prescribed burns should be used to reduce the cover of annual bromes.

We found that native species richness was higher in plots within areas of the park utilized by bison. This pattern is consistent with a past studies on the role of disturbance in maintaining grassland diversity.

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

We found only one rare plant in BADL. Barr’s milkvetch (*Astragalus barrii*) was observed in a single vegetation monitoring plot. Since the rare plants within BADL are found in such low abundance, we recommend a more targeted effort to monitor their populations.

4.8.5. Vegetation Overall Condition

Table 4.8.7. 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	🟡↔
Overall condition for all indicators and measures		🟡↔

<u>Condition</u>

Overall vegetation condition was determined by the average of the indicator conditions. The NRCA authors summarized the condition, confidence, and trend for each indicator, and assigned condition points. The score for overall vegetation condition was 63 points, which placed vegetation at Badlands National Park in the Warrants Moderate Concern category.

<u>Confidence</u>

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

<u>Trend</u>

Trend was Unchanging for all indicators and measures. The overall trend for vegetation was Unchanging.

4.8.6. Stressors

Exotic yellow clover has become an increasingly challenging issue in recent years and efforts to control the spread of the species have been ineffective (B. Kenner, personal communication, 12 December 2016).

4.8.7. Data Gaps

The full impact of the spread of yellow clover is not fully known, nor have methods to control the species been studied in full (B. Kenner, personal communication, 12 December 2016).

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4.9. Breeding Birds

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).

Western Meadowlark at Badlands National Park. Photo by Sara Feldt, NPS (2011).

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 Badlands National Park

Badlands National Park lists 206 species as "present" in the park, 3 species as "probably present", and 28 species as "unconfirmed" (https://irma.nps.gov/NPSpecies). Portions of two Breeding Bird Survey (BBS) routes are within park boundaries, and monitoring data for these routes are available dating back to 1967 for Cedar Pass and 1982 for Badlands.

As part of developing the current inventory and monitoring program in the NGPN, bird surveys were conducted in 1999 throughout grassland habitat in Badlands NP (Powell 2000). Thirty-eight species were detected in point counts and transects during peak breeding, and 72 species were seen overall. Methods and study design were further developed in 2011, when 581 point counts were conducted (Birek et al. 2014). Eighty-one species were seen during these surveys. In 2011 and 2012, a comparison of point count and acoustic monitoring techniques was conducted, revealing important differences in detectability among species (Pavlacky and Beason 2014).

In the NGPN group of parks to which Badlands NP 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 187 permanent point count locations, detecting 54 species in 2013, 75 species in 2014, and 77 species in 2015.

Regional Context

Badlands NP is located within the badlands and prairies bird conservation region (BCR 17; Figure 4.9.1). The badlands and prairies 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 Badlands NP.

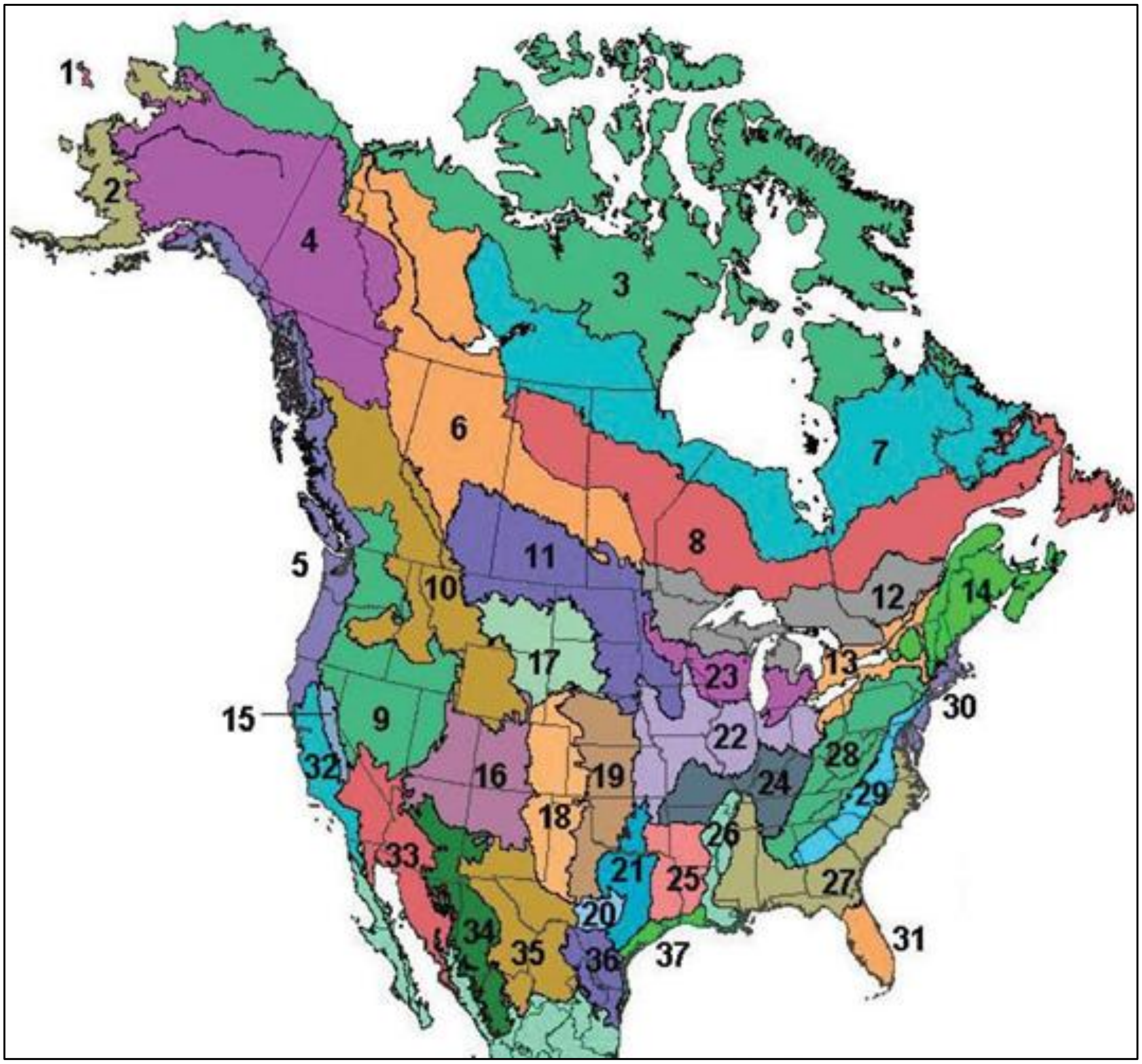

Figure 4.9.1. Bird conservation regions of North America (BCRs; www.nabci-us.org/map.html). Badlands NP is located within BCR17, the badlands and prairies BCR.

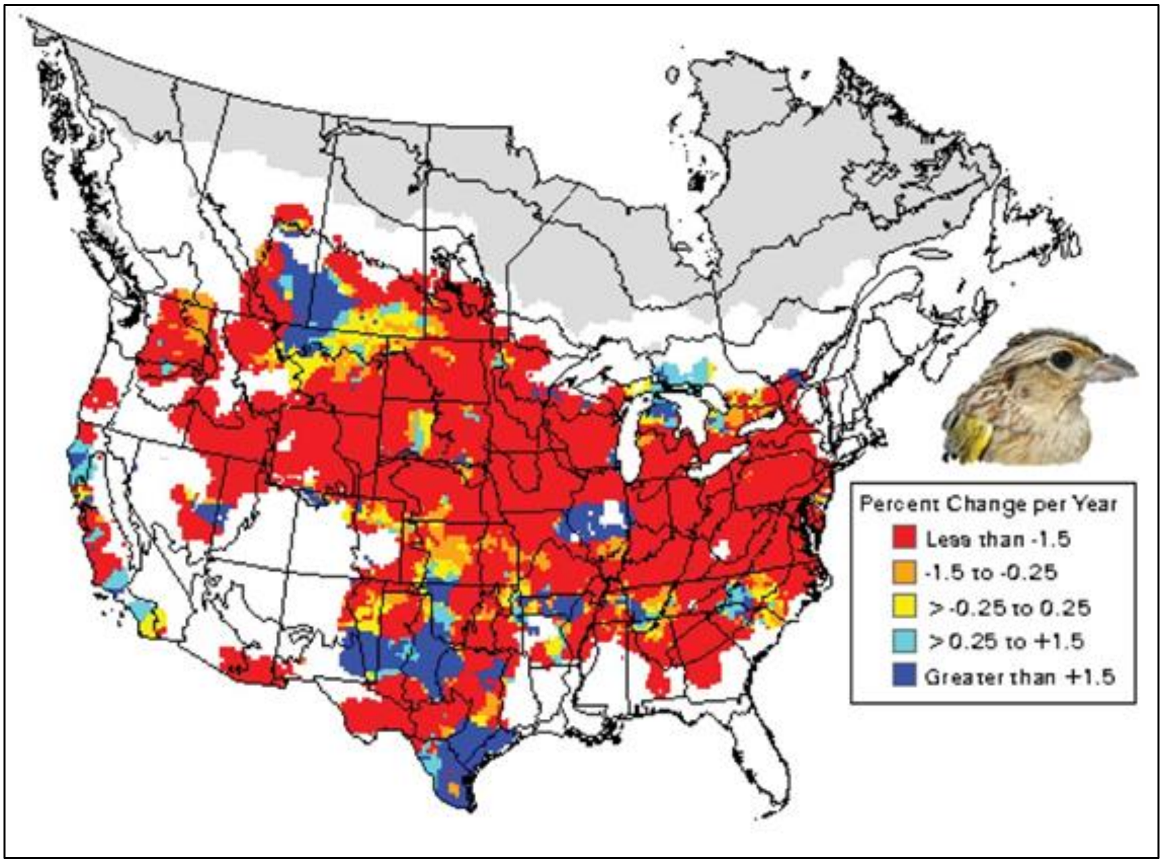

Figure 4.9.2. Population trends for the grasshopper sparrow from 1963 to 2013. The grasshopper sparrow is an example of a grassland species that has been declining for a variety of reasons, including habitat loss and degradation (USGS and BBS, image from Wikipedia).

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 badlands and prairies BCR is stable (Sauer et al. 2003), most 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.

4.9.2. Breeding Birds Standards

The Migratory Bird Treaty Act of 1918 (16 USC 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 Badlands NP. Of the 205 species considered to be present or probably present at Badlands NP, 37 species are considered species of federal concern. The golden-winged warbler is a species that is under review for listing and Sprague’s pipit is a candidate for federal listing. However, none of the birds at Badlands NP are formally protected under the Endangered Species Act. Both bald and golden eagles are protected under the Bald and Golden Eagle Act. The bald eagle is listed as threatened and the peregrine falcon as endangered in the state of South Dakota.

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 4.9.3). Twelve species at Badlands NP are identified in the 2014 Yellow Watch List.

Figure 4.9.3. Norther harrier in flight. Based on the Partners in Flight ranking system, the northern harrier was the highest priority species observed at Badlands NP in 2015. Photo by D. Pancamo, Wikipedia 2010.

South Dakota's State Wildlife Action Plan contains a list of species of greatest conservation need. Fifteen of 29 species designated as species of greatest conservation need can be found at Badlands NP (Figure 4.9.4). The top ranked species (ranks 1 and 2a) include the bald eagle, peregrine falcon, chestnut-collared longspur, lark bunting, long-billed curlew, and Sprague's pipit.

Figure 4.9.4. Perched lark bunting. The lark bunting is a South Dakota Species of Greatest Conservation Need frequently observed at Badlands NP in 2015. (Photo: by NPS).

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 Badlands NP. 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). 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). In the case of Badlands NP, occupancy estimates (y) 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, 20 May 2016). 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 (32–35 % 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).

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. As another example, 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 Badlands NP 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 Badlands NP 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 our 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 Asessment 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: Mean 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

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.

Field Protocol

Monitoring of birds at Badlands NP began in 2013 following a standardized protocol (Beaupré et al. 2013). Up to 187 permanent point-transect locations were surveyed each year (Buckland et al. 2001) (Figure 4.9.5). 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).

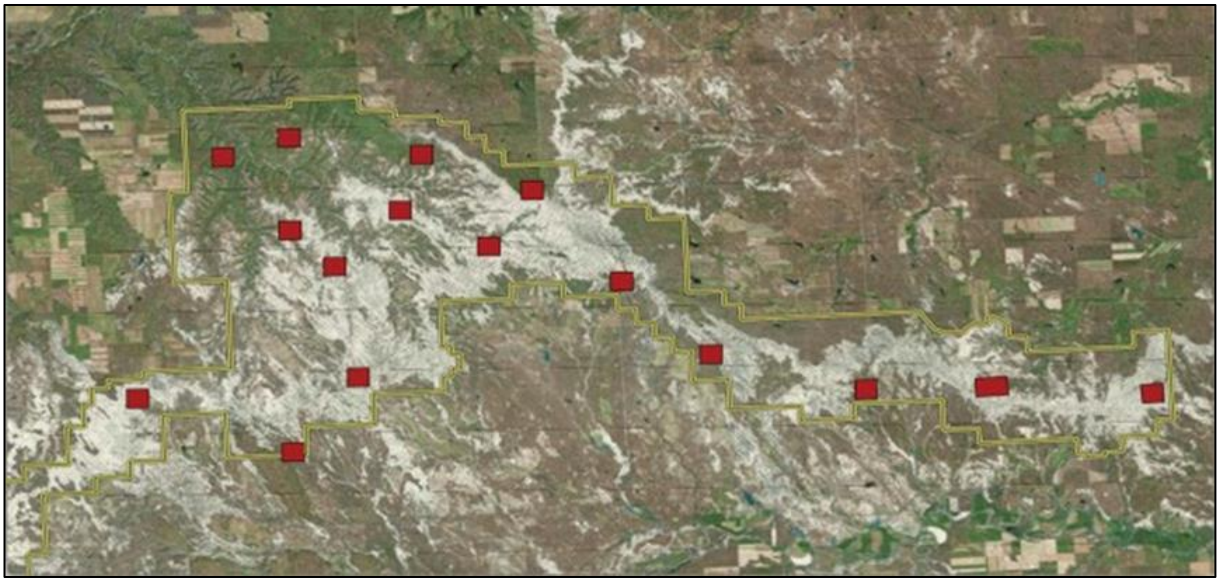

Figure 4.9.5. Bird monitoring locations at Badlands NP (Buckland et al. 2001). Each grid cell depicted includes 16 point-transect locations. Surveys were conducted at 161 locations in 2015.

Quantifying Breeding 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 Badlands NP are presented along with a comparison of the same calculations at the level of the bird conservation region. The IMBCR has completed full coverage of BCR17, so region-wide estimates are available. The BCR17 results are a combination of data from five states (Table 4.9.1).

Table 4.9.1. The distribution of sampling points among states in the badlands and prairies bird conservation region (BCR17).

State	2013	2014	2015
Montana	426	948	315
North Dakota	485	474	371
Nebraska	65	81	80
South Dakota	1799	1037	1197
Wyoming	498	367	690
Total	**3273**	**2907**	**2653**

Occupancy, density, and count data were extracted from the Avian Data Center for using "SD-BCR17-BN: Badlands National Park – North Unit" as the "individual stratum" for Badlands NP and the "superstratum: BCR17" for BCR17.

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 Badlands NP 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 4.9.2, Figure 4.9.6). Across 128 point-transect locations, 54 species were observed in 2013. Across 187 point-transect locations, 75 species were observed in 2014. Across 161 point-transect locations, 77 bird species were observed in Badlands NP in 2015. Of these observations, three non-native species were observed from 2013–2015 (European starling, ring-necked pheasant, and rock pigeon). These introduced species were excluded from richness estimates.

Table 4.9.2. Average species richness of breeding birds at Badlands NP (BADL) and within the badlands and prairies bird conservation region (BCR17).

Location	Year	Number of locations surveyed	Number of species observed	Number of species with occupancy estimates	Number of non-native species	Average species richness ± standard error
BADL	2013	128	53	38	2	12.02 ± 0.71
	2014	187	75	50	3	13.12 ± 0.82
	2015	161	77	50	2	13.41 ± 0.92
BCR17	2013	3273	190	148	5	17.22 ± 0.60
	2014	2907	197	150	5	19.57 ± 0.61
	2015	2653	196	154	5	17.72 ± 0.64

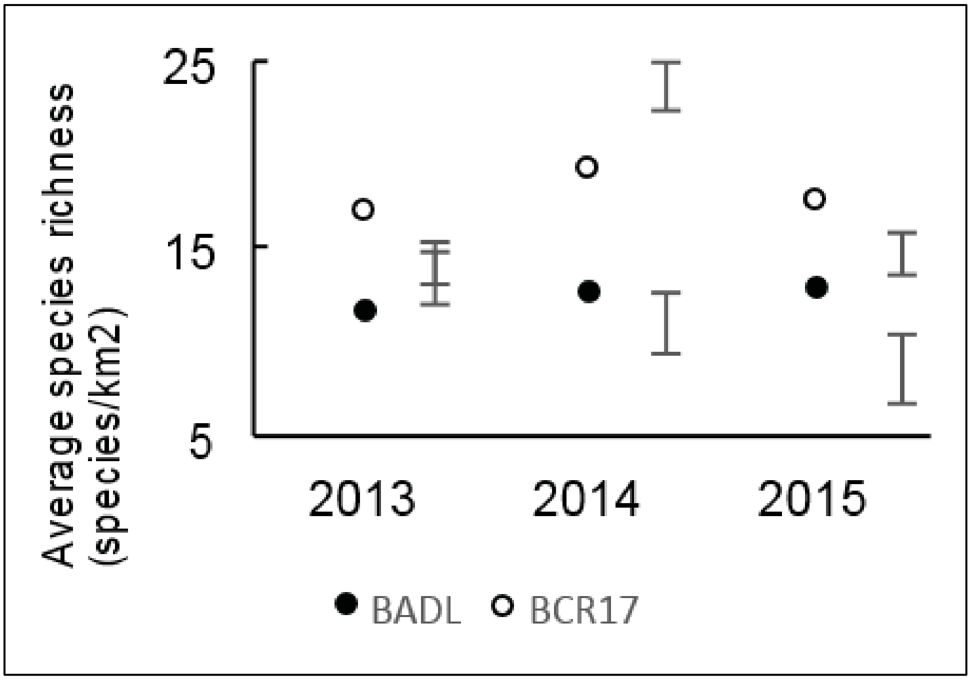

Figure 4.9.6. Average species richness with 95% confidence intervals of breeding birds within Badlands NP and the badlands and prairies bird conservation region (BCR17).

While species richness at Badlands NP was lower than that 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 4.9.2, Figure 4.9.6). 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 187 locations within the park. The confidence was *High*.

Trend

There were three years of point-transect data available from Badlands. Species richness estimates were similar for all years. The greatest number of species (77) was observed in 2015. It was too early to calculate a trend in species richness at the time of this assessment, but the richness estimates were similar 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 4.9.3, Figure 4.9.7). We used available density estimates for native species to calculate an average density for the study area (number of birds per square kilometer). In general, density estimates should be fairly sensitive to short-term changes in habitat quality, such as food availability.

Table 4.9.3. Average density of breeding birds at Badlands NP (BADL) and within the badlands and prairies bird conservation region (BCR17). 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
BADL	2013	128	54	43	2	5.98 ± 0.56
	2014	187	75	58	3	4.82 ± 0.96
	2015	161	77	60	2	4.79 ± 0.76
BCR17	2013	3273	190	124	5	2.84 ± 0.14
	2014	2907	197	140	5	2.71 ± 0.12
	2015	2653	196	140	5	2.71 ± 0.15

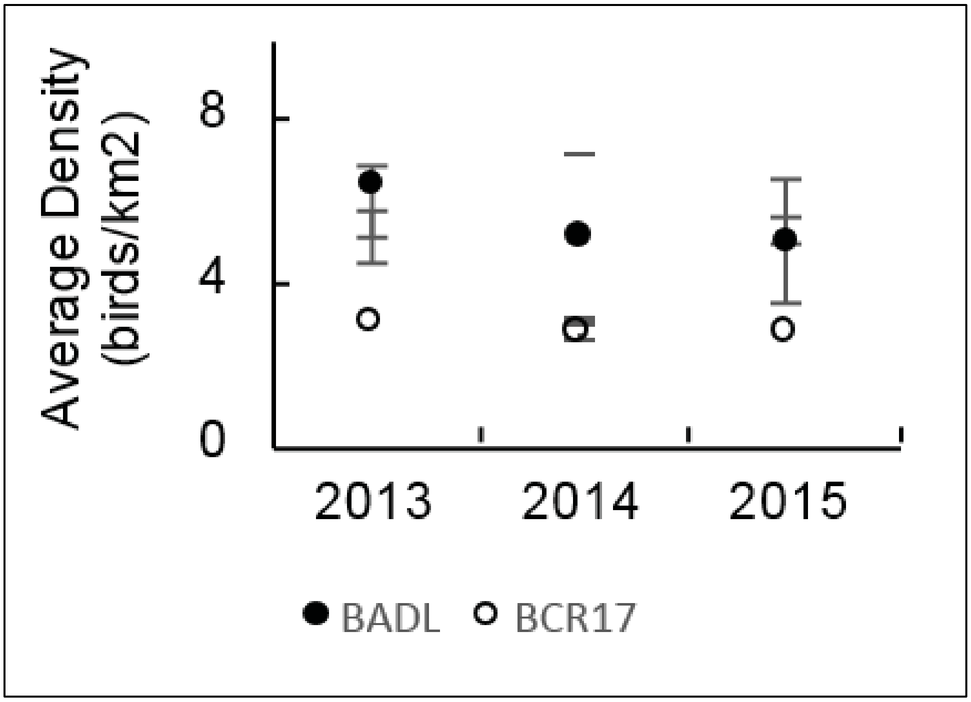

Figure 4.9.7. Average density with 95% confidence intervals of breeding birds within Badlands NP and the badlands and prairies bird conservation region (BCR17).

While species abundance at Badlands NP 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 187 locations within the park. The confidence was *High*.

Trend

There were three years of density estimates available from Badlands NP. The highest average densities were observed in 2013 (approximately 6 birds/square kilometer). The most abundant bird species was the grasshopper sparrow in 2013 (48 birds per square kilometer in 2013), and the cliff swallow in 2014 and 2015 (78 and 70 birds per square kilometer, respectively). It was too early to calculate a trend in species abundance at the time of this assessment, but the density estimates varied among the three survey years.

Conservation Value

○

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 4.9.4, Figures 4.9.8 and 4.9.9). 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 4.9.4. Conservation value score of native breeding landbirds at Badlands NP and within the badlands and prairies bird conservation region (BCR17).

Location	Year	Number of locations surveyed	Number of species observed	Number of ranked species	Number of non-native species	Average priority ranking ± standard error
BADL	2013	128	54	47	2	11.72 ± 0.34
	2014	187	75	61	3	11.67 ± 0.32
	2015	161	77	64	2	11.88 ± 0.31
BCR17	2013	3273	190	141	5	11.76 ± 0.22
	2014	2907	197	138	6	11.80 ± 0.22
	2015	2653	196	140	7	11.78 ± 0.22

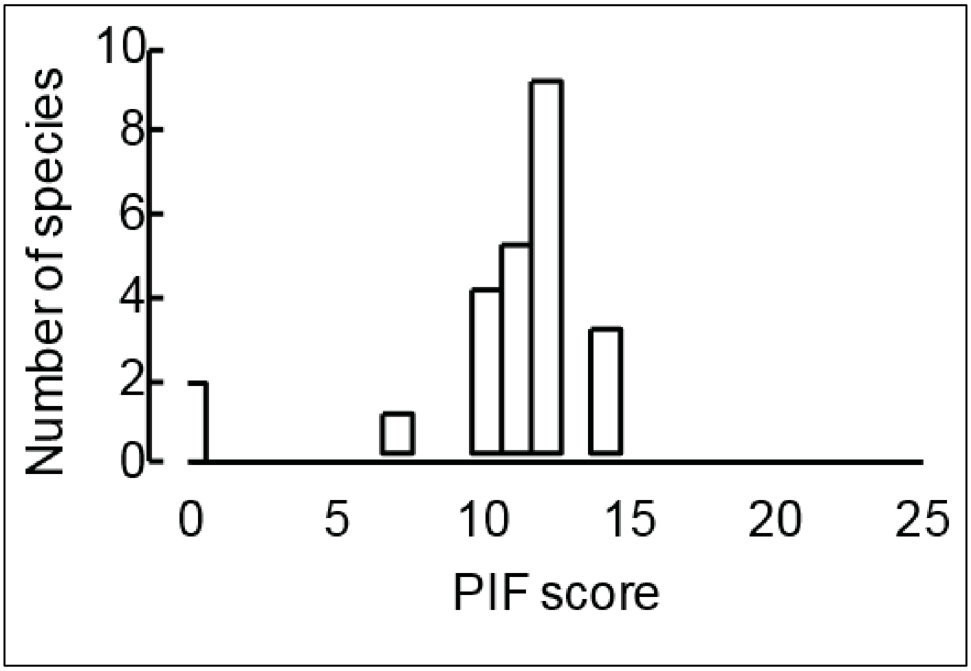

Figure 4.9.8. The distribution of Partners in Flight priority rankings for landbird species seen in 2015 at Badlands NP. The average ranking was 11.9 ± 0.2 out of a total possible score of 25. We assigned two non-native species a rank of zero. The lowest ranked native species was cedar waxwing with a score of 7. The highest ranked native species was northern harrier with a score of 17.

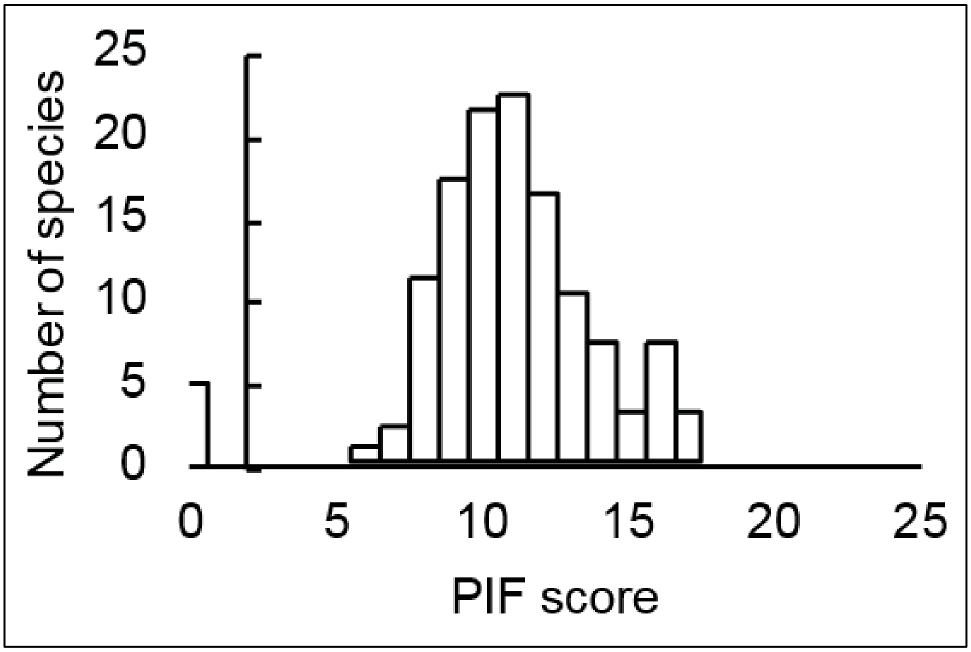

Figure 4.9.9. The distribution of Partners in Flight priority rankings for landbird species seen in 2015 within BCR17. The average ranking was 11.8 ± 0.2 out of a total possible score of 25. We assigned seven non-native species a rank of zero. The lowest ranked native species were cedar waxwing, dark-eyed junco, and house finch each with a score of seven. The highest ranked native species were chestnut-collared longspur and greater sage-grouse with scores of 19.

The BCR-wide average priority ranking for all landbirds known to occur was 11.64 (n = 174). In 2013, five landbird species for which PIF rankings were unavailable were reported within the BCR (blackpoll warbler, magnolia warbler, Tennessee warbler, white-winged crossbill, and yellow-throated vireo). In 2014, five landbird species for which PIF rankings were unavailable were reported within the BCR (American pipit, fox sparrow, ruby-throated hummingbird, Wilson’s warbler, and yellow-throated vireo). In 2015, seven landbird species for which PIF rankings were unavailable were reported within the BCR (Alder flycatcher, American tree sparrow, Bewick’s wren, fox sparrow, pileated woodpecker, Townsend’s warbler, and western scrub-jay).

While conservation values at Badlands NP 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 187 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

Partners in Flight priority 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 were too few years available at the time of this assessment to calculate a trend in these parameters.

Breeding Birds Overall Condition

Table 4.9.5. 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		○

We did not assign an overall breeding bird condition to birds at Badlands NP, due to a lack of clear or accepted standards for doing so. 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 Badlands NP (Table 4.9.5).

Table 4.9.6. Summary of breeding bird indicators and measures.

Indicator	Measure	Condition	Confidence	Trend	Condition rationale
Species diversity	Species richness	Not available	High	Not available	Species richness from 2013–2015 was 12.85 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 in 2015 was 5.2 birds/km^2. The data were collected as part of a rigorously designed monitoring program, so confidence was *High* and trend was *Not Available*.

Table 4.9.6 (continued). Summary of breeding bird indicators and measures.

Indicator	Measure	Condition	Confidence	Trend	Condition rationale
Conservation value	Mean priority ranking	Not available	High	Not available	The mean priority ranking from 2013–2015 was 11.76. 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 Badlans NP, the following section presents more general BCR trend data for high priority species and non-native species found in the park unit.

Top-ranked Priority Species

The top priority species observed at Badlands NP in 2015 were the northern harrier (17), burrowing owl (16), grasshopper sparrow (16), lark bunting (16), prairie falcon (16), vesper sparrow (16), northern flicker (15), red-headed woodpecker (15), and sharp-tailed grouse (15). The grasshopper sparrow was the most abundant and widely distributed of these species (Table 4.9.7).

Table 4.9.7. Occupancy and density estimates for the top-ranked priority species in Badlands NP 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 Badlands NP. There were not sufficient data to generate occupancy and/or density estimates for some species.

Common Name	RCS-B	Count	Psi	% CV	D	% CV	N
Northern harrier	17	1	0.181	98	0.06	98	25
Burrowing owl	16	2	–	–	0.05	97	21
Grasshopper sparrow	16	96	0.804	13	35.4	21	15363
Greater prairie-chicken	16	1	–	–	–	–	–
Lark bunting	16	15	0.067	97	0.7	74	302
Prairie falcon	16	5	0.33	106	–	–	–
Pesper sparrow	16	2	0.069	97	0.17	97	73
Brewer's sparrow	15	2	0.067	97	0.6	99	261
Northern flicker	15	1	–	–	0.09	102	38
Red-headed woodpecker	15	1	–	–	–	–	–
Sharp-tailed grouse	15	8	0.23	100	0.35	79	152

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. Northern harrier (17) populations have been stable to decreasing (Figure 4.9.10). Another top-priority species detected during monitoring efforts in the park, but not detected in 2015, is the golden eagle (11); this species has remained fairly stable within Badlands NP and the BCR (Figure 4.9.11).

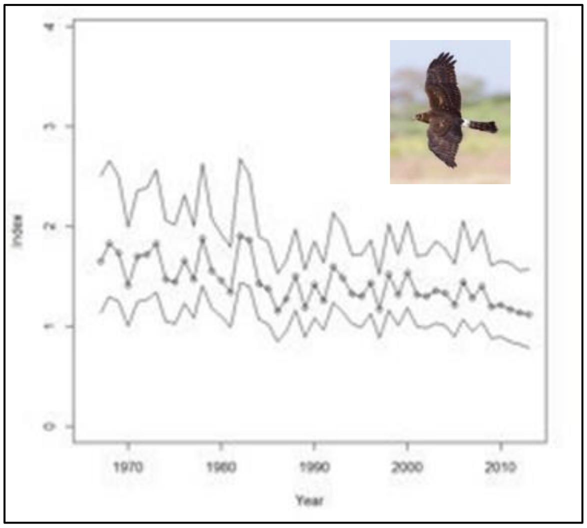

Figure 4.9.10. Northern harrier populations for 1968 to 2013. The Northern harrier has been stable to decreasing (-0.85% annual decrease, 95% credible interval: -2.05 to 0.28) within the badlands and prairies bird conservation region.

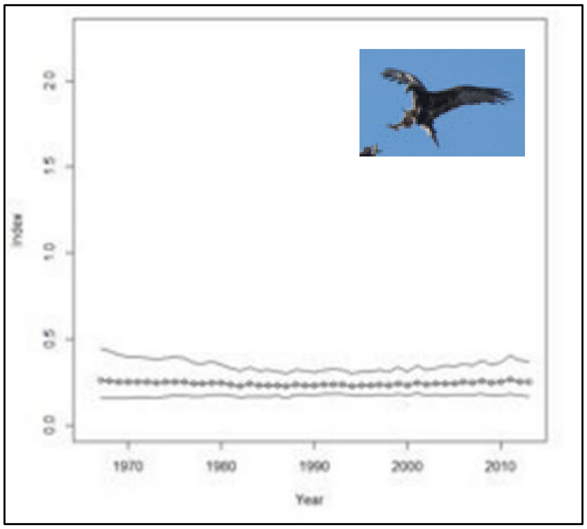

Figure 4.9.11. Golden eagle populations from 1968 to 2013. The golden eagle has remained stable (-0.09% annual decrease, 95% credible interval: -3.6 to -1.2) within the badlands and prairies bird conservation region.

The regional trends presented below show all available data within the badlands and prairies 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.

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 4.9.12), perhaps due to the same causes of population decline in native species.

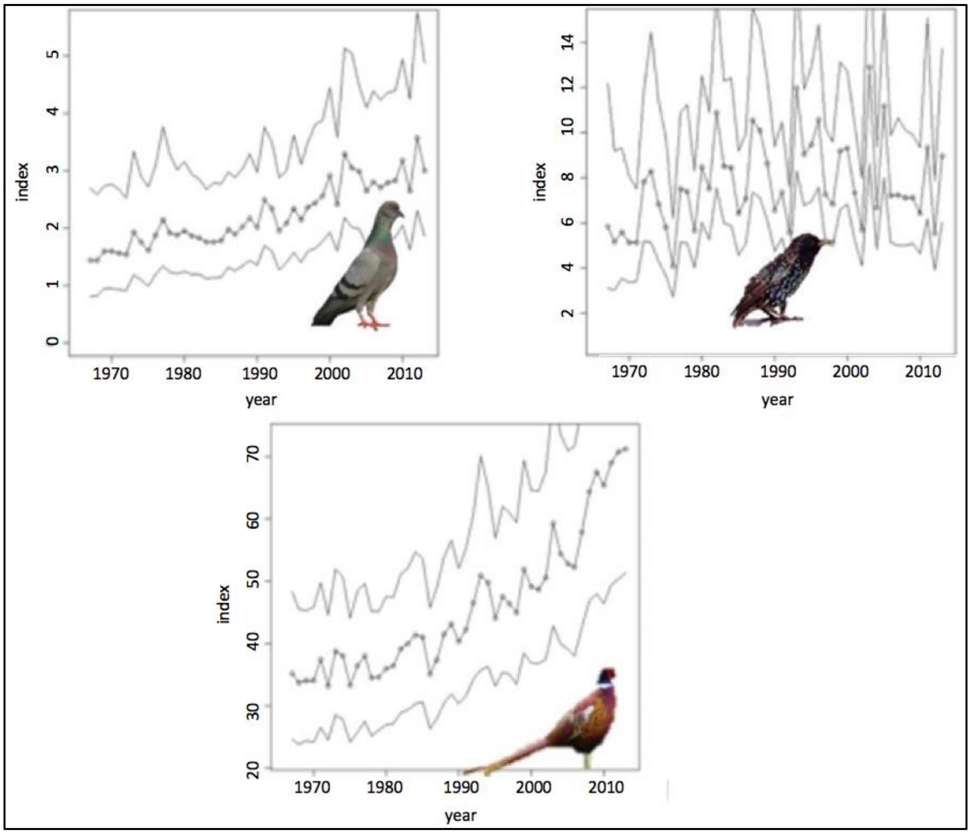

Figure 4.9.12. Region-wide trend data for three non-native species found at Badlands NP. From the top left: Rock pigeon (PIF rank 9) populations have remained stable to increasing in the badlands and prairies region. European starling (PIF rank 10) populations have remained stable over the long-term, but may have been decreasing over the last decade. Ring-necked pheasant (PIF rank 12) populations have increased over both the short- and long-term.

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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- Tim O’Connell (Oklahoma State University).

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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 in Badlands National Park. Photo by Larry McAfee, NPS 2011.

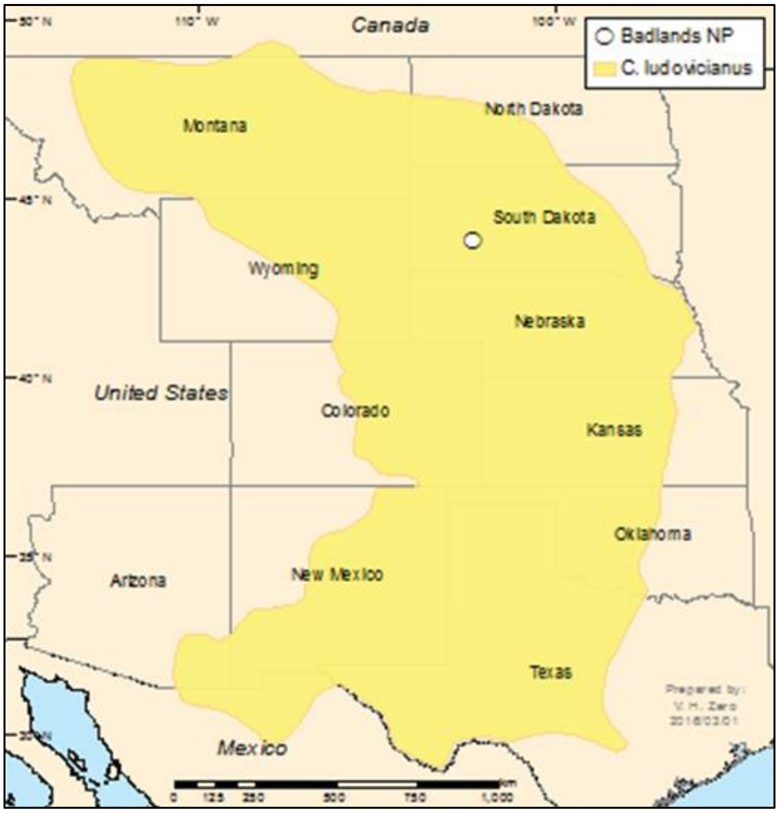

Figure 4.10.2. Geographical distribution of the black-tailed prairie dog (*Cynomys ludovicianus*). Range data from IUCN.

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 above ground 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 (Martinez-Estevez et al. 2013).

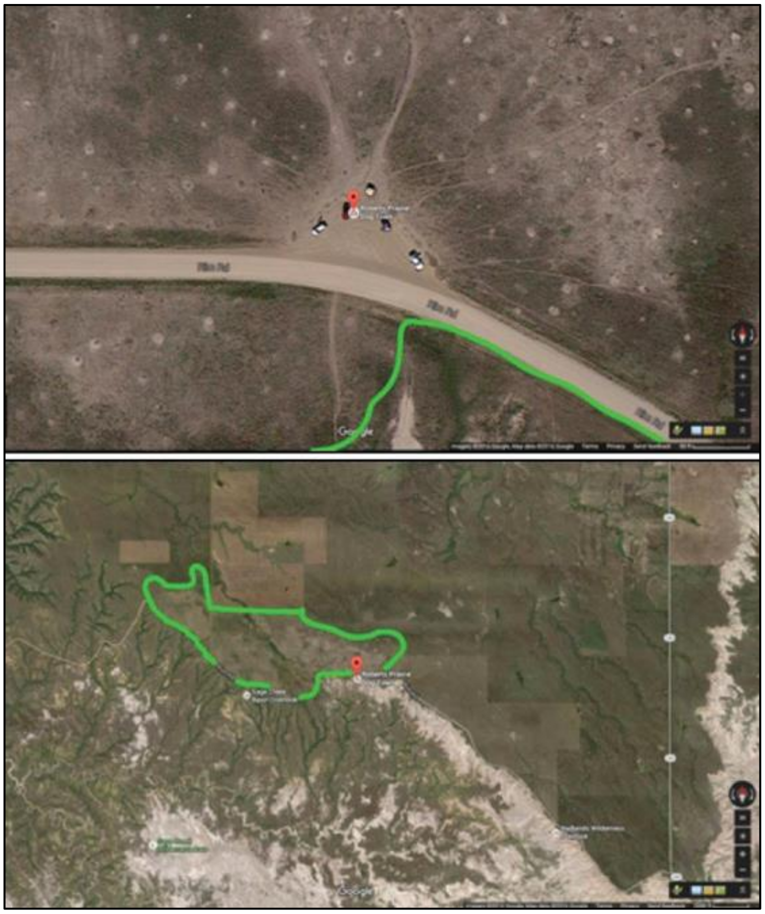

Figure 4.10.3. Roberts Prairie Dog Town at Badlands National Park as seen from the air at two resolutions. At fine scales, individual mounds are visible. At the landscape level, the colony can be seen in relation to its surroundings. Approximate colony boundary is shown in green.

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 globemallow (*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 are of conservation concern and appear to be tied to the fate of the prairie dog (Figure 4.10.4). Perhaps the best known of these species is the endangered black-footed ferret (Belant et al. 2015), an obligate of prairie dog colonies (Biggins and Godbey 2003). The success of ferret reintroductions is linked to the availability and quality of prairie dog habitat (Jachowski et al. 2011). Burrowing owls (*Athene cunicularia*) inhabit prairie dog colonies and exhibit population declines with reductions in prairie dogs (Desmond et al. 2000). The swift fox (*Vulpes velox*), a South Dakota state threatened species, also tracks changes in prairie dog populations (Kotliar et al. 1999). Ferruginous hawks (*Buteo* *regalis*) and 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: Black-footed ferrets (*Mustela nigripes*), a federally endangered species, are almost entirely dependent on prairie dogs for survival. 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. Swift foxes (*Vulpes velox*) and ferruginous hawks (*Buteo regalis*) prey upon prairie dogs; their populations track prairie dog availability (Photos by NPS and Wikipedia).

Maintaining healthy black-tailed prairie dog populations is fundamental to the character and ecological integrity of Badlands National Park. Prior to being affected by plague, Badlands NP accounted for about 59% of the acreage occupied by black-tailed prairie dogs on all NPS lands (Licht et al. 2009). Some prairie dog colonies, such as Roberts Prairie Dog Town in the northern part of the park, are important tourist attractions. Badlands NP is dedicated to protecting the species and participates in state and federal management protocols. The largest management issue facing prairie dogs in the park is sylvatic plague caused by *Yersinia pestis*, a lethal, generalist, non-native bacterium. Plague has greatly reduced the number of active prairie dog colonies within the park since 2008. Badlands NP has engaged in multi-agency efforts to curb plague within the park and surrounding grasslands.

Badlands NP has also served as a reintroduction site for endangered and threatened species, efforts that would not have been possible without an extensive population of prairie dogs. Badlands NP was the second reintroduction site for black-footed ferrets owing to the high quality of prairie dog habitat, and swift foxes were translocated to Badlands NP beginning in 2003.

Regional Context

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).

Historically, prairie dogs were found in the western three-fourths of South Dakota (U.S. Fish & Wildlife Service 2009). That range has since shrunk to the western two-thirds of the state, with the majority of colonies occurring on private and tribal lands (Kempema et al. 2015). Estimates of historical distribution of black-tailed prairie dogs in South Dakota range from 711,324 hectares (1,756,720 acres; Linder et al. 1972) to 2,594,000 hectares (6,411,000 acres; U.S. Fish and Wildlife Service, 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 allowed prairie dogs to expand in South Dakota (Figure 4.10.5).

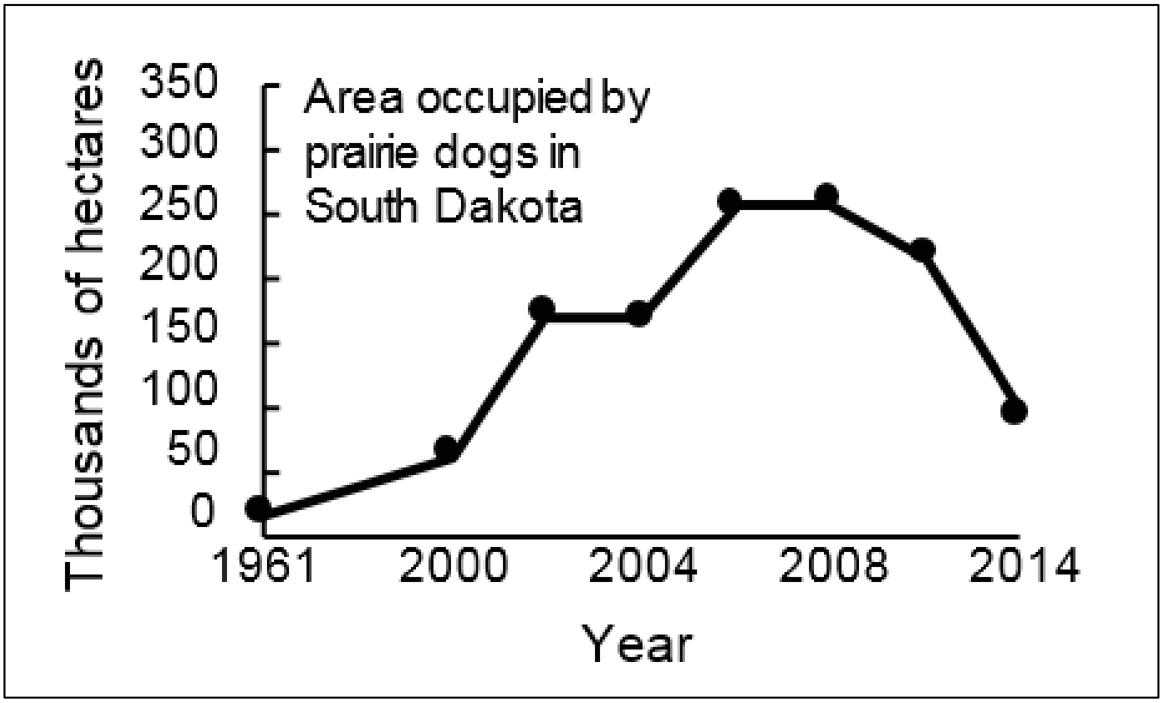

Figure 4.10.5. Estimates of area (in thousands of hectares) occupied by black-tailed prairie dogs in South Dakota. Large-scale poisoning was common through the 1960s. Prairie dog populations began to rebound following a change in federal policy in 1972. Post-2007 declines resulted from the expansion of plague into South Dakota. Note that estimates of historic occupied acreage are as high as 2.6 million hectares (data not shown). References: Bureau of Sport Fisheries and Wildlife 1961 (for 1961), U.S. Fish & Wildlife Service 2000 (for 2000), U.S. Fish & Wildlife Service 2004 (for 2004), Kempema et al. 2015 (for 2003, 2006, 2008, and 2012), and McDonald et al. 2015 (for 2014).

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 90,708 hectares (224,145 acres) in South Dakota (McDonald et al. 2015), a substantial reduction from historic levels. While historic declines were primarily driven by land conversion and poisoning, current losses are largely attributable to plague. Occupied area has declined by 64% since 2008 when plague first affected one of the largest prairie dog complexes in South Dakota at Conata Basin/Badlands. South Dakota now contains around 9% of all predicted black-tailed prairie dog habitat (Ernst et al. 2006) and around 12% 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 pest species in South Dakota (U.S. Fish & Wildlife Service 2009). Shooting is permitted year-round on private lands, with seasonal restrictions on public lands. There is no bag limit. Poisoning is permitted as well, but restricted to pesticides legally allowed for use on black-tailed prairie dogs. South Dakota is the only state that holds an EPA permit for the manufacture and sale of zinc phosphide, the most popular prairie dog toxicant (U.S. Fish & Wildlife Service 2009). Shooting is not permitted in Badlands National Park or the adjacent Conata Basin (Buffalo Gap National Grassland), but the state and Badlands NP provide control, either through chemical control or live trapping, when prairie dogs expand from public to private land.

South Dakota 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 also created a management plan within the guidelines of the multi-state agreement, but with additional goals and objectives for South Dakota (Cooper and Gabriel 2005).

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 section on Configuration). 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 Badlands NP.

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. Therefore, in addition to considering colony area, we also examined colony configuration. 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. We present raw data on colony configuration at Badlands NP and discuss several aspects of configuration that may be useful for management in variable future scenarios.

Colony size

The presence of large colonies is likely important for the long-term persistence of black-tailed prairie dogs and dependent species (Figure 4.10.6). 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).

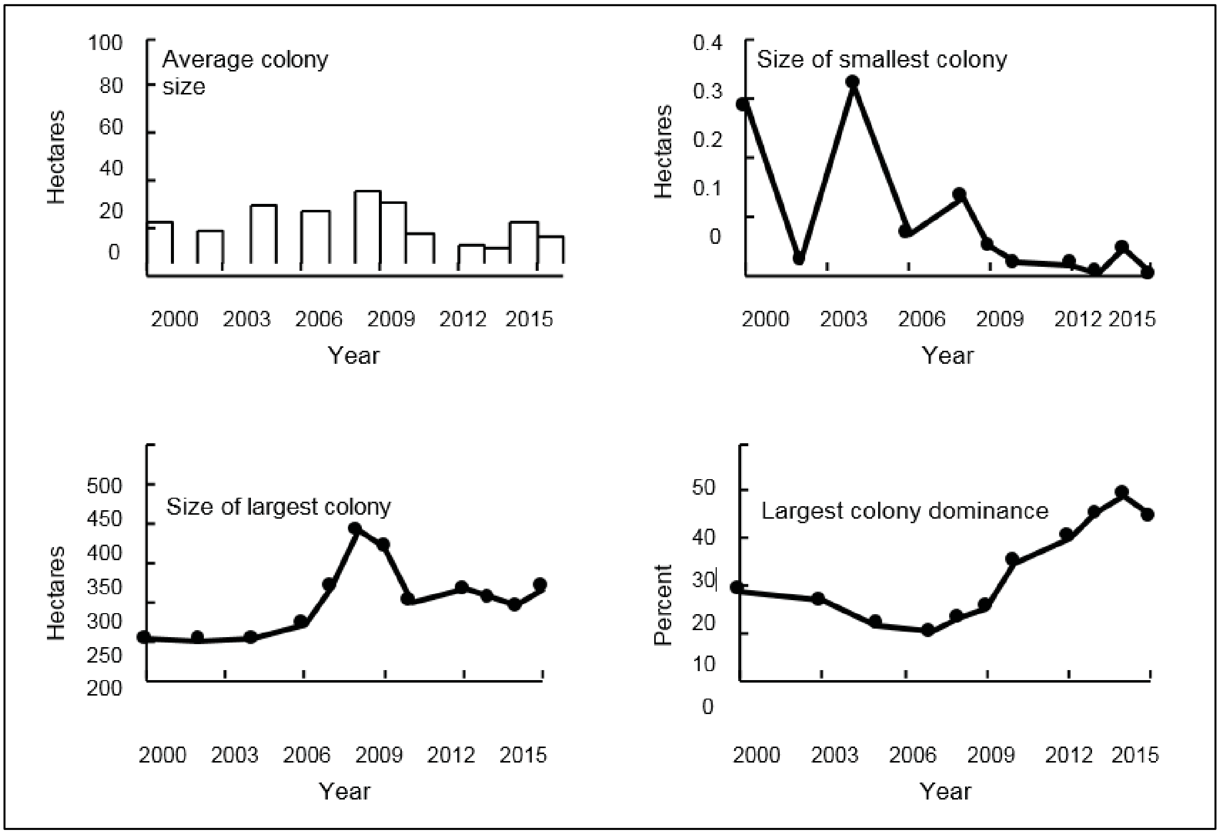

Figure 4.10.6. Black-tailed prairie dog colony size metrics for Badlands National Park. Both the average colony size and the size of the largest prairie dog colony peaked just prior to the onset of plague. Large colonies now account for a disproportionate amount of total colony acreage, largely due to the prioritization of plague mitigation on these colonies and reduction in the size and number of small colonies.

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 (Figure 4.10.7).

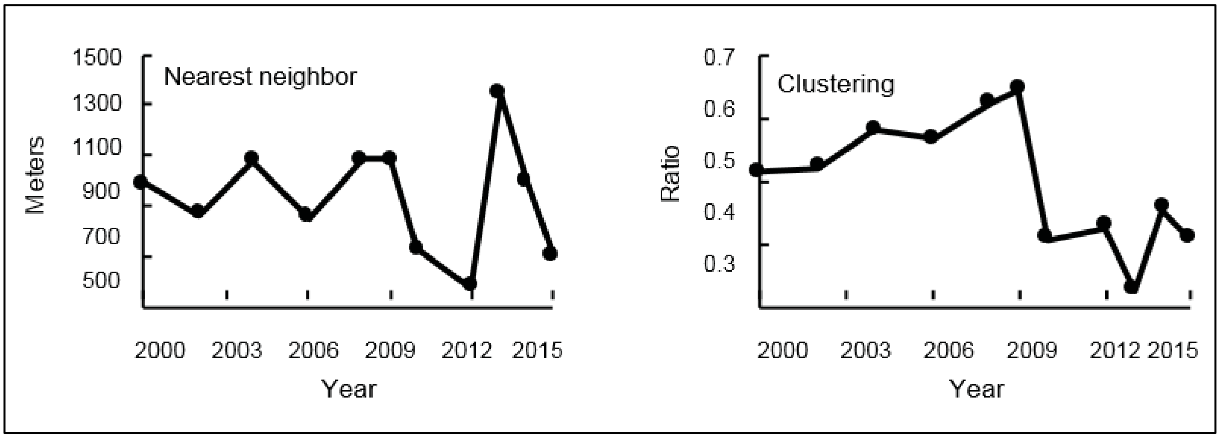

Figure 4.10.7. Black-tailed prairie dog colony distribution metrics for Badlands National Park. The average inter-colony distance (distance to nearest neighbor) has remained consistently lower than one and a half kilometers in Badlands. Data show that colonies have become less diffuse within the park between 2000 and 2015.

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 (Figure 4.10.8). 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).

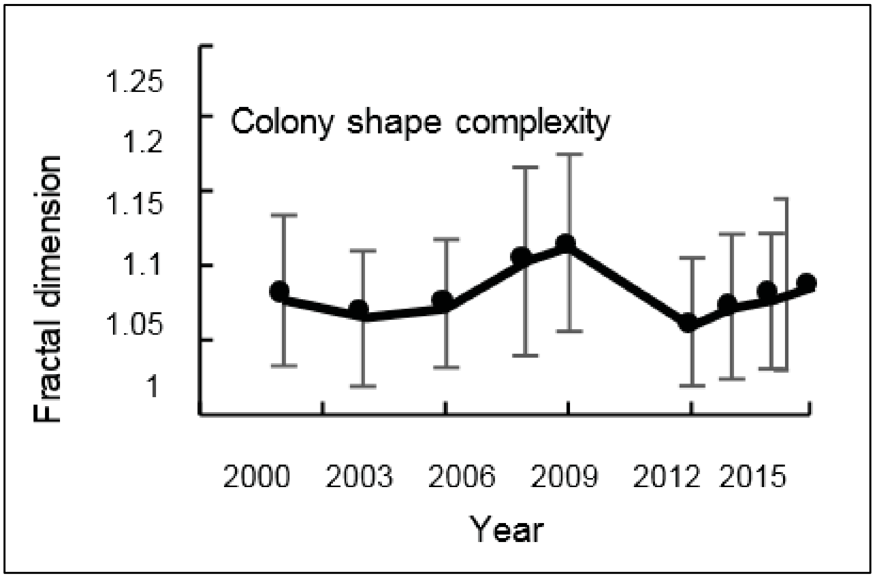

Figure 4.10.8. Black-tailed prairie dog colony shape metrics for Badlands National Park. Colony expansion peaked at the time of greatest shape complexity.

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 black-footed ferret and swift fox 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); this relationship may not be as strong in the presence of plague. Furthermore, the management goals for Badlands NP are set based on colony area (NPS 2007).

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).

Badlands NP has identified 24,215 hectares (59,834 acres) of suitable black-tailed prairie dog habitat in the north unit and is managing prairie dogs to maintain 7–15% occupancy of available suitable habitat. If prairie dog acreage declines to 5% or less of suitable habitat, park resource managers are committed to restoring prairie dogs (NPS 2007).

We applied a 5% threshold to the lowest category, *Warrants Significant Concern* based on the recommendation of Mulhern and Knowles (1997) and the management goals of Badlands NP (NPS 2007; Table 4.10.1). To assign values to the *Warrants Moderate Concern category*, we created an even break between the lowest and highest categories (5–10%). The lower end of the management goal for the north unit of Badlands (7% occupancy) falls within this range. Finally, for the *Resource in Good Condition* category, we assumed that anything above 10% occupancy would be desirable (Mulhern and Knowles 1997), and this value falls within the management goals of the Park Service (NPS 2007).

Table 4.10.1. Black-tailed prairie dog condition categories for proportion 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 2000–2015. 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). Personnel attempted to map at least half of the north unit each year; we restricted our analyses to this portion of Badlands NP. Through 2007, maps from the year of interest were combined with those from the previous year in order to provide total acreage estimates for the north unit. For example, the acreage reported for 2007 is the combined total of portions of the park mapped in 2007 and 2006, while the acreage reported for 2006 is the sum of areas mapped in 2006 and 2005. Since 2008, when plague first reduced the numbers and sizes of colonies, personnel have mapped all colonies in the north unit each year. We used ArcMap 10.2.2 to calculate colony metrics in each year.

Quantifying Black-tailed Prairie Dog Condition, Confidence, and Trend

Indicator Condition

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 (Figure 4.10.9).

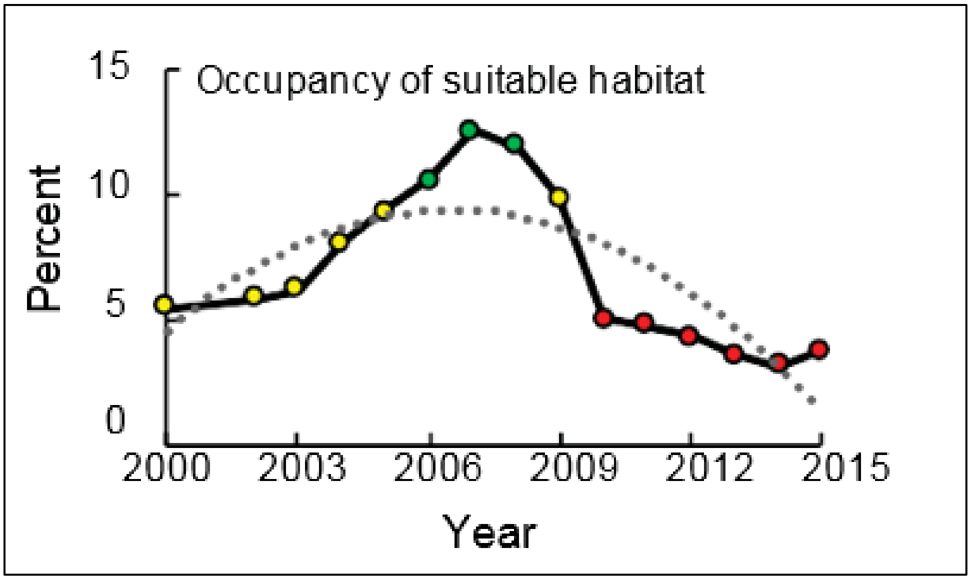

Figure 4.10.9. Changes in the percentage of suitable habitat occupied by black-tailed prairie dogs in the north unit of Badlands National Park. The green dots represent a period during which the occupancy of suitable habitat fell within the *Resource in Good Condition* category, yellow dots represent the *Warrants Moderate Concern* category, and red dots represent the *Warrants Significant Concern* category. A quadratic trend is shown with a dotted line. Occupancy peaked in 2007. Plague was first detected in the region in 2005 and in Badlands in 2009. Acreage was not available for 2001.

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 2000–2015 to capture the effects of plague. 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 Badlands NP (Table 4.10.2).

Table 4.10.2. Summary of black-tailed prairie dog indicators and measures.

Indicator	Measure	Condition	Confidence	Trend	Condition rationale
Colony area	Percentage of suitable habitat occupied	Warrants significant concern	High	Deteriorating	Acreage was 3.8% of suitable habitat in 2015; 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*.

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 Significant Concern
Confidence: High
Trend: Deteriorating

Condition

To assign a condition to colony area, we used a proportion of suitable habitat occupied by prairie dog colonies in the north unit. In 2015, there were 910 hectares of active prairie dog colonies in the north unit. The latest estimate of suitable prairie dog habitat (based on land cover and slope characteristics) from 2007 was 24,215 hectares (NPS 2007). Therefore, 3.8% of suitable habitat was occupied by prairie dogs in 2015. This value placed black-tailed prairie dog area for Badlands in the *Warrants Significant Concern* category.

Confidence

Occupancy was calculated from maps in ArcMap 10.2.2. At least half of the north unit was mapped each year. Because the intent was to map all colonies at least every two years and the same procedure was used for all surveys, the confidence was *High*.

Trend

We used 16 years of mapped colonies to assess a trend in black-tailed prairie dog acreage (Figure 4.10.10). From 2000–2007, at least half of the north unit was surveyed each season so that acreage estimates for those years represent the colonies mapped in that year plus the previous year. Since 2008, it has been possible to map all colonies each season owing to the reduced number and area of colonies.

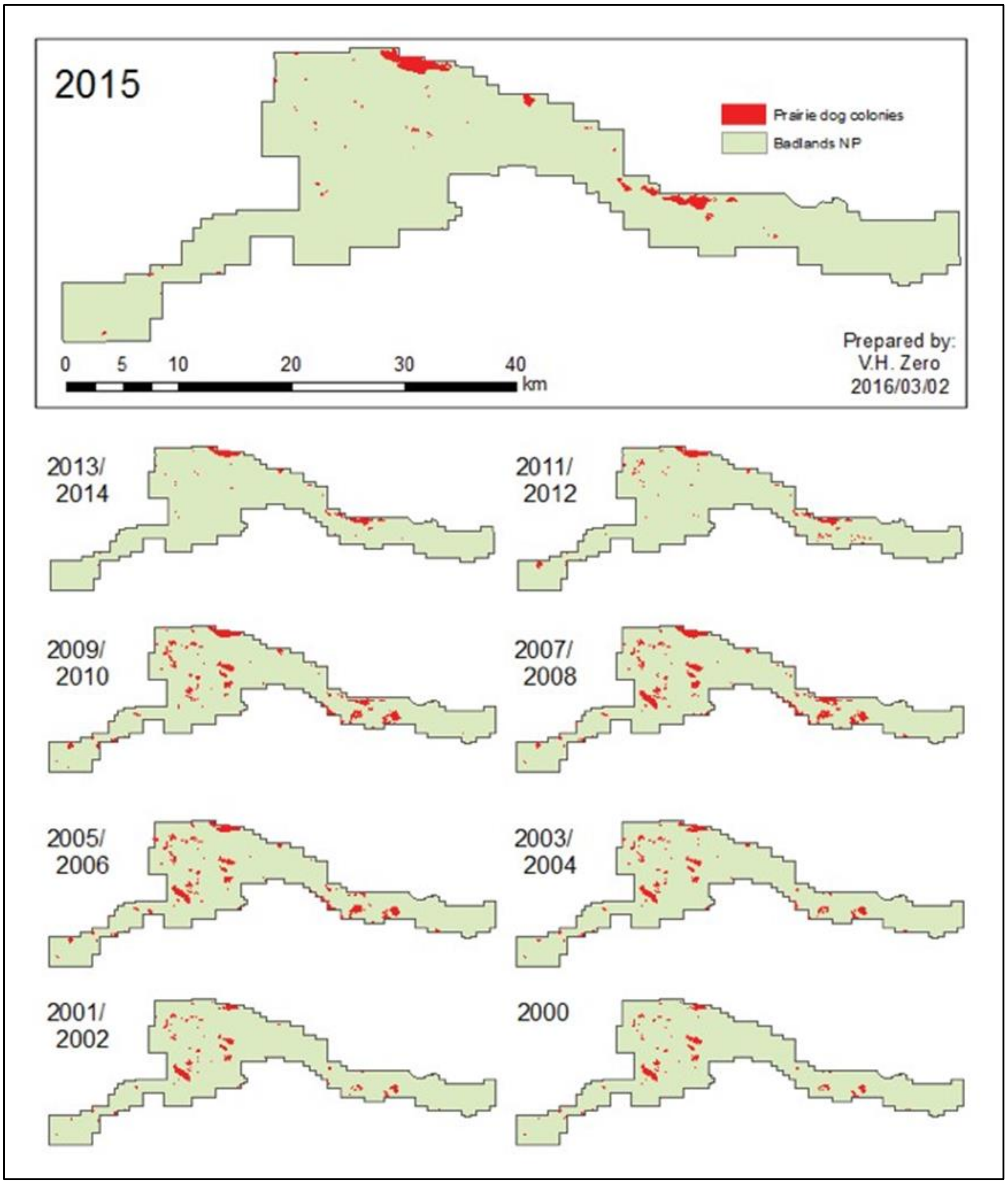

Figure 4.10.10. Changes in the distribution of black-tailed prairie dog colonies in Badlands National Park between 2000 and 2015. Acreage peaked at 3,027 hectares in 2007, two years before the first detection of plague within the park. Acreage hit a low of 750 hectares in 2014, a 75% area loss since before plague.

We fit one linear and three nonlinear models to the data. We selected a quadratic model as the best fit for the data based on significance and model improvement ($R^2 = 0.6266$, df = 12, $P = 0.002712$). The slope of the trend line following plague was negative, so trend was *Deteriorating*.

Black-tailed Prairie Dog Overall Condition

Table 4.10.3. Black-tailed Prairie Dog overall condition.

Indicators	Measures	Condition
Colony area	Percentage of suitable habitat occupied	⬇

The overall black-tailed prairie dog condition was the same as the single indicator condition, which placed the condition of black-tailed prairie dogs at Badlands National Park in the *Warrants Significant Concern* category (Table 4.10.2).

Confidence

Confidence was *High* for prairie dog condition.

Trend

Trend data were *Available* for colony acreage from 2000–2015 and overall trend for black-tailed prairie dogs was *Deteriorating*.

4.10.5. Stressors

Disease

Sylvatic plague is the greatest threat to prairie dogs and associated species in Badlands NP. 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 a 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) and may have reached South Dakota around the early 2000s when it was first detected in the southwestern part of the state. Prairie dog colonies in nearby Conata Basin and Badlands NP were expanding until plague outbreaks occurred in 2008 and 2009, respectively.

The primary strategy for controlling plague outbreaks is “dusting” burrow entrances with insecticide to kill the fleas that transmit plague. Dusting has been used at these sites annually since plague was first detected in the region. Dusting, while largely successful, is not the panacea for black-tailed prairie dog recovery. Fleas have begun to show signs of resistance to the current dusting insecticide (deltamethrin; E. Childers, personal communication, 24 November 2015), so the success of longer-term dusting efforts hinges on finding an alternative insecticide. Dusting is also an expensive endeavor ($16.30 per acre in 2015; Griebel 2015). Historically, funding for dusting in Badlands came from recreational fee demonstration funds. The NPS did not renew this funding in 2015, and funding for 2016 is uncertain.

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

Yellow sweet clover (*Melilotus officinalis*) invasion may pose a moderate threat in wet years, such as 2014, when this plant is able to expand rapidly. Prairie dogs rarely consume sweet clover (Uresk 1984), and this forb recently accounted for ~ 20% of plant cover in Badlands (Prowatke and Wilson 2015). Prairie dogs generally avoid areas of tall vegetation; sweet clover can grow very tall (up to 1.8 m), well above the preferred vegetation height of < 30 cm (Figure 4.10.11). Expansion of sweet clover reduces and fragments colonies (Griebel 2014), which may magnify colony losses from plague. Sweet clover is not listed as a species of management concern (Prowatke and Wilson 2015), but evidence suggests that this species may pose a threat to prairie dog management goals.

Figure 4.10.11. Yellow sweet cover. Yellow sweet clover growth may compromise prairie dog habitat (Photo courtesy of Wikimedia Commons 2014).

4.10.6. Data Gaps

Disease Ecology

Although discussion of plague typically centers on its lethality to black-footed ferrets and 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). Biologists with the USGS 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 forage species (Roe and Roe 2003) that can be found within Badlands include: western wheatgrass (*Pascopyrum smithii*; ~ 40% of total plant cover in the park), blue grama (*Bouteloua gracilis*; ~ 5% of total plant cover), buffalograss (*Bouteloua dactyloides*), sand dropseed (*Sporobolus cryptandrus*), sixweeks fescue (*Vulpia octoflora*), nine species of sedge (*Carex* spp.), scarlet globemallow (*Sphaeralcea coccinea*; ~ 1% of total plant cover), and plains prickly pear (*Opuntia polyacantha*). It may be possible for the park to manipulate vegetation composition and structure, and consequently prairie dog acreage, by varying bison stocking rates (D. Licht, personal communication, 29 April 2016).

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4.11. Black-footed Ferret

4.11.1. Background and Importance

Black-footed ferrets (*Mustela nigripes*) are charismatic, globally endangered carnivores endemic to North America (Figure 4.11.1). They are nocturnal, solitary, territorial animals that are closely tied to prairie dog (*Cynomys* spp.) colonies. Prairie dogs are a primary prey source for ferrets and their burrows provide shelter for this unique member of the weasel family (Mustelidae).

Figure 4.11.1. Black-footed ferret (Photo by Dan Foster, NPS).

Historically, ferret distribution coincided with the ranges of three prairie dog species, from southern Canada throughout the Great Plains to northern Mexico (Anderson et al. 1986, NatureServe 2007). Fossilized remains of black-footed ferrets have been found outside of the known ranges of prairie dogs, where they may have subsisted on other ground-dwelling rodent species (Owen et al. 2000), but ferrets now co-occur exclusively with prairie dogs. The majority of ferret habitat overlaps with that of black-tailed prairie dogs (*Cynomys ludovicianus*), which have experienced as much as a 98% reduction in their historic range (Miller et al. 2007). Prairie dog populations have declined precipitously both in terms of number and geographic extent. Initial declines were due to habitat loss from cropland conversions and systematic poisoning. Later, sylvatic plague wiped out large numbers of prairie dog colonies. Ferret populations have consequently declined and have further suffered direct mortality from plague and canine distemper.

The black-footed ferret was listed as a federally endangered species in 1967 and as a South Dakota endangered species in 1978. Later thought to be extinct in the wild, a remnant population was rediscovered in Wyoming in 1981 and the remaining 18 individuals were removed for captive breeding. Reintroductions began in 1991 and extended to Badlands National Park in 1994 and Conata Basin (Buffalo Gap National Grassland) in 1996. There are 26 total reintroduction locations to date. Black-footed ferret populations in Conata Basin and Badlands NP are now considered one biological population so we refer to them jointly throughout our assessment; Conata Basin/Badlands is the interagency name for this black-footed ferret recovery area. The black-footed ferret remains one of the rarest free-ranging mammals in North America, with an estimated self-sustaining population of 167 mature individuals range-wide (Belant et al. 2015).

The black-footed ferret's dependence on prairie dogs was a critical factor in its decline and is a continual challenge for successful recovery of the species. The immediate threat of canine distemper has been ameliorated through the use of vaccines. Perhaps the largest current impediment to recovery is sylvatic plague, to which both prairie dogs and ferrets are highly susceptible.

The National Park Service (NPS) has demonstrated its dedication to protecting this resource through reintroduction, research, and monitoring efforts. Black-footed ferrets were reintroduced to Badlands National Park in 1994 after more than two decades of absence (Plumb et al. 1995) in a collaborative effort between the NPS, U.S. Forest Service (USFS), and U.S. Fish & Wildlife Service (USFWS). Badlands NP and Wind Cave NP are the only two national parks where black-footed ferrets have been reintroduced. Badlands NP strives to inform the public about black-footed ferrets, including through an educational display at the visitor center, summer programs on ferrets and prairie dogs, and the 2011 Badlands Ferret Festival.

The Conata Basin/Badlands population of ferrets remains one of the most successful reintroduction efforts to date, largely due to the quantity and quality of black-tailed prairie dog colonies at these sites. Since the time of reintroductions, the black-footed ferret population has been monitored annually. From 2000–2008, the Conata Basin site was producing surplus kits that were used for translocation to other reintroduction sites (Figure 4.11.2). Southwestern South Dakota was plague-free during the early years of reintroduction, but outbreaks occurred in 2008 in Conata and 2009 in Badlands. Prairie dog and ferret populations are now a fraction of pre-outbreak numbers. The primary strategy for controlling plague outbreaks is "dusting" burrow entrances with insecticide to kill the fleas that transmit plague. Dusting has been employed at these sites annually since plague was first detected. Ferrets in Conata Basin/Badlands are given a vaccine series when they are captured during surveys. Oral vaccines for prairie dogs are being tested throughout the country, including at Conata Basin since 2013, as an additional line of defense against plague (USGS 2013).

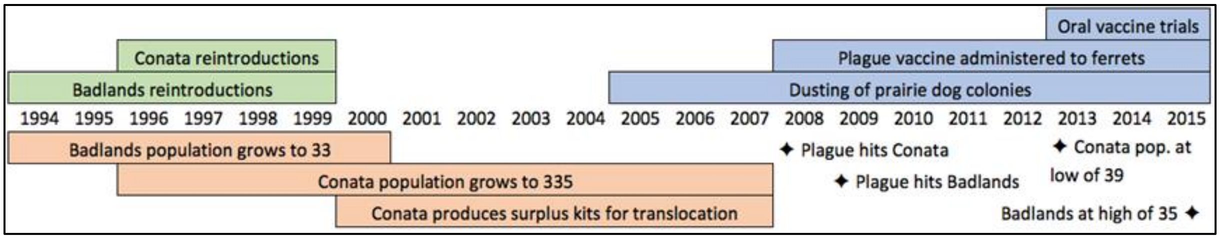

Figure 4.11.2. Timeline of black-footed ferret management actions and resource condition Conata Basin/Badlands.

Between 1994 and 1999, ferrets were released at three locations within the north unit of Badlands, but three of them failed to establish and have since succumbed to plague (T. Livieri, personal communication, 9 March 2016). Ferrets were later translocated to Roberts Prairie Dog Town. Prairie Wind Overlook was likely colonized by natural dispersal of nearby animals from Conata Basin. As of 2015, ferrets inhabited the latter two black-tailed prairie dog complexes, or clusters of colonies, within Badlands (Roberts and Prairie Wind; Figure 4.11.3). They also occurred on four prairie dog complexes bordering the park in Conata Basin (Heck Table, Sage Creek, Agate, and Steer Pasture).

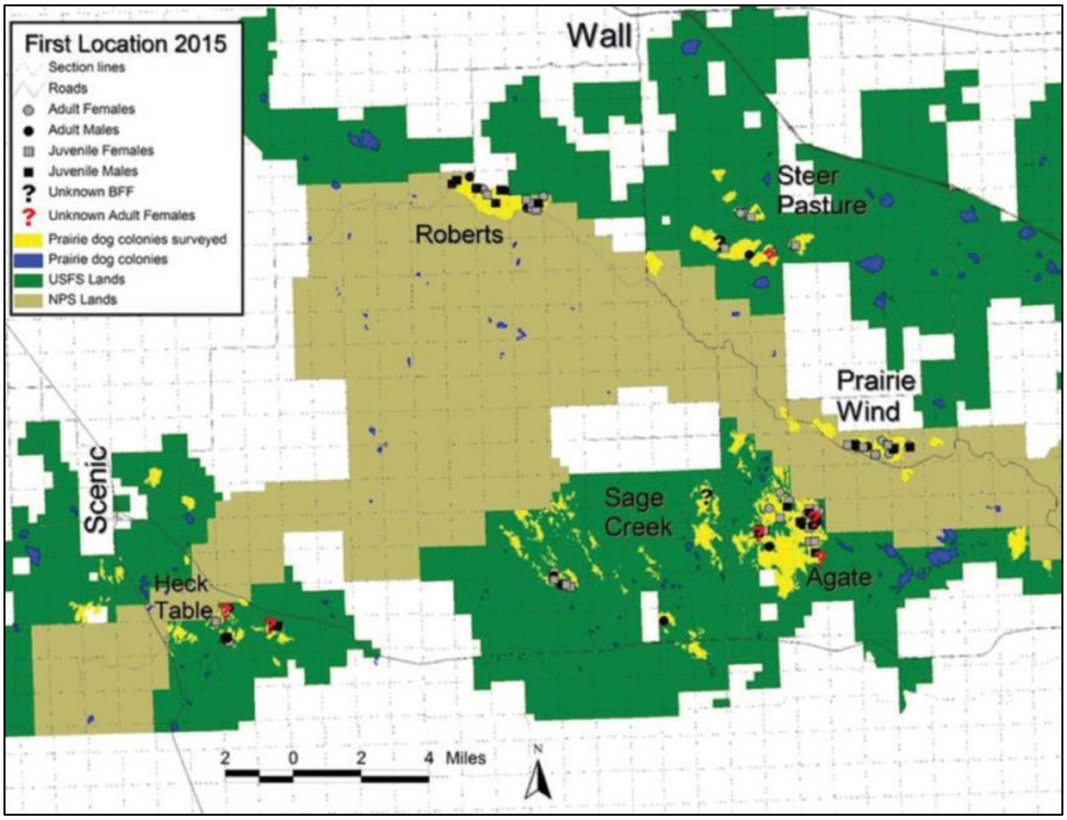

Figure 4.11.3. Locations of five prairie dog complexes known to have black-footed ferrets in Conata Basin/Badlands, South Dakota for 2015 (Livieri 2016). The first location and type of each ferret observed in 2015 is also mapped. Black-tailed prairie dog colonies shown in yellow were spotlight surveyed, while colonies in blue were not.

The black-footed ferret is a flagship species, or conservation symbol, for the North American prairie. Historically, grasslands were North America's most extensive biome, but today most prairie has been altered by agriculture or development. Badlands National Park protects one of the largest expanses of mixed-grass prairie in the United States. Protecting ferrets in Badlands and elsewhere provides opportunities to conserve other animals and plants that depend on this imperiled ecosystem.

Regional Context

Since 1991, ferrets have been reintroduced to 26 sites in eight states (Wyoming, South Dakota, Montana, Arizona, Utah, Colorado, Kansas and New Mexico), one site in Mexico, and one site in Canada (Figure 4.11.4). Populations in Mexico and Canada are now extirpated. At present, populations are self-sustaining at only four locations: Conata Basin/Badlands and Cheyenne River in South Dakota, one in Arizona, and one in Wyoming (Belant et al. 2015). It is possible that even these "self-sustaining" sites may require additional ferret allocations in the near future. Even with ongoing and intensive management, wild black-footed ferret populations remain small and fragmented.

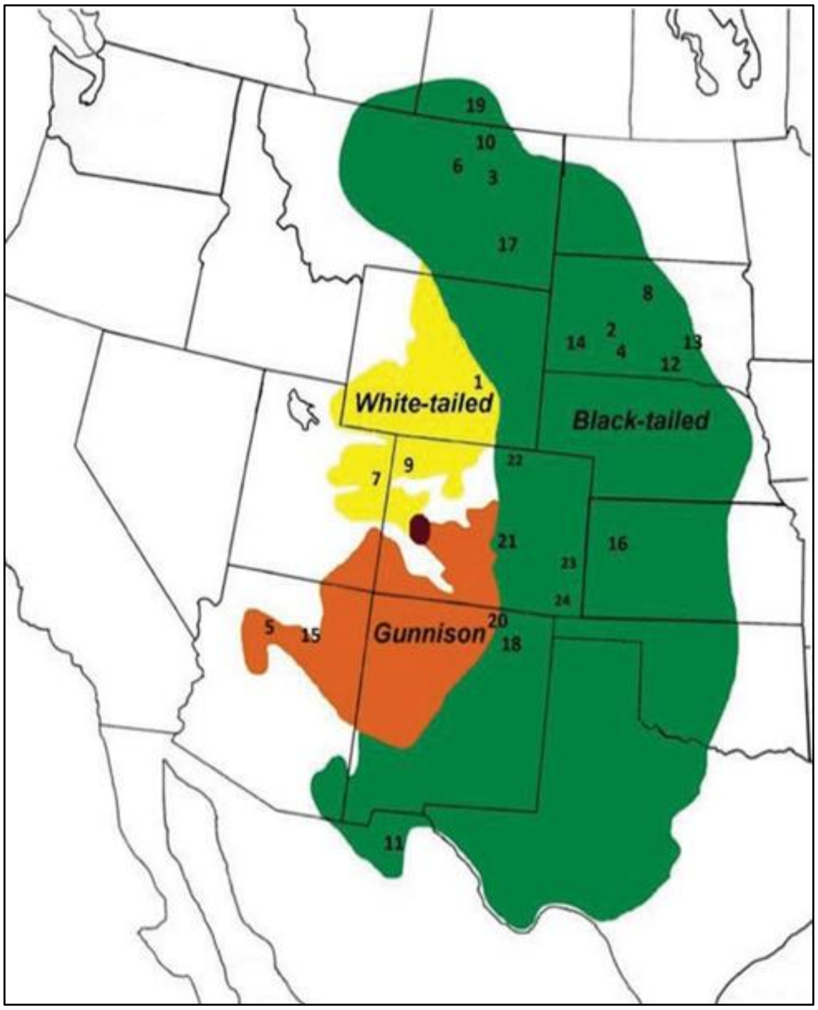

Figure 4.11.4. Black-footed ferret reintroduction sites mapped over the ranges of three prairie dog species. Populations are numbered in the order in which they were reintroduced. The most recent reintroduction sites (25-26) are not included. Badlands National Park, 2; Conata Basin, 4 (USFWS 2015).

Across all reintroduction sites, the estimated total number of wild ferrets calculated from minimum number alive observations was close to 400 in 2015 (Figure 4.11.5), with an estimated 295 wild-born individuals (Belant et al. 2015). Of these individuals, the majority were found at just four reintroduction sites that are considered to be self-sustaining, including Conata Basin/Badlands. Just two generations prior, in 2009, the estimated number of mature (breeding) individuals was 448 (IUCN 2015). This loss of roughly a third of the population of mature adults occurred in only six years (Table 4.11.1).

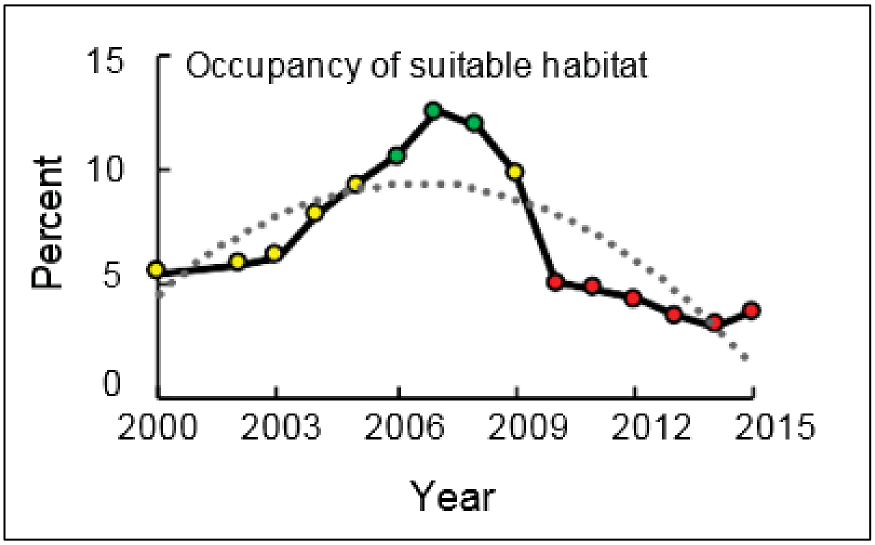

Figure 4.11.5. Minimum total number of black-footed ferrets known to be alive in the wild each year since reintroductions began. These numbers include both wild-born individuals and translocated ferrets. Data are approximate estimates from Black-Footed Ferret Recovery Implementation Team Conservation Subcommittee reports and Jachowski and Lockhart (2009). Data points are missing for 2009, 2010, 2012, and 2013.

Table 4.11.1. Estimated number of mature (breeding) individuals across all reintroduction sites (Belant et al. 2015). These estimates are derived by halving minimum number alive estimates from the previous fall. The number of breeding adults is the metric used in Endangered Species Act listing criteria.

Year	Ferrets
2009	448
2012	274
2014	296
2015	295
2016	170

4.11.2. Resource Standards

Black-footed ferrets are protected under the Endangered Species Act (ESA; 39 FR 1171). This act mandates that all federal agencies fully promote and support black-footed ferret recovery. Some reintroductions, including those at Conata Basin/Badlands have been accomplished under a special provision of the ESA (section 10[j]) that provides for designation of reintroduced ferret populations as "nonessential, experimental." Ferrets released into nonessential, experimental population areas are given protection and management flexibility similar to that provided for "candidate" species (candidates for listing under ESA but not yet listed). They are also listed as a state endangered species in South Dakota (http://gfp.sd.gov/wildlife/threatened-endangered/).

The national goal is to establish ten or more self-sustaining wild populations of black-footed ferrets in order to downlist the ferret from endangered to threatened (U.S. Fish & Wildlife Service 2013). Downlisting further stipulates that there be no fewer than 30 breeding adults in any of the ten populations for a minimum of three years. Removing black-footed ferrets from ESA protection (delisting) requires that a minimum of 3,000 free-ranging breeding adults persist in 30 or more populations. Populations must be established in at least 9 states within the historical range of the species. To count towards the 30 populations, a population must contain no fewer than 30 breeding adults, and at least 10 populations must have 100 or more breeding adults (U.S. Fish & Wildlife Service 2013).

4.11.3. Methods

Important note on methods: although managed by different agencies, the reintroduced populations at Badlands (NPS) and Conata Basin (USFS) have long been considered a single biological population. The NPS manages for ferrets within the north unit of the park, so indicator data are presented for this unit. The USFS manages for ferrets within Black-Footed Ferret Management Area 3.63 in the Wall Ranger District of Buffalo Gap National Grassland. Wild-born ferrets regularly disperse up to 7 kilometers (Forrest et al. 1988) but may occasionally move 20 kilommeters or more (U.S. Fish & Wildlife Service 2013). Ferret colonies within Badlands NP are farther apart from one another than they are to some colonies in Conata. Most, if not all, prairie dog colonies within the Conata Basin/Badlands complex are within the possible range of ferret movement. Ferrets have been observed to move between management boundaries, and individuals are occasionally translocated between sites. We therefore assessed condition of the Conata Basin/Badlands complex as a single biological unit. We present indicators and measures for this combined population.

Indicators, Measures, and Data Sources

Overall black-footed ferret condition depends first on the level of conservation concern, and then on the conditions of population size and habitat quality. To assign a condition to each indicator, we used measurements provided by NPS, USFS, and Prairie Wildlife Research (Wellington, Colorado) and applied these measurements to ferret populations at Conata Basin/Badlands. Potential condition categories were: *Resource in Good Condition*, *Warrants Moderate Concern*, and *Warrants Significant Concern*. We then considered all indicator conditions together in an overall black-footed ferret condition assessment.

Indicator: Conservation Concern

Species that have experienced declines or are likely to decline often receive an official classification of conservation concern and special conservation status.

Measure of Conservation Concern: Federal Protection Status

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). If black-footed ferrets were listed under the ESA at the time of the assessment, we gave the condition Warrants Significant Concern and this condition served as the overall resource condition. This condition supersedes those given by all other indicators. In South Dakota, the State Wildlife Action Plan (SDGFP 2014) designates Species of Greatest Conservation Need (SGCN) as high priority for conservation focus. The USDA Forest Service and Bureau of Land Management also maintain sensitive species lists (USFS 2015, BLM 2009). In the future, if black-footed ferrets are no longer listed under ESA but are listed as South Dakota SGCN, have some other sensitive species status, or are being considered for ESA listing, we suggest the condition as Warrants Moderate Concern. This condition supersedes those given by all other indicators. In the future, if black-footed ferret recover to the point that they do not need a conservation priority status, condition should be determined by other indicators and measures that we described below.

Indicator: Population Size

Predator populations naturally fluctuate, often in cycles that follow changes in prey density (e.g., O’Donoghue et al. 1997). Ferrets in particular may cycle with prairie dogs, and prairie dogs themselves may fluctuate with plague and drought cycles (Shoemaker et al. 2014). This indicator is therefore highly dependent on other indicators (such as habitat quality and disease).

Simulation models have indicated that a minimum of 120 individuals is required to maintain the viability of isolated ferret populations (Harris et al. 1989), while genetic models incorporating effective population size recommended at least 200 ferrets (Groves and Clark 1986). The delisting and downlisting criteria for the ESA require a minimum of 30 mature adults per population (U.S. Fish & Wildlife Service 2013). The ESA goal will ultimately be the metric that determines the listing status of ferrets in the United States. Population size also informs other management actions like the need for additional reintroductions (in the case of low population size), or the ability to provide kits for translocation to other sites (in the case of a highly productive population).

Measure of Population Size: Count of Adult Ferrets

Population size can be assessed in a number of ways. Among these approaches are abundance estimates of the total population, the number of individuals contributing offspring (often assessed through genetics), or demographic traits. Ideally, abundance estimates are corrected for imperfect detection and include estimates of error (Williams et al. 2002); however, it is generally beyond the resource capabilities of the NPS and other agencies to derive this sort of abundance estimate (but see Grenier et al. 2009).

The standard has therefore been to report the minimum number alive (MNA). The MNA is the number of unique individuals captured, plus a (typically small) number of unknown individuals that are presumed to be unique through a conservative assessment of time and distance separation (Biggins et al. 2006a). After four nights of spotlight searching, between 82 and 98% of ferrets may be detected (Biggins et al. 2006a). The age and sex of all individuals captured are also reported. The number of adult (mature) individuals can thus be used as an approximation of the number of breeding adults. This is probably an overestimate, as the actual number of breeders may range from 20-50% of adults (U.S. Fish & Wildlife Service 1988), or 50-75% by another estimate (T. Livieri, personal communication, 9 March 2016).

Spotlighting surveys at Badlands NP occurred inconsistently until recently but now occur annually. Almost 800 hectares (2,000 acres) were surveyed in 2015 during 206 spotlighting hours. Given the substantial survey effort employed at Badlands, it is likely that nearly all individuals within the surveyed area were sighted during surveys (Biggins et al. 2006a). The area covered within Badlands is similar from year to year; prairie dog colonies known and suspected to be inhabited by ferrets were surveyed, with the greatest survey effort devoted to known and suspected colonies (T. Livieri, personal communication, 15 January 2016). Overall survey effort and coverage was generally consistent between years in both locations, varying somewhat according to site accessibility, the number of personnel available for surveys, and the suspected locations of ferrets.

We used the most conservative interpretations of ESA criteria for downlisting and delisting to assess the condition of the Conata Basin/Badlands ferret population. To contribute to downlisting, Conata Basin/Badlands would need at least 30 breeding adults for at least three years. To contribute to delisting, the more substantial status change, Conata Basin/Badlands would need to be one of ten populations with no fewer than 100 breeding adults. The Conata Basin/Badlands population has historically been one of only four self-sustaining reintroduction sites, so it is reasonable to assume that it could serve as one of ten populations meeting the requirement for a larger population (> 100 adults) that contributes to downlisting. We also used 100 breeding adults as a benchmark when assigning population size categories because early simulation and genetic studies suggested minimum population sizes on this order of magnitude (Groves and Clark 1986, Harris et al. 1989). We used the downlisting and delisting criteria to assess population quality: a population that *Warrants Significant Concern* would meet neither of these criteria, a population that *Warrants Moderate Concern* would meet downlisting criteria, and a population in *Good Condition* would be indicated by meeting delisting standards (Table 4.11.2). We rated these populations for the most recent year, 2015, and included previous years in our analysis of population trends.

Table 4.11.2. Black-footed ferret condition categories for count of adult ferrets (i.e., potential breeder).

Resource condition		Adults counts
Warrants significant concern	🔴	< 30
Warrants moderate concern	🟡	30 ≥ x < 100
Resource in good condition	🟢	≥ 100

Indicator: Habitat Quantity

The amount and quality of habitat limits the abundance, distribution, and quality of ferrets that may be present. The most important component of habitat quality for ferrets is prey availability (See section on Ferret Family Rating). Prairie dogs compose the majority of a ferret's diet. Ferrets also capitalize on prairie dog burrows for shelter, hunting, and raising young.

Ferret Family Rating

During the planning stage of ferret reintroductions, the need for a quantitative measure of habitat quality became evident. A metric was developed and later refined (Biggins et al. 1993, 2006b) that could be used both in assessing and monitoring the habitat quality of current and future reintroduction sites. While a variety of factors may contribute to habitat quality, the calculations focus on the black footed ferret's primary prey—prairie dogs. The ferret family rating (FFR) combines information about the extent of available prairie dog colonies and the density of prairie dogs within those colonies. The calculation also includes a number of variables that are generally assumed to be constant (but which could be varied given improved data availability), which are combined to give the number of prairie dogs consumed annually by one ferret family. The output generated by the equation represents the number of ferret families (1 female, 0.5 male, 3.3 kits) that could theoretically be supported by the prairie dog complex/subcomplex of interest. This is essentially a point estimate of carrying capacity. For example, an FFR of 20 would suggest that a particular area of prairie dogs is capable of supporting 20 female, 10 male, and 66 kit ferrets. This corresponds to the lower threshold for downlisting criteria (Table 4.11.3). It is important to note that equation's greatest utility is in the comparison of reintroduction sites, as it rarely predicts the actual number of ferrets a site supports.

Ferret family rating (Biggins et al. 1993):

$$R = \sum_{i=1}^{n} (A_i \times P_i) \ / \ 763 \ \ for \ (A_i \ \times \ P_i) \geq 272.5$$

Where:

R = the number of ferret family groups that could be supported by the prairie dog complex (prairie dog complex is defined later),

A = the area of the colony with at least 3.63 prairie dogs per ha,

P = the density of prairie dogs in area A (prairie dogs per ha),

763 = the number of prairie dogs, under typical conditions, required to support one ferret family group for 1 year,

272.5 = the minimum number of prairie dogs needed to support one ferret family group for 1 year,

i = colony number, and

n = the number of colonies in the complex.

All of the data needed to calculate FFR for the areas of interest were not available, so we present an example for a portion of Conata Basin extracted from a plague report.

Table 4.11.3. The FFR values for Conata Basin for 2006, and 2008 to 2014. The FFR values indicate a significant reduction in carrying capacity since plague first appeared in the management area in 2009. In the example below, ferret family ratings for the Conata Basin (excluding Steer Pasture) dropped from 400.8 in 2006 to 106.2 in 2014. This loss of nearly three quarters (73.5%) of potential ferret habitat occurred in the span of just four generations (Griebel 2014).

Ferret Family Rating	2006	2008	2009	2010	2011	2012	2013	2014
FFR	400.8	286.5	214.3	207.9	125.2	159.9	136.6	106.2
% Change from prior year	–	-28%	-25%	-3%	-40%	+28%	-15%	-22%

Measure of Habitat Quantity: Black-tailed Prairie Dog Acreage

Research findings differ on the minimum area of prairie dog colonies required to sustain a female ferret and her kits. Recommended area varies from at least 30 hectares (75 acres) of occupied black-tailed prairie dog habitat (Hillman and Clark 1980) to 90 hectares (225 acres; U.S. Fish and Wildlife Service 2013). In Conata Basin, 95% fixed-kernel home-range sizes of female ferrets were 65 hectares (160 acres) and 132 hectares (326 acres) for males, with minimum convex polygon home range estimates of 42 hectares (104 acres) for females and 86 hectares (213 acres) for males (Livieri and Anderson 2012). Any acreage requirements are necessarily somewhat arbitrary, as the actual extent used per ferret family depends on prairie dog densities, the spacing of ferret territories, and other factors. Not all areas inhabited by prairie dogs may be suitable habitat for ferrets. We used the USFWS recommendation in our assessment because it combines the best available information on ferret habitat requirements.

We assumed a male:female sex ratio of 1:2 (Forrest et al. 1988, U.S. Fish & Wildlife Service 2013) and used the ferret population size categories to generate a required amount of prairie dog habitat for female ferrets and their kits based on the USFWS recommendation (Table 4.11.4). For example, using a sex ratio of 2 females for every 3 ferrets for the *Warrants Significant Concern* category would yield a threshold of 1,800 prairie dog acres (2/330 ferrets 90 hectares = 1,800 hectares of potential ferret habitat for females and their kits). Again, this estimate is approximate as not all prairie dog colonies may be suitable for ferrets.

Table 4.11.4. Black-footed ferret condition categories for ranges of black-tailed prairie dog acreage.

Resource condition		**Black-tailed prairie dog acreage**
Warrants significant concern	🔴	< 1,800 ha
Warrants moderate concern	🟡	1,800 ≥ x < 6,000 ha
Resource in good condition	🟢	≥ 6,000 ha

We used all available maps of active prairie dog colonies for Badlands NP provided to us as digital shapefiles. We restricted our analyses for Conata Basin to the mapped areas within the Wall Ranger District.

Data Collection

Data on adult counts were extracted from site reports for Conata Basin/Badlands, and from unpublished data (T. Livieri, personal communication, 9 March 2016).

Mapped data of prairie dog colonies were available in GIS shapefiles from 2000 to 2015 for Badlands NP. At least half of all colonies in the north unit were mapped every other year, so acreage for each year represents the sum of mapped colonies for that year and the year prior. Mapped data of active prairie dog colonies were available for the Wall Ranger District from 1993 to 2015. For Conata, mapped colonies within the Wall Ranger District were included. Area was calculated in ArcMap 10.2.2.

Quantifying Black-footed Ferret Condition, Confidence, and Trend

Indicator Condition

We assessed overall condition by examining black-footed ferret population size and habitat quantity, and assigned points to each measure to obtain a score for both indicators.

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.

Indicator Trend

Trend categories are *Improving*, *Unchanging,* or *Deteriorating*. Calculation of trend estimates required data that were quantified in the same way over multiple years. For both indicators, we fit a linear regression from 2005–2015. 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*. We fit additional regressions in order to capture the effects of plague.

Overall Black-footed Ferret Condition

To assess overall black-footed ferret condition, we used measures of population size and habitat quality. Indicators in the worst category, *Warrants Significant Concern*, were each assigned zero points, indicators in the *Warrants Moderate Concern* category received 50 points, and indicators in the best category, *Resource in Good Condition*, received 100 points. The average of these points was the total score for black-footed ferret condition high scores (67–100) indicated that black-footed ferrets were in *Good Condition*, medium scores (34–66) indicated that it *Warrants Moderate Concern*, and low scores (0–33) indicated that black-footed ferret condition *Warrants Significant Concern*.

Overall Black-footed Ferret Trend

If trend data were available, overall black-footed ferret trends were calculated similarly to overall black-footed ferret condition—using a points system to assign an overall trend category of *Improving*, *Unchanging*, or *Deteriorating*. If both indicators were improving, the overall trend was *Improving.* If both indicators were deteriorating, the overall trend was *Deteriorating.* If the indicator trends were not in agreement or both were unchanging, the overall trend was *Unchanging.*

Overall Black-footed Ferret Confidence

Overall confidence may be *High*, *Medium*, or *Low*. We calculated this confidence using a points system parallel to the one that we used for the overall condition; 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.

4.11.4. Black-footed Ferret Conditions, Confidence and Trends

Conservation Concern

↔

Condition: Warrants Moderate Concern
Confidence: High
Trend: Unchanging

Condition

Black-footed ferret are federally-listed as an endangered species under the Endangered Species Act (ESA) and therefore have the condition, *Warrants Significant Concern*.

Confidence

Ferret are closely monitored as an endangered species under the ESA and subject to frequent monitoring. Confidence was *High*.

Trend

Black-footed ferrets were thought to be extinct until 1981 and, though reintroductions have increased numbers, wild populations do not meet the requirements for changing their ESA listing status. Trend is *Unchanging.*

Population Size

⇩

Condition: Warrants Moderate Concern
Confidence: Medium
Trend: Deteriorating

Condition

To assign a condition for population size, we used the number of confirmed (captured or identified) adult ferrets in 2015. Fourteen (14) and 18 adults were captured or identified in Badlands NP and Conata Basin, respectively, for a total of 32 adult ferrets. This value placed population size for the Conata Basin/Badlands complex in the *Warrants Moderate Concern* category.

Confidence

Ferret populations were on site in Badlands NP or within approximately 30 kilometers (20 miles) of populations on surrounding grasslands in Conata Basin. Population size was measured by the number of adult ferrets captured or identified, using monitoring data from within the park and surrounding national grasslands. These counts may be underestimates, but the number of captured adults is typically a good approximation of the true number of adult ferrets within the area surveyed (Grenier et al. 2009). As described above, population estimates did not include estimates of variance. There are, however, population estimation methods that provide not just a population estimate, but a measure of confidence.

Survey efforts in Badlands exceed the recommended standards (Biggins et al. 2006a) and only eight ferrets were observed but not identified in Conata Basin/Badlands surveys in 2015 (T. Livieri, personal communication). While abundance estimates ideally come from surveys in which site selection and survey areas are standardized, those data are not always available. At Conata Basin/Badlands, search efforts were most intensive in areas known to have ferrets and the majority (85%) of prairie dog acreage was searched (T. Livieri, personal communication, 9 March 2016). Other potential occupied habitat in the park may have received minimal or no survey effort, although the chances of these areas supporting ferrets is thought to be low (T. Livieri, personal communication, 9 March 2016). Though survey effort was intensive, the confidence was *Medium* because the error for population size was not estimated and survey design was not randomized or stratified.

Trend

Data were available for the number of adult ferrets captured in Conata Basin/Badlands since 2005, when plague was first detected in the region (Figure 4.11.6). Plague was subsequently detected in Conata in 2008 and in Badlands in 2009. Since the arrival of plague at these sites, the overall population has declined, largely driven by changes in population size at Conata. A linear trend line was fit from 2005 to 2015, which indicated that the population of adult ferrets was declining ($R^2 = 0.6202$, df = 9, P = 0.0040). A linear trend line was also fit from 2007 to 2015 to capture impacts due to plague, which also indicated that the population of adult ferrets was declining ($R^2 = 0.7288$, df = 7, P = 0.0034). While the overall trend is that of decline since the time of plague, data from the last three years indicate possible recent stabilization in population size (Figure 4.11.7).

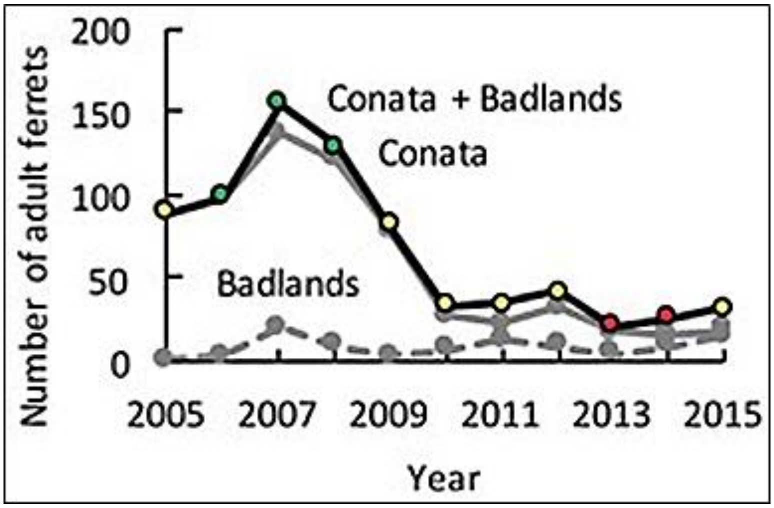

Figure 4.11.6. Trend in the number of adult black-footed ferrets captured in Conata Basin/Badlands over a 10-year period. Declines coincide with the advent of plague within these reintroduction sites. The green dots represent a period during which the total number of adults ferrets fell within the *Resource in Good Condition* category, yellow dots represent the *Warrants Moderate Concern* category, and red dots represents the *Warrants Significant Concern* category. Note that delisting and downlisting criteria require that population size fall within a particular category for at least three years. Under these criteria, the Conata Basin/Badlands population would not be considered a successful population for the period between 2013-2015.

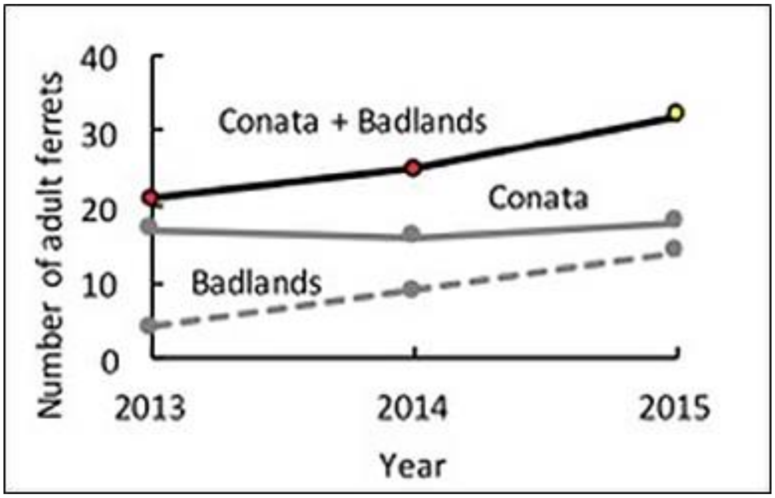

Figure 4.11.7. Short-term trend in the number of adult black-footed ferrets captured in Conata Basin/Badlands over a 3-year period. There is no statistical change in population size over this time period ($R^2 = 0.9758$, df = 1, P = 0.09943). Note that delisting and downlisting criteria require that population size fall within a particular category for at least three years. Under these criteria, the Conata Basin/Badlands population would not be considered a successful population for the period between 2013-2015.

Habitat Quantity

⇩

Condition: Warrants Moderate Concern
Confidence: High
Trend: Deteriorating

Condition

To assign a condition for habitat quantity, we used black-tailed prairie dog acreages calculated for 2015 from ground mapping performed by the NPS, USFS, and Prairie Wildlife Research. In Badlands NP and Conata Basin, 910 and 3,131 hectares were mapped, respectively, for a total of 4,041 hectares of potential habitat. This value placed habitat quality for Conata Basin/Badlands in the *Warrants Moderate Concern* category.

Confidence

Prairie dog acreage was mapped and monitored on site at Conata Basin/Badlands every other year. The same technique was used for all surveys (Plumb et al. 2001). Therefore, the confidence in this indicator was *High*.

Trend

Prairie dog acreage has been sampled regularly at Conata Basin/Badlands since the time of black-footed ferret reintroductions. Trend data are presented from the time plague was first detected in the region (Figure 4.11.8). Acreage peaked in Badlands in 2008 at 2,872 hectares. Since a 2006 peak of 13,548 hectares within the Wall Ranger District in Buffalo Gap NG, black-tailed prairie dog acreage has declined. Conata Basin acreage in 2015 was the lowest since 1993, with 9% (compared to 39% in 2006) of the management area surface area being covered by prairie dog colonies. The average size of a colony and the size of the largest colony have been decreasing, while the number of colonies has increased. Colonies have shrunk in size while becoming increasingly fragmented since plague appeared (Figure 4.11.9). A linear trend line was fit from 2005 to 2015, which indicated that prairie dog acreage was declining ($R^2 = 0.8547$, df = 5, P = 0.0029). A linear trend line was also fit from 2007 to 2015 to capture the impact of plague, which also indicated that prairie dog acreage was declining ($R^2 = 0.8049$, df = 3, P = 0.0390). Trend was *Deteriorating.*

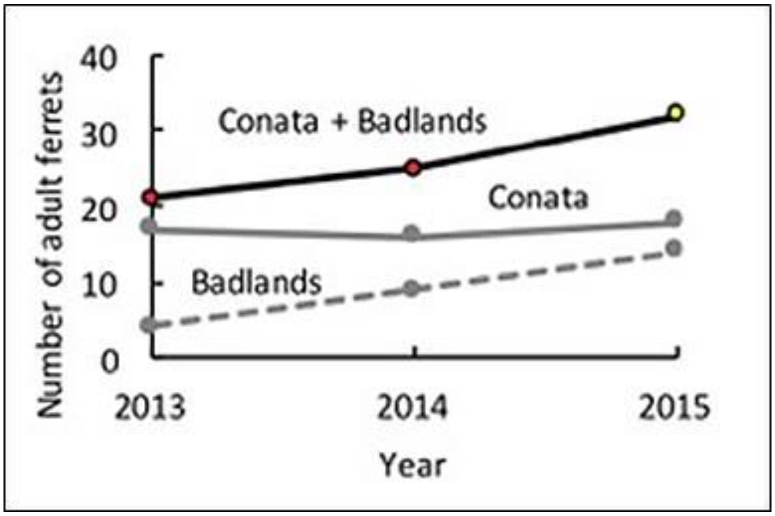

Figure 4.11.8. Trend in the acreage of black-tailed prairie dogs in Conata Basin/Badlands over a 10-year period. Declines coincide with the advent of plague within these reintroduction sites. The green dots represent a period during which prairie dog acreage fell within the *Resource in Good Condition* category, and yellow dots represents the *Warrants Moderate Concern* category.

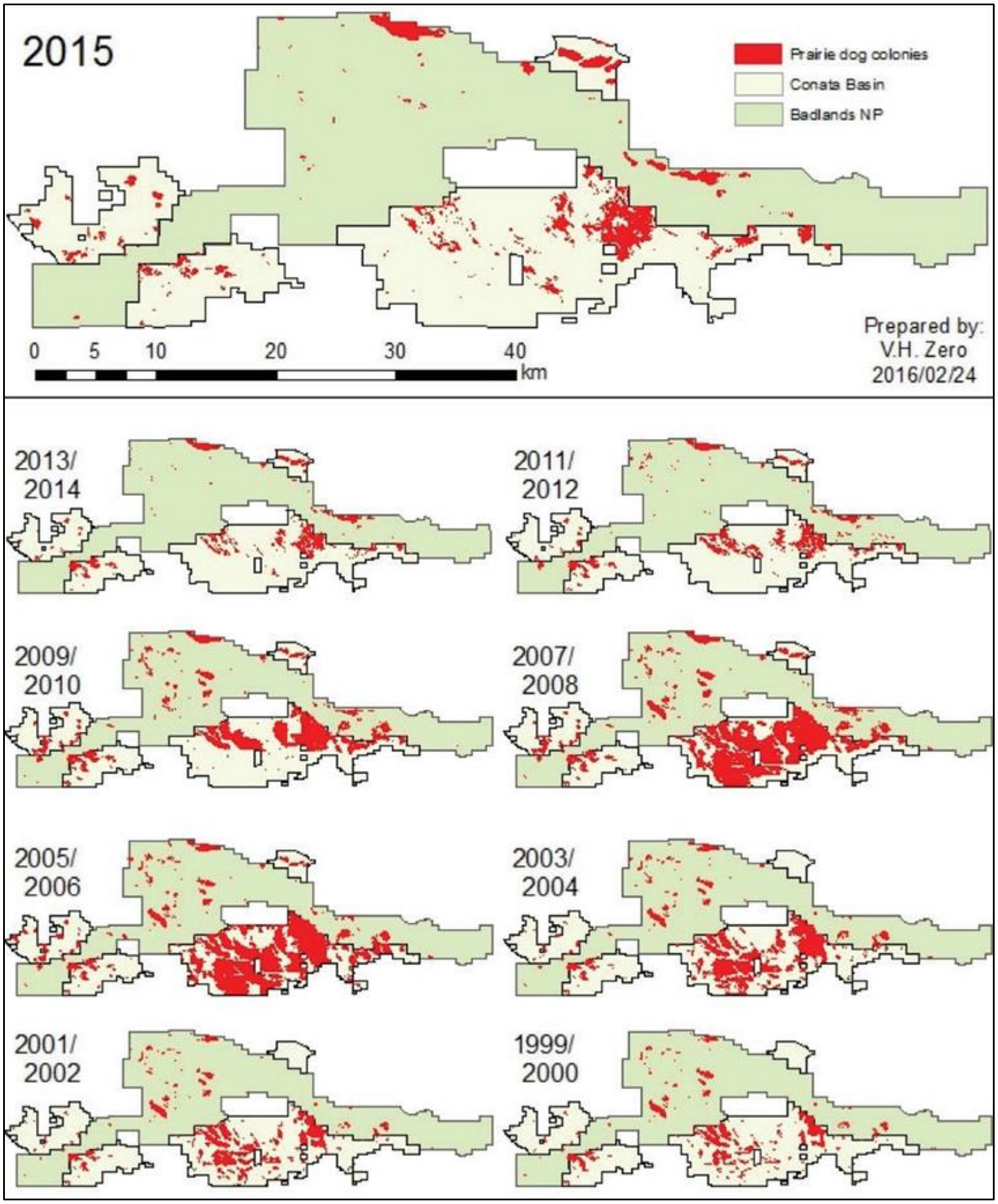

Figure 4.11.9. Changes in black-tailed prairie dog acreage through time for Badlands National Park (green) and Black-Footed Ferret Management Area 3.63 within the Wall Ranger District (light green). Plague was first detected in Conata Basin in 2008 and in Badlands in 2009.

Black-footed Ferret Overall Condition

Table 4.11.5. Black-footed ferret overall condition.

Indicators	Measures	Condition
Conservation concern	Federal protection status	🔴 ⇔
Population size	Count of adult ferrets	🟡 ⇩
Habitat quality	Black-tailed prairie dog colony acreage	🟡 ⇩
Overall condition for all indicators and measures		🔴 ⇔

Condition

The federal status of endangered under ESA gave black-footed ferrets the overall condition of *Warrants Significant Concern* This condition supersedes all other indicators.

Confidence

Survey efforts in Badlands exceed the recommended standards (Biggins et al. 2006a). The conservation status of the species depends on intensive monitoring efforts for known and suspected black-footed ferret populations throughout their range. Confidence was *High*.

Trend

Black-footed ferrets were thought to be extinct until 1981 and, though reintroductions have increased numbers, wild populations do not meet the requirements for changing their ESA listing status. Trend is *Unchanging*. Table 4.11.6 provides a summary of black-footed ferret condition.

Table 4.11.6. Summary of black-footed ferret indicators and measures.

Indicator	Measure	Condition	Confidence	Trend	Condition rationale
Conservation concern	Federal protection status	Warrants significant concern	High	Unchanging	Black-footed ferret are listed under ESA and they have not recovered to the point that their listing can be changed.
Population size	Count of adult ferrets	Warrants moderate concern	Medium	Deteriorating	The count of adult ferrets was 32 in 2015; this placed population size in the Warrants Moderate Concern category. Monitoring data were collected annually on-site, but without error estimates so confidence was *Medium* and trend was *Deteriorating*.
Habitat quality	Black-tailed prairie dog colony acreage	Warrants moderate concern	High	Deteriorating	Habitat increased from 1993-2007 and decreased from 2008–2015; this placed habitat quality in the *Warrants Moderate Concern* category. Acreage was mapped on-site so confidence was *High* and trend was *Deteriorating*.

4.11.5. Stressors

The single largest threat to black-footed ferrets is plague. Plague affects ferrets both indirectly through reduced prairie dog numbers and directly through mortalities. While extensive dusting of burrows and vaccination of ferrets have prevented extirpation of black-footed ferrets in Conata Basin/Badlands, the population has been drastically reduced since plague first moved into the area.

Dusting, while largely successful, is not the panacea for black-footed ferret recovery. Fleas have begun to show signs of resistance to the current dusting insecticide (deltamethrin; E. Childers, personal communication, 24 November 2015), so the success of longer-term dusting efforts hinges on finding an alternative insecticide. Dusting is also an expensive endeavor ($16.30 per acre in 2015; Griebel 2014). Historically, funding for dusting in Badlands came from recreational fee demonstration funds. The NPS did not renew this funding in 2015, and funding for 2016 is uncertain.

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. Even if the oral vaccine protects prairie dogs from plague, ferrets would likely require continued vaccinations (T. Livieri, personal communication, 9 March 2016).

4.11.6. Data Gaps

Population Estimates

There are two potential sources of uncertainty in the current population estimation approach. The first is that survey effort is not randomized or stratified, so the area of inference differs somewhat from year to year. The survey area is focused on a small number of known black-footed ferret colonies and is therefore similar from year to year. Additional survey areas have been incorporated if they were suspected to have ferrets (i.e., large enough to be capable of supporting ferrets). Areas surveyed minimally or not at all that are outside of known ferret colonies may contain undetected ferrets that have dispersed to new sites, although the chance of this is thought to be low (T. Livieri, personal communication, 9 March 2016). Over 85% of all prairie dog acreage was surveyed in Badlands in 2015. The consequence of using the current survey approach is the possibility that the number of ferrets has been underestimated.

The second potential source of uncertainty is that variance in population size is not estimated. The ability to detect ferrets during surveys may change over time according to a variety of factors, including weather, surveyor experience, detection method, etc. There are numerous population estimation techniques that correct for imperfect detection and provide estimates of the level of confidence. It is likely that most ferrets at Conata Basin/Badlands were captured or detected in recent years, when population size was low and potential habitat was restricted. However, without knowing the level of confidence in population size estimates as the population begins to grow, it may be difficult to adequately inform a downlisting or delisting decision.

Genetic Data

Even though the national black-footed ferret population consists of hundreds of individuals, the founding population was very small (10 individuals), so genetic diversity is likely low. Genetic diversity is critical in the face of changing environmental conditions (e.g., disease, climate) and contributes to long-term population viability.

Genetic data for Conata Basin black-footed ferrets were analyzed from captures conducted from 1999 – 2005 (Wisely et al. 2008, Cain et al. 2011). They showed that while the Conata population had low genetic diversity, it had not lost genetic diversity as compared to the founding (captive) population. These analyses were, however, prior to the onset of plague, which has caused a downturn in population size. If the ferret population in Conata is sufficiently small as to create a population bottleneck, there could be a significant loss of genetic diversity (as was seen in the Shirley Basin, Wyoming population during the same period of the genetic study) that may have demographic and phenotypic consequences (Wisely et al. 2008). Genetic studies for Conata Basin/Badlands since the time of plague are ongoing.

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4.12. American Bison

4.12.1. Background and Importance

The American bison (*Bison bison*) is an iconic species in North America. Badlands National Park hosts one of two subspecies of American bison, the plains bison (*Bison bison bison*; Figure 4.12.1). Historically, an estimated 30–70 million plains bison ranged from central Canada to Mexico (Reid 2006; Figure 4.12.2) in herds of up to 10,000 animals (Redford and Fearn 2007). These herds played a key role in the grassland ecosystems of North America, shaping both the landscape (Knapp et al. 1999) and the way of life for native cultures in the region (Redford and Fearn 2007).

Figure 4.12.1. A plains bison on the mixed grasslands of Badlands National Park (Photo by Larry McAfee, NPS).

The American bison is a behemoth among native land mammals, standing up to two meters (six and a half feet) at the shoulder and weighing up to 1,000 kilograms (2,200 pounds). Plains bison once inhabited 22 major ecoregions (Sanderson et al. 2008) including the northern mixed grasslands habitat in which the Badlands herd is located. Herds wandered across the grasslands in the spring and fall, traveling upwards of 320 kilometers (200 miles). In mixed grasslands, the majority (~90%) of the bison's diet is made up of grasses and sedges (Gates et al. 2010). Bison make wallows—topographical depressions that can hold water—that can persist for over a century (Knapp et al. 1999). Herds are segregated by sex; group size is highly variable (Berger and Cunningham 1995) but typically consists of 5–20 individuals (Reid 2006). The bison is a polygynous species, meaning that a single male may mate with multiple females, while many males do not reproduce in a given year. Mating occurs in July and August. Following an approximately nine-month gestation, calves are born in early May.

Bison were once a critical component in the processes that shaped the grasslands of North America. It will likely take large-scale recovery of bison to resume their former ecological functions, but local reintroductions such as the population at Badlands National Park provide the necessary first steps toward ecological restoration.

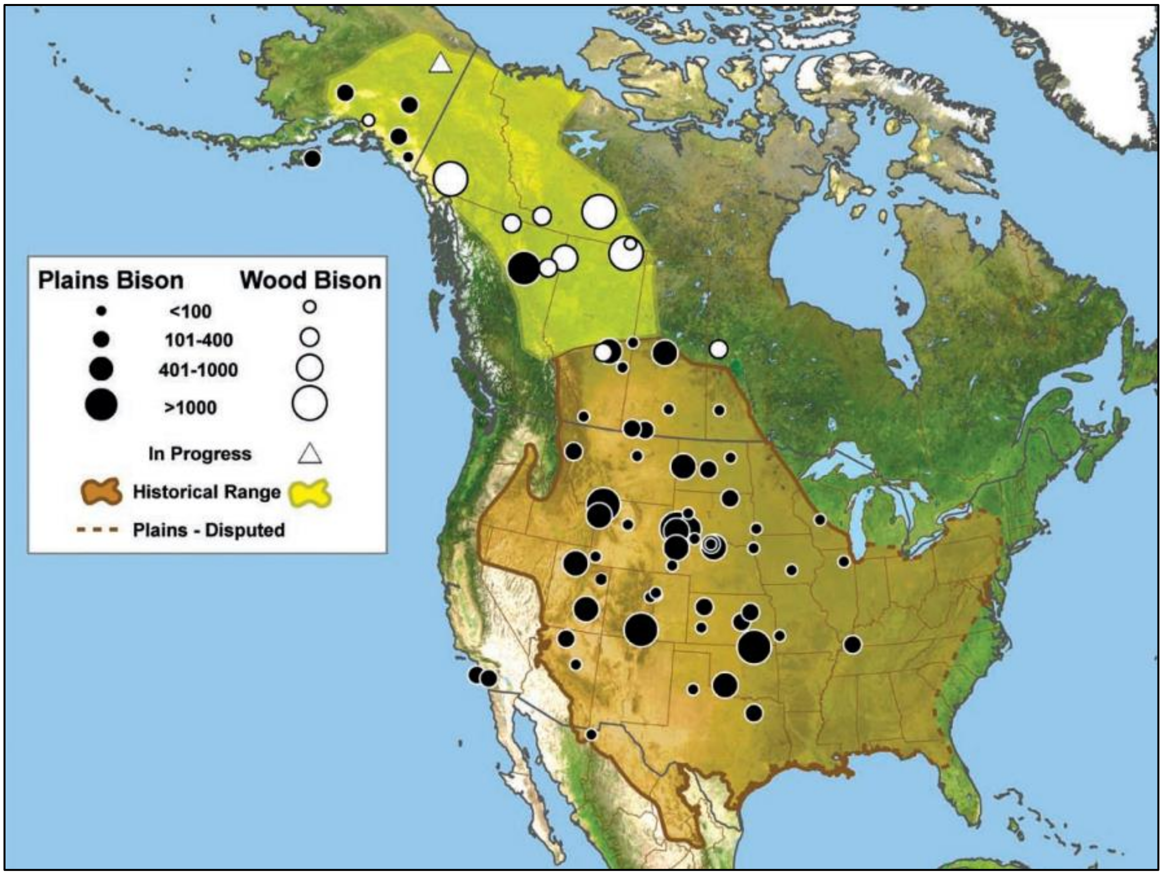

Figure 4.12.2. Current (publicly-owned herds) and historic distribution of the American bison (Gates et al. 2010).

Historically, bison played a major role in ecosystem dynamics, affecting everything from plant communities to fire regimes and nutrient cycling. Bison help to maintain meadows and grasslands through their grazing activities; grazing also increases rates of nutrient cycling, improves the nutritive value of grasses, and disperses seeds (Gates et al. 2010). Wallows created by bison support a variety of wetland plants and serve as breeding habitat for a number of amphibian species (Gates et al. 2010). Grazing by bison may facilitate colonization by prairie dogs and create habitat for a number of upland bird species (Gates et al. 2010). Grazing also influences fire behavior, which in turn influences grazing patterns; historically, bison and fire together largely influenced the distribution of plant communities in the Great Plains (Gates et al. 2010).

The NPS is dedicated to protecting bison. Bison are so integrated with the identity of the Park Service that a bison even features on the NPS logo (Figure 4.12.3). Bison are a major tourist attraction, and the Service conducts education and outreach programs. For example, Badlands has created a freely-available lesson plan on bison populations to teach students about conservation and basic science skills.

Figure 4.12.3. The National Park Service logo. The bison has played a crucial role in the history of the National Park Service, and its prominence as a flagship species continues today.

Badlands NP is one of nine NPS units that currently supports bison and is also one of the most recent to participate in bison restoration. Substantial numbers of bison historically inhabited the grasslands within the park. From 1963–1964, 50 bison from Theodore Roosevelt National Park and three from Fort Niobrara National Wildlife Refuge were introduced into the Badlands Wilderness Area (Plumb and Sucec 2006). An additional 20 bison from Colorado National Monument were added to the Badlands NP herd in 1983 (Dratch and Gogan 2010). Badlands NP currently has a management goal of maintaining 500–700 bison in the 23,458-hectare (57,967-acre) Badlands Wilderness Area (Badlands National Park 2008). The herd is culled opportunistically, and surplus bison are given to the neighboring Oglala Sioux Tribe and distributed to other native tribes through the InterTribal Bison Cooperative.

Regional Context

By the end of the 1800s, bison had been reduced to approximately 1,000 animals living within Yellowstone National Park, zoos, and private ranches (Redford and Fearn 2007). Today, conservation efforts have restored bison populations to over 500,000 animals, although only 5% of these bison exist in publicly owned, or conservation, herds (Boyd 2003). These “conservation herds” are managed in the public interest by governments and environmental organizations. The number of bison in conservation herds has remained stable since the 1930s (Figure 4.12.4). It should also be noted that the number of bison thought to be free of cattle genes number significantly fewer than these estimates. Bison currently occupy less than 1% of their historical range (Sanderson et al. 2008).

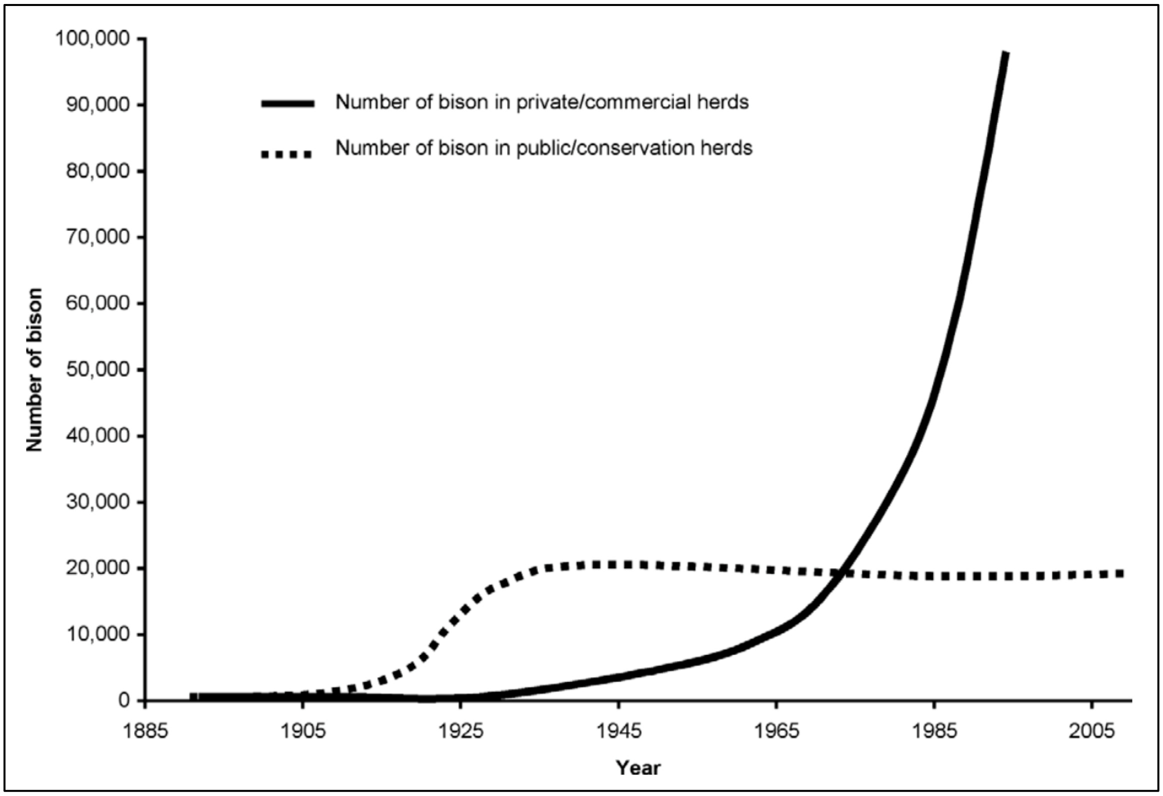

Figure 4.12.4. Change in the total bison population from the time of mass extermination to recent years (Freese et al. 2007). Dotted line indicates the number of bison in public/conservation herds, and solid line indicates bison in private/commercial herds.

4.12.2. Resource Standards

The American bison is listed as near-threatened by the International Union for Conservation of Nature (IUCN; Gates and Aune 2008). Because bison population sizes in conservation herds are stable, the U.S. Fish & Wildlife Service (USFWS) did not conduct a review to list the plains bison as threatened (USFWS 2011). Both the IUCN and the USFWS focused on the assessment of conservation herds, and not commercial herds. Bison are variously classified as livestock and wildlife throughout their range. Bison in South Dakota are classified as livestock when they are raised for commercial use and as wildlife if they are a publicly owned, conservation herd. They are managed as wildlife within National Parks.

The Department of the Interior (DOI) has developed frameworks to improve the management of bison and the effectiveness of conservation efforts within federal lands (DOI 2008). Some of the priorities of the DOI Bison Conservation Initiative are non-native diseases, the creation of bison metapopulations, the conservation of genetic variation, and collaboration across herds and management agencies.

4.12.3. Methods

Indicators, Measures, and Data Sources

We used indicators and measures specified by a “scorecard” that shows how bison herds can contribute to overall ecological restoration (Redford and Fearn 2007, Sanderson et al. 2008). We assessed overall bison condition using five main indicators: 1) herd size and composition, 2) landscape size and use, 3) ecological interactions, 4) geography, and 5) health and genetics. Each of these indicators contributes to different aspects of bison condition and can affect the herd’s contribution to ecological restoration in different ways. Note that the original scorecard also contains four measures of sociopolitical environment and capacity as well as two measures of human cultural interactions, which were beyond the scope of this report. As far as we know, our assessment is the first published effort to use the bison scorecard. To assign a condition to each indicator, we used categories for 12 measures specified by the scorecard. Potential condition categories were: *Resource in Good Condition* if the Badlands NP bison herd fell into the “large contribution” or “exceptional contribution” categories, *Warrants Moderate Concern* if it fell into the “modest contribution” category, and *Warrants Significant Concern* if it fell into the “small” or “no contribution” categories (Table 4.12.1). We then used indicator condition to assess an overall bison condition at Badlands NP.

Table 4.12.1. Bison indicators, ranges of measures, and notes with background and biological explanations. Measures of human cultural interactions as well as sociopolitical environment and capacity (elements of the original scorecard) were beyond the scope of this report. Reproduced with slight modifications from Sanderson et al. 2008. Also see Redford and Fearn 2007.

Indicator	**Measure**	**No contribution**	**Small contribution**	**Modest contribution**	**Large contribution**	**Exceptional contribution**	**Notes**
Herd size and composition	Herd size	< 2	2–400	400–1,000	1,000–5,000	> 5,000	Cutoffs based on models of population sustainability and maintenance of long-term genetic diversity, assuming a natural population structure (Gross & Wang 2005); population sizes assume sufficient habitat area is available to support herd at natural densities
	Population structure	Age structure, sex ratio, social units, and population size managed for goals inconsistent with ecological recovery	At least one aspect of population structure (i.e., age structure, sex ratio, social units and population density) managed to match natural reference conditions	Two or more aspects of population structure managed to match natural reference conditions	All aspects of population structure managed to match natural reference conditions	Population structure managed by natural conditions without need for human intervention	Factors related to population structure include age structure, sex ratio, social units, and population density; details on natural age structure, sex ratio, social units, and other demographic parameters at reference sites in Gates et al. (2005) and IUCN action plan (Gates et al. 2010)
Landscape size and use	Landscape size available to bison	< 4 hectares (< 10 acres)	4–2,023 hectares (10–5,000 acres)	2,023–20,234 hectares (5,000–50,000 acres)	20,234–202,340 hectares (50,000–500,000 acres)	> 202,342 hectares (500,000 acres)	Scale landscape size with population size so that densities suitable for social interactions and ecological functions are maintained (e.g., Sanderson 2006)
	Human footprint	> 20% landscape converted to human uses incompatible with bison	15–20% landscape converted to human uses incompatible with bison	5–15% of landscape converted to human uses incompatible with bison	1–5% of landscape converted to human uses incompatible with bison	< 1% of landscape converted to human uses incompatible with bison	Human uses incompatible with bison are habitat conversions that destroy bison habitat (e.g., agriculture, housing, roads) or render it unusable (e.g., overgrazing by domestic animals, soil toxins)
	Management of movements	Movements are tightly controlled within small, fenced lots	Movements are confined by perimeter barrier and limited by some internal barriers	Animals are free to move anywhere within the managed landscape, but are limited at landscape perimeter (e.g., perimeter fencing, but no internal fencing)	Animals free to move on their own, with rare exceptions	Animals are free to move on their own, with no exceptions	Bison may make nomadic or migratory movements if free to move unhindered

Table 4.12.1 (continued). Bison indicators, ranges of measures, and notes with background and biological explanations. Measures of human cultural interactions as well as sociopolitical environment and capacity (elements of the original scorecard) were beyond the scope of this report. Reproduced with slight modifications from Sanderson et al. 2008. Also see Redford and Fearn 2007.

Indicator	**Measure**	**No contribution**	**Small contribution**	**Modest contribution**	**Large contribution**	**Exceptional contribution**	**Notes**
Ecological interactions	Natural selection	All selection by humans for production or purpose other than ecological recovery	Some but limited natural selection or management to mimic natural selection (at least 1 of the 5 selection pressures active)	Some but limited natural selection or management to mimic natural selection (at least 3 of the 5 selection pressures active)	Most natural selection processes operational (4 of 5 selection pressures); others managed to mimic nature	All natural selection processes are present without active human intervention	Natural-selection pressures on bison include mortality from native predators, native diseases, drought, climatically induced food limitation (including interannual variation in forage quality), and unmanipulated mate competition
	Interaction with suite of native vertebrate species	No native vertebrate species and no plans for restoration of species	No or few (< 10%) other native vertebrate species present, but restoration is planned	Some (10–50%) native vertebrate species present (e.g., some native herbivores, few or no predators, some dependent species) and/or restoration efforts are underway	Most (50–90%) native vertebrate species present (e.g., all native herbivores, some predators, most dependent species)	All native vertebrate species are represented in the system and there is no known impairment to intra-specific interactions	Lists of native species dependent on or associated with bison need to be developed for each major habitat type; representative lists for shortgrass prairie in johnsgard (2005); direct bison interactions with other animal species include predation, provision of carcasses, and habitat creation; further research required (see text)
	Interaction with ecosystem processes	Herd does not interact in any significant way with ecosystem processes	Herd interacts significantly with ecosystem processes, over < 10% of landscape	Herd interacts significantly with ecosystem processes, over 10–50% of landscape	Herd interacts significantly with ecosystem processes, over 50–90% of landscape	Herd interacts significantly with ecosystem processes, over the entire landscape	Bison interactions with ecosystem processes include differential grazing, disturbance through wallowing, modification of fire regimes, and nutrient redistribution from excretion; further research required (see text)

Table 4.12.1 (continued). Bison indicators, ranges of measures, and notes with background and biological explanations. Measures of human cultural interactions as well as sociopolitical environment and capacity (elements of the original scorecard) were beyond the scope of this report. Reproduced with slight modifications from Sanderson et al. 2008. Also see Redford and Fearn 2007.

Indicator	**Measure**	**No contribution**	**Small contribution**	**Modest contribution**	**Large contribution**	**Exceptional contribution**	**Notes**
Geography	Representation	Herd lives in a habitat that was not in the historical range of the species	In a major habitat type	One of top 10 representatives of a major habitat type in terms of ecological recovery within the historical range of the species	One of top 3 representatives of a major habitat type in terms of ecological recovery and within the historical range of the appropriate subspecies	Best representative of a major habitat type within the historical range of the appropriate subspecies	Herds assigned to potential major types based on geographic location and/or ecological baseline information; comparisons of scores (based on other factors) are made within major habitat type to score this factor
Health and genetics	Presence and management of disease	Presence of reportable disease prevents recovery	Presence of reportable disease constrains recovery, but management is planned	Presence of reportable disease constrains recovery, but disease is managed	No “reportable” diseases	No “reportable” disease and herd is not mixing with or adjacent to any sources of “reportable” disease	Reportable diseases include foot and mouth disease, anthrax, tuberculosis and brucellosis; “constraining recovery” means a disease issue limits some other aspect of ecological recovery to only a “modest” contribution
	Genetic diversity	Low genetic diversity and no unique genetic traits	Some genetic diversity or some unique traits	Moderate genetic diversity or unique genetic traits or lineage history unknown	High genetic diversity and some unique genetic traits and known lineage	High genetic diversity and many unique genetic traits and fully documented lineage	Examples of genetic diversity ranges for different herds in Halbert et al. (2005)
	Genetic integrity	Strong physiognomic resemblance to domestic cattle, indicating significant hybridization	> 5% detected cattle markers or hybridization status is unknown, but physiognomically similar to bison	< 5% detected nuclear cattle genes and/or cattle mtdna but physiognomically similar to bison	< 1% detected nuclear cattle genes with no or limited cattle mtdna	No detected cattle genes and no known genetic history with hybrid populations	Cattle markers in bison genetics defined in Halbert et al. (2005)

Badlands NP has monitored its bison since they were first reintroduced in 1963. Population size estimates of varying quality were available for most years. The park has recorded information on the age and sex of bison captured during roundups since 2002, with moderate coverage dating back to 1995. For more information on aging and sexing bison, see Berger and Cunningham (1994).

Indicator: Herd Size and Composition

Herd size and composition largely determine population sustainability (Berger and Cunningham 1994). Herds as large as 10,000 individuals once existed, but now conservation herds are much smaller.

Measure of Herd Size and Composition: Herd Size

Following the reintroduction of bison to Badlands in the 1960s, annual herd counts were conducted from helicopters; since 1999, personnel have used a combination of ground and aerial surveys for these counts (Badlands NP 2008). The condition ranges for herd size come from simulation models of population sustainability and genetic diversity, assuming a natural population structure (Gross et al. 2006). A loss of genetic heterozygosity is often observed in small populations, and can result in lowered population persistence in the short-term. Allelic diversity is another measure of a population’s ability to respond to change, and is indicative of longer-term persistence. Modeling results predict that 400 bison have a 90% chance of retaining 90% of the herd’s genetic heterozygosity for 200 years, while 1,000 bison have a 90% chance of retaining 90% of the herd’s allelic diversity over the same period. We used the modeling results of Gross et al. (2006) to assess population quality: a population < 400 bison *Warrants Significant Concern*, a population between 400–1,000 *Warrants Moderate Concern*, and a population > 1,000 was in *Good Condition* (Table 4.12.2). One-and-one-half-year-old bison were culled most years in October before they had a chance to breed, and therefore did not contribute genetically to the population. Therefore, we subtracted the number of culled animals from population estimates to obtain herd size.

Table 4.12.2. American bison condition categories for herd size. Ranges were based on models of population sustainability and genetic diversity (Gross et al. 2006). Population ranges for each category were calculated under the assumption that sufficient habitat was available to support natural densities of bison.

Resource condition		Herd size (post-cull)
Warrants significant concern	🔴	< 400
Warrants moderate concern	🟡	400–1,000
Resource in good condition	🟢	> 1,000

Measure of Herd Size and Composition: Population Structure

Detailed data on population structure came from a non-random sample of bison captured during roundups dating back to 2002. There were no natural predators of bison in Badlands NP for many years prior to this assessment, so population size and structure were manipulated through annual culling. Between 85–95% of one-and-a-half-year-old bison captured in roundups were culled annually (Pyne et al. 2010).

Factors related to population structure include age structure, sex ratio, social units, and population density. In one study on age structure of plains bison in the Henry Mountains, Utah, subadults (calves and yearlings) accounted for 38% of the total population (Van Vuren and Bray 1986). Age structure is often examined through population pyramids; different pyramid shapes are characteristic of populations in different stages of growth (Figure 4.12.5). The sex ratio in the Henry Mountains herd was roughly one female to two males, but this skewed sex ratio is thought to have resulted largely from preferential hunting of male bison (Van Vuren and Bray 1986), and also the fact that mortality rates of males tend to be slightly higher. Conservation recommendations suggest that herds be managed for a 1:1 sex ratio, or no less than 40% males (Dratch and Gogan 2010). Other guidelines are in line with this ratio, suggesting that neither sex make up more than 60% of the population, with a preference for a slightly female-biased adult sex ratio (Gates et al. 2010). Detailed information on social units in other populations is limited. Outside of the mating season, bison form sex-segregated herds of 5–20 individuals (Reid 2006), with females associating with their young and older males often roaming solitarily. In Yellowstone NP, population densities averaged 3.2 ± 0.19 (standard error) and 4.2 ± 0.26 bison/square kilometer ± standard error for two herds (Taper et al. 2000).

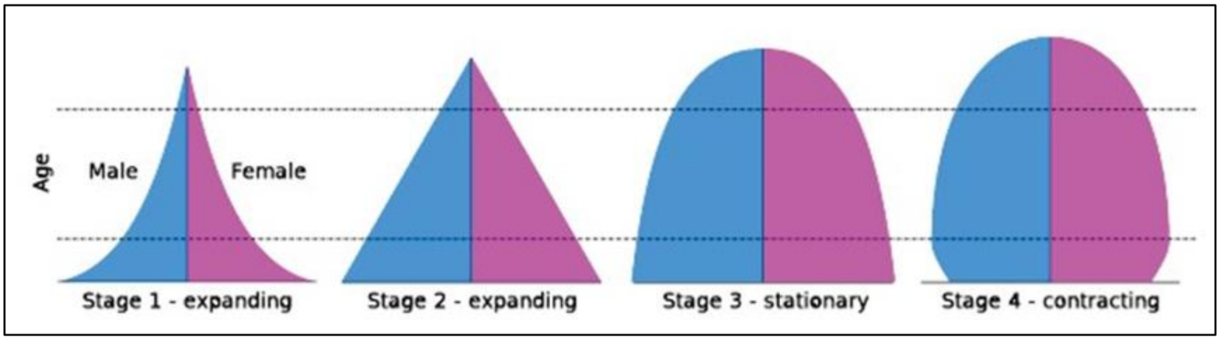

Figure 4.12.5. Examples of theoretical population pyramids indicative of the growth rate and viability of a population. Modified from Wikipedia.

We assigned condition based on the number of management outcomes matching the above reference conditions at the time of this assessment. If fewer than two aspects of population structure (i.e., age structure, sex ratio, social units, and population density) were managed to match natural conditions, then bison *Warrant Significant Concern*. If at least two aspects of population structure were managed to match natural conditions, then bison *Warrant Moderate Concern*. If all aspects of population structure were managed to match natural conditions or population structure was not manipulated, then bison were in *Good Condition* (Table 4.12.3).

Table 4.12.3. American bison condition categories for population structure. Reference conditions are based on studies in natural populations of bison.

Resource condition		**Population structure**
Warrants significant concern	🔴	< 2 aspects of population structure managed to match natural reference conditions
Warrants moderate concern	🟡	≥ 2 aspects of population structure managed to match natural reference conditions
Resource in good condition	🟢	All aspects of population structure managed to match natural reference conditions or no manipulation of population structure

Indicator: Landscape Size and Use

Large landscapes allow bison to behave more naturally, which in turn allows them to fulfill a more natural ecological role.

Measure of Landscape Size and Use: Landscape Available to Bison

For bison to have the same effect on their ecosystems as they once did, landscape availability should be proportional to population size (Sanderson 2006). Historic bison movements included seasonal movements of 320 kilometers (200 miles) or more (Reid 2006). Even daily movements may be substantial, as bison may move approximately three kilometers per day between foraging sites in the summer (Meagher 1986). Condition categories were based on the expert opinions of many bison biologists (Sanderson et al. 2008). A landscape of < 5,000 acres would *Warrant Significant Concern* because it does not allow natural behaviors and functions, a landscape between 5,000–50,000 acres *Warrants Moderate Concern* because it allows some natural behaviors and functions, and a landscape > 50,000 acres is in *Good Condition* because it allows for the full range of bison behavior and ecological function (Table 4.12.5; Sanderson et al. 2008).

Table 4.12.4. American bison condition categories for landscape available to bison.

Resource condition		Landscape available to bison
Warrants significant concern	🔴	< 5,000 acres
Warrants moderate concern	🟡	5,000–50,000 acres
Resource in good condition	🟢	> 50,000 acres

Measure of Landscape Size and Use: Human Footprint

A number of human uses can reduce available habitat for bison. These include land conversion and overgrazing by domestic livestock. We referred to Sanderson et al. (2008; Table 4.12.1) to assign a condition to human footprint (Table 4.12.5).

Table 4.12.5. American bison condition categories for human footprint.

Resouce condition		Human footprint
Warrants significant concern	🔴	> 15% landscape converted to human uses incompatible with bison
Warrants moderate concern	🟡	5–15% landscape converted to human uses incompatible with bison
Resource in good condition	🟢	< 5% landscape converted to human uses incompatible with bison

Measure of Landscape Size and Use: Management of Movements

As described above, bison movements historically included movements of 320 kilometers (200 miles) or more (Reid 2006) and still include daily movements of up to three kilometers per day in the summer (Meagher 1986). Fencing or other barriers may limit natural nomadic or migratory tendencies. Movement barriers may also limit natural interactions with other bison populations and other native vertebrate species. We referred to Sanderson et al. (2008; Table 4.12.1) to assign a condition to management of movements (Table 4.12.6).

Table 4.12.6. American bison condition categoris for management of movements.

Resource condition		**Management of movements**
Warrants significant concern	🔴	Movements are tightly confined or limited by internal barriers
Warrants moderate concern	🟡	Animals free to move within managed landscape, but limited at perimeter
Resource in good condition	🟢	Animals are free to move on their own with rare or no exceptions

Indicator: Ecological Interactions

Restoring ecological interactions to their natural state is important for the longevity of bison and the integrity of the communities and ecosystems to which they belong.

Measure of Ecological Interactions: Natural Selection

Many natural selection pressures for bison have been reduced or eliminated by changes in ecological communities and active management of herds. First, native predators of bison, such as wolves (*Canis lupus*) and grizzly bears (*Ursus arctos* ssp.), have been extirpated across much of their former ranges (Laliberte and Ripple 2004) and no longer contribute to bison mortality in most herds. Culling is the primary means of population control in bison. Second, managed herds are sometimes vaccinated or otherwise treated for pests and parasites, thus potentially limiting their exposure to native diseases. Third, some herds may be provided supplemental sources of water. Fourth, bison that are provided supplemental food do not experience natural variation in forage limitation and quality. Lastly, mate competition may be controlled in managed herds. We looked for the presence of each of five natural selection pressures in the Badlands NP bison herd. If two or fewer of these natural selection pressures were active, then the herd *Warrants Significant Concern*. If three of these natural selection pressures were active, then the herd *Warrants Moderate Concern*. If four or more natural selection pressures were active, then the herd was in *Good Condition* (Table 4.12.7).

Table 4.12.7. American bison condition categories for natural selection. Natural selection pressures include: 1) mortality from native predators, 2) native diseases, 3) drought, 4) climatically induced food limitation, and 5) un-manipulated mate competition.

Resource condition		Natural selection
Warrants significant concern	🔴	No or some limited natural selection or management to mimic natural selection (≤ 2 selection pressures active)
Warrants moderate concern	🟡	Some limited natural selection or management to mimic natural selection (3 selection pressures active)
Resource in good condition	🟢	Most or all natural selection processes operational (≥ 4 selection pressures active)

Measure of Ecological Interactions: Interaction with Suite of Native Vertebrate Species

Bison benefit from the presence of a number of native vertebrates. One native herbivore that is beneficial for bison is the black-tailed prairie dog (*Cynomys ludovicianus*; Figure 4.12.6). Bison will preferentially graze on the high quality forage associated with prairie dog colonies (Coppock et al. 1983).

Figure 4.12.6. Bison graze preferentially around colonies of prairie dogs (Photo by J. Ravi, Wikimedia Commons, 2011).

An even larger number of native species benefit from the activities of bison. Many species likely benefit from the habitat heterogeneity and improved forage quality that result from bison activities occurring at natural rates. We referred to Sanderson et al. (2008; see Table 4.12.1) to assign a condition to species interactions (Table 4.12.8).

Table 4.12.8. American bison condition categories for speces interaction.

Resource condition		Species interactions
Warrants significant concern	🔴	< 10% native vertebrate species present
Warrants moderate concern	🟡	10–50% native vertebrate species present (e.g., some native herbivores, few predators, some dependent species) or restoration underway
Resource in good condition	🟢	> 50% native vertebrate species present (e.g., all native herbivores, some predators, most dependent species)

Measure of Ecological Interactions: Interaction with Ecosystem Processes

Bison historically played a large role in shaping the landscape. Their grazing activities and wallowing modified fire regimes, redistributed nutrients (through feces and carcasses), and created habitat for a variety of species (Figure 4.12.7). Interactions with ecosystem processes may be limited through controlled movements, removal of carcasses, fire suppression, and a number of other management actions. We referred to Sanderson et al. (2008; Table 4.12.1) to assign a condition to interaction with ecosystem processes (Table 4.12.9).

Figure 4.12.7. A bison wallow. Bison may have large impacts on the look and function of a landscape. These wallows, for example, may represent important habitat for amphibians (Photo by USGS).

Table 4.12.9. American bison condition categories for interaction with ecosystem processes. These interactions include differential grazing, wallowing, modification of fire regimes, and nutrient redistribution.

Resource condition		**Interaction with ecosystem processes**
Warrants significant concern	🔴	No interaction or herd interacts significantly with ecosystem process over < 10% landscape
Warrants moderate concern	🟡	Herd interacts significantly with ecosystem processes over 10–50% landscape
Resource in good condition	🟢	Herd interacts significantly with ecosystem process over > 50% of landscape

Indicator: Geography

Bison are commonly envisioned roaming in large herds over vast stretches of grasslands, but in reality they historically inhabited a range of habitats. They once occurred in 22 major habitat types corresponding to different ecoregions in North America (Sanderson et al. 2008) large-scale recovery efforts. We highlight five attributes of a recent range-wide vision-setting exercise for ecological recovery of the North American bison (*Bison bison*).

Measure of Geography: Representation

Representation is a measure of how a herd compares to other herds in the same major habitat type (i.e., ecoregion). Badlands NP falls within the northern mixed grasslands habitat. This major habitat type is found primarily in Montana, Wyoming, North Dakota, South Dakota, Nebraska, and Saskatchewan. Around a dozen conservation herds are located within the northern mixed grasslands region, and there are many more private herds. We referred to Sanderson et al. (2008; Table 4.12.1) to assign a condition to representation (Table 4.12.10).

Table 4.12.10. American bison condition categories for representation.

Resource condition		Representation
Warrants significant concern	🔴	Herd outside of historical range or herd in a major habitat type
Warrants moderate concern	🟡	One of top 10 representatives of a major habitat type in terms of ecological recovery within the historical range
Resource in good condition	🟢	One of top 3 representatives of a major habitat type in terms of ecological recovery and within the historical range

Indicator: Health and Genetics

The health and genetics of bison are critical resource indicators, partly because diseases and genes may be transferred between bison and livestock. Diseases may be transferred not only among bison herds but possibly to and from other livestock and wildlife species. Bison can breed with domestic cattle, and some argue that the introgression of cattle genes diminishes the wild nature of this species. This hybridization can occur naturally, but is most often the result of planned hybridization by livestock growers. A population bottleneck—a severe reduction in numbers—at the turn of the 20th century reduced genetic diversity of the species and still threatens the long-term population viability of bison herds. Maintaining genetic diversity and integrity is a priority of agencies managing bison in "wild" or "conservation" herds (Dratch and Gogan 2010).

Measure of Health and Genetics: Presence and Management of Disease

Bison handled during annual captures at Badlands NP are tested for brucellosis, although conservation herds outside of northwestern Wyoming are considered brucellosis-free (USFWS 2011). Some testing for tuberculosis and Johne's disease has been conducted at Badlands NP (DOI

2014). We referred to Sanderson et al. (2008; Table 4.12.1) to assign a condition to presence and management of disease (Table 4.12.11).

Table 4.12.11. American bison condition categories for presence and management of disease. Reportable disease are those that “restrict trade or pose a risk to human health and are ‘reportable’ under federal, provincial, and state legislation (Gates et al. 2010).”

Resource condition		Presence and management of disease
Warrants significant concern	🔴	Presence of reportable disease prevents/constrains recovery
Warrants moderate concern	🟡	Presence of reportable disease constrains recovery, but disease is managed
Resource in good condition	🟢	No reportable disease

Measure of Health and Genetics: Genetic Diversity

Genetic diversity is one sign of a healthy population and allows for evolutionary change and adaptation. Genetic diversity is measured in a number of different ways, often using neutral (microsatellite) markers (Halbert and Derr 2008). We referred to Sanderson et al. (2008; Table 4.12.1) to assign a condition to genetic diversity (Table 4.12.12).

Table 4.12.12. American bison condition categories for genetic diversity.

Resource condition		Genetic diversity
Warrants significant concern	🔴	Low/some genetic diversity and no/some unique genetic traits
Warrants moderate concern	🟡	Moderate genetic diversity or unique genetic traits or lineage history unknown
Resource in good condition	🟢	High genetic diversity and some/many unique genetic traits and known/fully documented lineage

Measure of Health and Genetics: Genetic Integrity

Bison managers are concerned about the presence or potential for introgression (hybridization) with cattle, which results in a loss of genetic integrity. The introduction of cattle genes into bison may have negative fitness consequences for bison (Halbert and Derr 2007) and represents an undesirable move towards domestication of bison. Evidence of introgression in maternally inherited DNA (mitochondrial DNA) and DNA that can be inherited by either parent (nuclear DNA) has been found in conservation herds to varying degrees (Halbert and Derr 2007). We referred to Sanderson et al. (2008; Table 4.12.1) to assign a condition to genetic integrity (Table 4.12.13).

Table 4.12.13. American bison condition categories for genetic integrity.

Resource condition		Genetic integrity
Warrants significant concern	🔴	> 5% detected cattle markers, but physiognomically similar to bison
Warrants moderate concern	🟡	< 5% detected nuclear cattle genes and/or cattle mitochondrial DNA, but physiognomically similar to bison
Resource in good condition	🟢	< 1% detected nuclear cattle genes with no or limited cattle mitochondrial DNA

Quantifying Bison Condition, Confidence, and Trend

Indicator Condition

To assess indicator condition, we used the approach described by Redford and Fearn (2007) and Sanderson et al. (2008). Their approach illustrates the contributions of individual bison herds to range-wide ecological restoration goals. If an indicator had multiple measures, we used a points system to assign indicator conditions. Measures that placed the indicator in the worst category, *Warrants Significant Concern*, were each assigned zero points, measures in the *Warrants Moderate Concern* category received 50 points, and measures in the best category, *Resource in Good Condition*, received 100 points. The average of these points was the total score for bison condition. High scores (67–100) indicated that bison were in *Good Condition*, medium scores (34–66) indicated that bison *Warrant Moderate Concern*, and low scores (0–33) indicated that bison condition *Warrants Significant Concern*.

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. If there were no data available that met these requirements for a particular indicator, we indicated that trend was *Not Available* for that indicator.

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 data were collected on site or nearby, data were collected recently, and the data were collected methodically. We indicated a *Medium* confidence when data were not collected 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 to support the condition.

Overall Bison Condition, Trend, and Confidence

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.

4.12.4. Bison Conditions, Confidence, and Trends

Herd Size and Composition

●

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

Condition

To assign a condition to herd size and composition, we used data from censuses and roundups conducted by the NPS as well as published data (Berger and Cunningham 1995).

Badlands NP has managed their bison herd for between 600–700 individuals. However, pre-roundup population estimates have been over 1,000 animals since 2010. The estimated herd size before roundup was 1,250 bison in 2015 (Figure 4.12.8). In 2015, 274 bison were removed, yielding a post-cull estimate of 976 (Figure 4.12.9). This value placed herd size for Badlands in the *Warrants Moderate Concern* category.

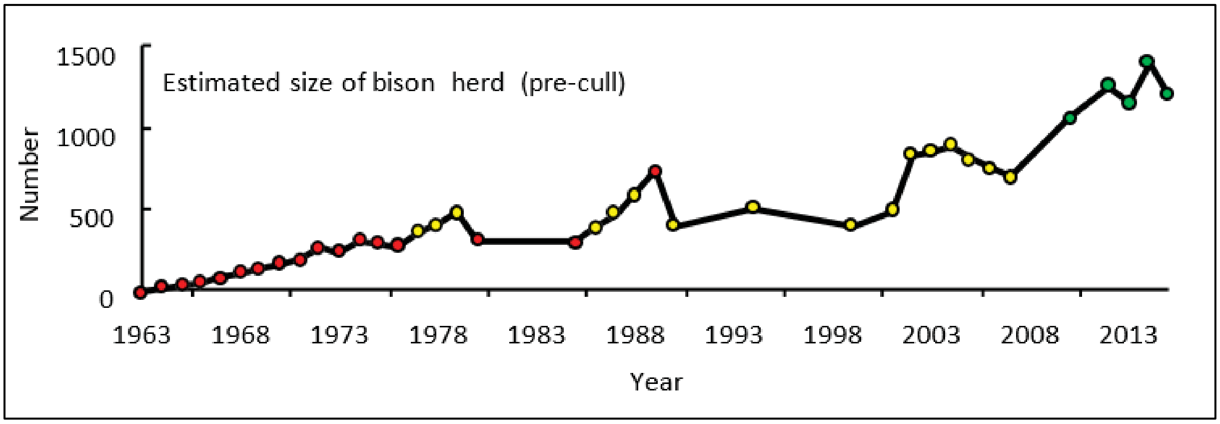

Figure 4.12.8. Badlands National Park bison herd population size estimate prior to culling, 1963–2015. The herd has experienced culling since 1969. Values for 1985–1988 approximated from of Berger and Cunningham (1994). The herd has grown significantly since reintroduction ($R^2 = 0.8729$, df = 36, $P < 0.0001$). Red dots correspond to a year when the herd size fell within the *Warrants Significant Concern* category, yellow dots to *Warrants Moderate Concern*, and green dots to *Good Condition*.

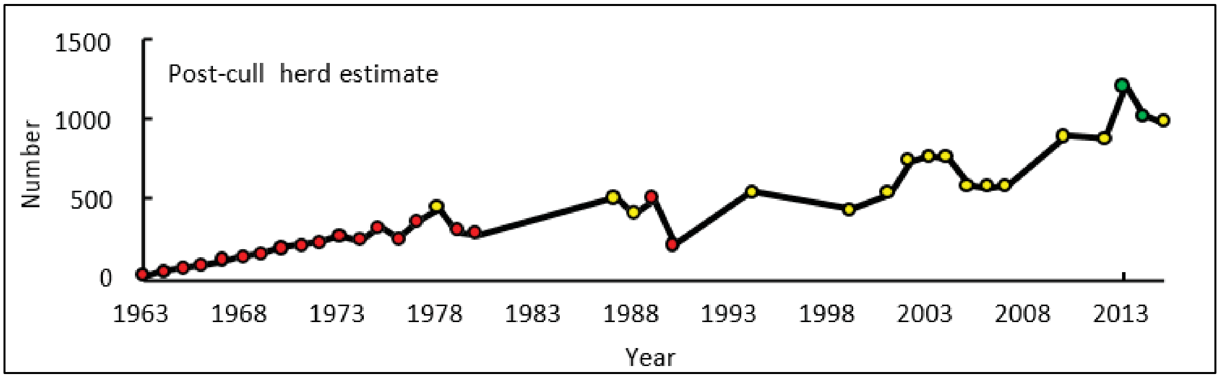

Figure 4.12.9. Badlands National Park bison herd population size estimate following culling, 1963–2015. The herd has grown significantly since reintroduction ($R^2 = 0.8631$, df = 34, $P< 0.0001$). Red dots correspond to a year when the herd size fell within the *Warrants Significant Concern* category, yellow dots to *Warrants Moderate Concern*, and green dots to *Good Condition*.

By placing herd sizes into these condition categories we assumed that the available habitat could support these densities; larger herds are undesirable if the land cannot support the herd. Evidence indicates that annual culling maintained the herd below carrying capacity in past years (Pyne et al. 2010), but population estimates have increased substantially in recent years. The herd size estimate for 2014 was more than double the park's population goal, which is based on forage values in a drought year (unpublished NPS data). Park personnel are currently wanting to reduce the herd to 500–600 animals in case of dry conditions (E. Childers, personal communication, 17 March 2016); this goal is limited by the park's ability to conduct roundups (conducted in six of the 10 most recent years). However, it should be noted that the North Unit Bison Resource Stewardship Plan is currently in preparation. The plan seeks to expand bison range by an additional 9,800 hectares (24,275 acres) in the eastern portion of the park (NPS 2015). This change could potentially increase the carrying capacity of the herd above the current target herd size, assuming that bison have access to sufficient water sources.

The age structure of the bison herd at Badlands was characteristic of a rapidly growing population (Figure 4.12.10). Half (51%) of the herd was made up of young bison (≤ one and a half years old) in 2015. This structure contrasts with 37% young animals in plains bison from the Henry Mountains, Utah (Van Vuren and Bray 1986), and 26% young wood bison from Slave River, NWT (Van Camp and Calef 1987, as cited in Gates et al. 2010).

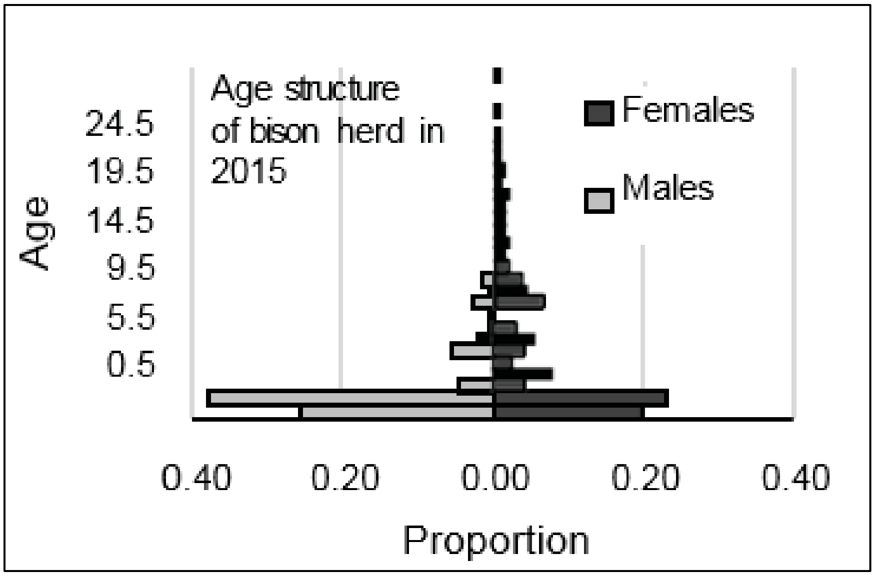

Figure 4.12.10. Estimated age structure of bison in the 2015 roundup. Count data were corrected for capture probabilities (Pyne et al. 2010).

We estimated that 40% of bison in Badlands NP in 2015 were males and that percentage has declined since 2002 (Figure 4.12.11). These calculations were based on roundup counts corrected for capture probabilities (Pyne et al. 2010) and excluded a small number of individuals of unknown sex (1% of total sample in 2015). The sex ratio of bison herds should be managed as close to 1:1 as possible, with no more than 60% of either sex as a minimum standard (Dratch and Gogan 2010, Gates et al. 2010). Therefore, the sex ratio in 2015 just marginally met management recommendations. Reference data were unavailable on bison social units, but social units were allowed to form naturally at Badlands NP.

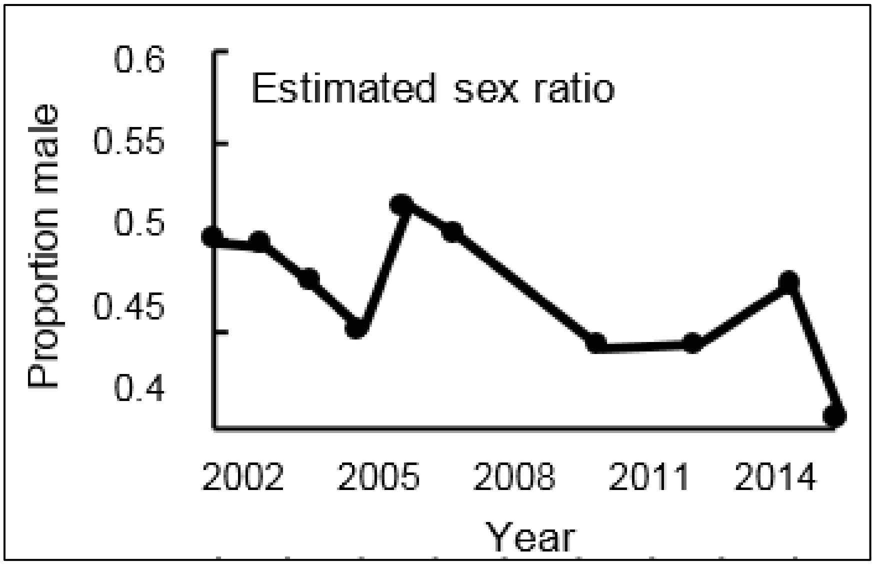

Figure 4.12.11. Sex ratio of the Badlands bison herd, 2002–2015. Data are from roundup counts (NPS data) adjusted for capture probabilities obtained from Pyne et al. 2010. The proportion of males has been decreasing ($R^2 = 0.4549$, df = 8, P = 0.0324).

Approximately 60% of the wilderness area is usable by bison, after excluding areas of gravel and non-vegetated areas. If bison used all of the available 16,000 hectares (40,000 acres), the population estimate of 1,250 would yield a density of 7.7 bison/square kilometer in 2015. If the full extent of the Wilderness Area were available to bison (an overestimate, given badlands features not used by bison), the population density would be 5.3 bison/square kilometer. Little information is available on natural densities of bison in similar habitats, but comparisons to herds in other regions may still prove useful. These estimates exceeded the average densities at which Yellowstone bison were expected either to decline in population growth or to expand the area used (Taper et al. 2000). Yellowstone is located in an area with a larger number of water sources and higher annual precipitation, and is therefore likely capable of supporting higher densities of bison than Badlands. The fact that the Badlands herd exists at higher densities than herds in resource-rich areas such as Yellowstone, suggests that the Badlands herd may have exceeded natural densities in recent years and may have come close to carrying capacity. Work from the 1960s suggested that Badlands was capable of supporting approximately 1,000 bison (Badlands NP 2008). The management goal of 600–700 bison would more closely match the observed densities in Yellowstone. For example, 650 bison roaming over 40,000 acres would yield a density of 4.0 bison/square kilometer. While this comparison is necessarily crude due to a lack of available data, we believe it still represents a useful frame of reference. It is not believed that bison in Badlands NP are anywhere close to exceeding forage limitations in the park, but managers have attempted to maintain bison numbers well below carrying capacity due to limited water availability and the potential for bison leaving the property to pursue resources on private lands during dry conditions (E. Childers, personal communication, 17 March 2016; Table 4.12.14).

Table 4.12.14. Plains bison conservation herds in the northern mixed grasslands habitat type.

State/Province	Site	Managing Authority	Population	Year
South Dakota	Badlands National Park	U.S. National Parks Service	1,250	2015
North Dakota	Theodore Roosevelt National Park	U.S. National Parks Service	850	2011
Montana	American Prairie Preserve	American Prairie Foundation	600	2015
Nebraska	Niobrara Valley Preserve	The Nature Conservancy	473	2011
South Dakota	Wind Cave National Park	U.S. National Parks Service	375	2011
Saskatchewan	Grasslands National Park	Parks Canada Agency	370	2013
Nebraska	Fort Niobrara National Wildlife Refuge	U.S. Fish and Wildlife Service	352	2011
Montana	National Bison Range	U.S. Fish and Wildlife Service	350	2013
South Dakota	Ordway Prairie Preserve	The Nature Conservancy	255	2011
North Dakota	Cross Ranch Nature Preserve	The Nature Conservancy	140	2011
Nebraska	Sully’s Hill herd at Ft. Niobrara	U.S. Fish and Wildlife Service	40	2006
North Dakota	Sully’s Hill National Game Preserve	U.S. Fish and Wildlife Service	37	2011
Saskatchewan	Buffalo Pound Provincial Park	Saskatchewan Environment, Parks Branch	33	2011
South Dakota	Bear Butte State Park	South Dakota Game Fish and Parks Dept.	–	–

Age structure and population size were not in line with natural reference conditions and sex ratio, which just barely met the recommended standards, was declining. There were no data on social units of Badlands bison. Population structure therefore *Warrants Significant Concern*.

Confidence

We determined herd size and composition from a combination of annual population counts (aerial and ground) and roundup data from Badlands NP. Because the details of annual count methodology were unknown and differed somewhat over time, and roundups did not constitute a random sample of bison, the confidence was *Medium*. Herd size estimates would also benefit from estimates of error.

Trend

Trend data were available for herd size and population density since the time of first reintroduction. Data were missing for some years, and the methods used to count bison changed in 1999. Data on age structure and sex ratio of roundup bison were available since 2002, with no data for 2008, 2009, 2011, or 2013. Data on social units were *Not Available*.

Landscape Size and Use

●

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

Condition

Bison had full access to the Badlands Wilderness Area (23,458 hectares; 57,967 acres). When taking into account the badlands geological areas not used by bison, the herd had access to ~16,000 hectares (40,000 acres; NPS 2006). This value placed available landscape in the *Warrants Moderate Concern* category.

The human footprint in the wilderness area was minimal; there is no development (buildings, roads), and there is no grazing by domestic livestock. This lack of development and human impact placed the human footprint within the bison management area in the *Resource in Good Condition* category.

Bison were free to move within the wilderness area, but were contained by natural badlands geographical features and fencing at the perimeter to prevent movement outside of the park. This placed management of movement in the *Warrants Moderate Concern* category. The overall condition for landscape size and use was *Warrants Moderate Concern*.

Confidence

Bison had access to about 16,000 hectares within the park, but it is not known how much of this available habitat was actually used. A study from the 1980s showed that female home ranges occupied a large proportion (26–57%) of the wilderness area (Berger and Cunningham 1995). Current studies of telemetered bison should reveal detailed information on the extent of bison movements within the wilderness area. Therefore, the confidence in landscape available to bison was *Medium*. The confidence for both human footprint and management of movements was *High*, so overall confidence was *High*.

Trend

Bison have had access to the same area within Badlands NP since their reintroduction in 1963. Trend for landscape size and use was *Not Available*.

Ecological Interactions

●

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

Condition

To assign a condition to ecological interactions, we used data from the NPS and the scientific literature.

Two of five natural selection pressures are active in Badlands: unmanipulated mate competition, native diseases, and climatically induced food limitation. Bison are not exposed to natural predation pressures owing to the absence of wolves and grizzly bears. Bison are not subject to the full effects of drought because water impoundments are maintained and considered essential to maintaining bison (Badlands National Park 2008). They also do not experience climatically induced food limitation because they are culled to a population level that is likely below the carrying capacity for the park. This placed natural selection in the *Warrants Significant Concern* category.

Bison share the wilderness area with other native ungulates, including bighorn sheep, pronghorn, and mule deer. They also overlap with areas of prairie dog colonies. However, natural predators (wolves, grizzlies) are absent. These factors placed species interactions in the *Resource in Good Condition* category.

Interactions with ecosystem processes are generally allowed to occur naturally within Badlands NP. Bison graze and wallow freely anywhere within the Wilderness Area, and their movements are not controlled within the boundaries of this wilderness area. While unplanned fires are suppressed within the park, prescribed burns are meant to mimic natural conditions (Painter 2003). While bison carcasses are generally allowed to remain in place (Badlands National Park 2008), overall nutrient redistribution does not mimic natural conditions, as a large proportion of the herd biomass is removed annually during culls. These combined factors placed ecosystem interactions in the *Warrants Moderate Concern* category.

Overall, these three measures placed ecological interactions for Badlands NP in the *Warrants Moderate Concern* category.

Confidence

Confidence was *High* because details of bison management in Badlands NP were readily available.

Trend

Exposure to different natural selection pressures has been the same since bison were reintroduced to the park. A number of native vertebrate species were reintroduced to Badlands in addition to bison, including Rocky Mountain bighorn sheep (1964), black-footed ferrets (1994) and swift foxes (2003). Badlands NP adopted a fire management plan that attempts to mimic natural conditions and restore habitat. However, unplanned fires are suppressed. Trend for the ecological interactions indicator was *Not Available*.

Geography

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

Condition

Badlands bison are one of about 14 conservation herds in the northern mixed grasslands ecoregion (Figure 4.12.12). At the time of this assessment, the bison herd at Badlands NP was the largest herd in the region (Table 4.12.15) and contributed broadly to large-scale restoration in a variety of ways. Since 1969, the park has distributed 4,813 bison to 29 different Native American tribes throughout North America (E. Childers, personal communication, 17 March 2016). This status placed representation of habitat type for Badlands NP in the *Resource in Good Condition* category. Representation of habitat type for Badlands NP in the *Resource in Good Condition* category.

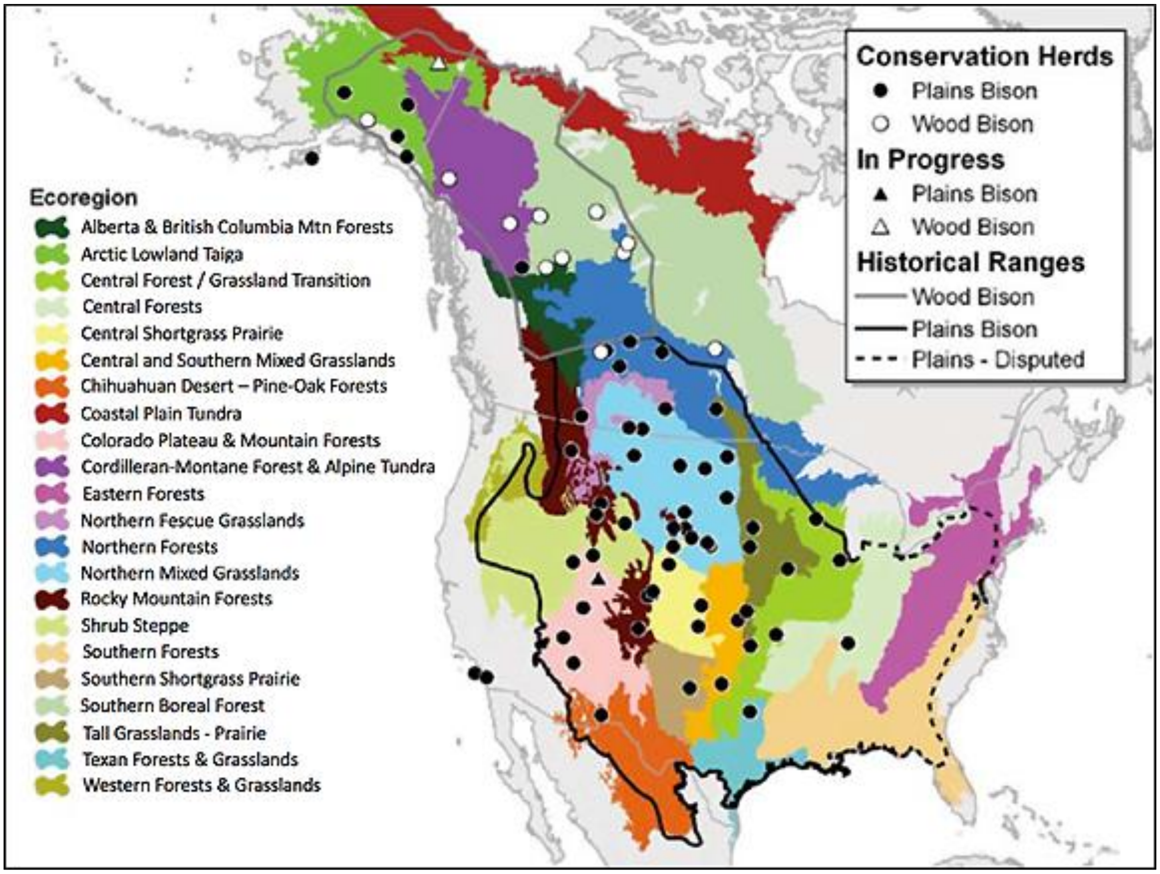

Figure 4.12.12. Representation of plains and wood bison conservation herds along with their historical ranges and major habitat types (Sanderson et al. 2008, Gates et al. 2010).

Table 4.12.15. Summary of bison indicators and measures.

Indicator	**Measure**	**Condition**	**Confidence**	**Trend**	**Condition Rationale**
Herd size and composition	Herd size	Warrants moderate concern	Medium	Improving (but see discussion of bison densities)	Herd size has been managed for 600–700 bison, and the post-cull estimate was 976 in 2015; this value placed herd size in the *Warrants Moderate Concern* category. Censuses were generally conducted annually, but not methodically, so confidence was *Medium* and trend was *Improving*.
	Population structure	Warrants significant concern	Medium	Not available	40% of the herd was male, age structure was characteristic of a young population, and densities were high; this placed population structure in the *Warrants Significant Concern* category. Population structure data were from roundup animals, so confidence was *Medium*. Trend was *Not Available*.
Landscape size and use	Landscape available to bison	Warrants moderate concern	Medium	Not available	~40,000 acres were available to bison; this value placed available landscape in the *Warrants Moderate Concern* category Confidence was *High* and trend *Unchanging*.
	Human footprint	Resource in good condition	High	Not available	Bison inhabited a wilderness area that has little to no infrastructure and minimal visitation; this placed human footprint in the *Good Condition* category. Confidence was *High* and trend was *Unchanging*.
	Management of movements	Warrants moderate concern	High	Not available	Bison were confined at the perimeter but are otherwise free to roam throughout the wilderness area; this freedom of movement placed management of movements in the *Moderate Concern* category. Confidence was *High* and trend was *Unchanging*.
Ecological interactions	Natural selection	Warrants significant concern	High	Not available	Bison were exposed to 2 of 5 natural selection pressures; this value placed natural selection in the *Warrants Moderate Concern* category. Confidence was *High* and trend was *Unchanging*.

Table 4.12.15 (continued). Summary of bison indicators and measures.

Indicator	Measure	Condition	Confidence	Trend	Condition Rationale
Ecological interactions (continued)	Interaction with suite of native vertebrate species	Resource in good condition	High	Not available	Bison are able to interact with many native vertebrate species, with the exception of natural predators; this interaction placed species interactions in the *Good Condition* category. Confidence was *High* and trend was *Improving* because some extirpated species have been reintroduced since 1963.
	Interaction with ecosystem processes	Warrants moderate concern	High	Not available	Bison were generally allowed natural interactions with ecosystem processes, placing this category in *Good Condition*. Confidence was *High* and trend was *Unchanging*.
Geography	Representation	Resource in good condition	Medium	Not available	The bison herd at Badlands was in moderate condition and was the largest in its habitat type; this status placed representation in *Good Condition*. Confidence was *Medium* because we did not have reliable data on other herds in the region, and trend was *Not Available.*
Health and genetics	Presence and management of disease	Resource in good condition	High	Not available	There were no reportable diseases, so the Resource in *Good Condition*. Disease testing occurs at all roundups, so confidence is *High*. Trend data were *Unchanging*.
	Genetic diversity	Warrants moderate concern	High	Not available	The BNP herd had moderate genetic diversity, warranting *Moderate Concern*. The confidence was *High* because 37% of the herd was sampled in 2002. Trend data were *Not Available*.
	Genetic integrity	Warrants significant concern	High	Not available	14% detected nuclear cattle genes placed genetic integrity in the W*arrants Significant Concern* category. The confidence was *High* because 14 markers were tested and 56% of the herd was sampled in 2002. Trend data were *Not Available*.

Confidence

Some of the herd size estimates for other conservation herds in the region were out of date, and we did not have time to conduct a comprehensive scorecard assessment for the other herds in the region. Confidence for geography was *Medium*.

Trend

We did not have access to multiple years of herd size or other scorecard rankings for other populations in the northern mixed grasslands, so trend for geography was *Not Available*.

Health and Genetics

●

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

Condition

To assign a condition for health and genetics, we used data from Badlands NP and the scientific literature. Disease data were taken from NPS publications. At the time of this assessment, bison had been free of reportable diseases after more than 10 years of testing (NPS 2007; E. Childers, personal communication, 17 March 2016). This health status placed the presence and management of disease in the *Resource in Good Condition* category.

Genetic diversity data were taken from a study of genetic variation in federal bison herds (Halbert and Derr 2008). The authors found that the Badlands NP herd had moderate levels of genetic diversity, but found multiple lines of evidence for genetic drift, which can lead to loss of genetic diversity. These data placed genetic diversity in the *Warrants Moderate Concern* category.

We used genetic integrity data from a study of cattle introgression in federal bison herds, including the herd at Badlands NP (Halbert and Derr 2007). They found that 2 of 14 (14%) nuclear DNA (microsatellite) markers in the Badlands NP herd originated from domestic cattle. This result placed genetic integrity in the *Warrants Significant Concern* category.

Overall, these values placed health and genetics for Badlands in the *Resource in Moderate Condition* category.

Confidence

All bison in roundups were tested for reportable diseases, so confidence in the presence of disease was *High*. Genetic diversity and integrity data were collected from 37% and 56%, respectively, of the bison herd (Halbert and Derr 2007, 2008) so confidence was *High*. Overall, health and genetics confidence was *High*.

Trend

Trend data were *Not Available* for health and genetics.

American Bison Overall Condition

Table 4.12.16. American bison overall condition.

Indicators	Measures	Condition
Herd size and composition	• Herd size • Population structure	🔴
Landscape size and use	• Landscape available to bison • Human footprint • Management of movement	🟡
Ecological interactions	• Natural selection • Interaction with native invertebrates • Interaction with ecosystem processes	🟡
Geography	• Representation	🟢
Health and genetics	• Presence and management of disease • Genetic diversity • Genetic integrity	🟡
Overall condition for all indicators and measures		🟡

The overall bison condition was determined by the average of the indicator conditions. We summarized the condition, confidence, and trend for each indicator, and assigned condition points. The total score for overall bison condition was 50 points, which placed Badlands National Park in the Warrants *Moderate Concern* category.

Confidence

Confidence was *High* for three of five indicators and *Medium* for two of five indicators. The score for overall confidence was 66 points, which met the criteria for *High* confidence in overall bison condition.

Trend

Trend data were *Not Available* for all indicators. Trend data for individual measures were only available for herd size (*Improving*) and sex ratio (*Deteriorating*). The remaining measure trends were *Not Available*, so overall trend for bison was *Not Available*.

4.12.5. Stressors

Population density is a concern for bison condition at Badlands NP. The bison population at Badlands has expanded rapidly since reintroduction. At the time of this assessment, densities were high relative to water availability, and age and sex structure were skewed. The amount of suitable water sources within the wilderness area may not be capable of sustaining more than the current number of bison.

4.12.6. Data Gaps

Landscape and Forage Use

Information on how bison use the landscape at Badlands NP is generally lacking. USGS scientists are in the initial stages of a research project using collared bison to fill this data gap. They are studying the density and distribution of bison within the park, and seeing how these are related to forage availability, composition, and utilization. During the most recent roundup in October 2015, 25 female bison were fitted with GPS collars programmed to collect locations at 1-hour intervals (G. Sargeant, personal communication, 6 March 2016). The project will be completed in 2019.

Human Cultural Interactions

We did not consider cultural interactions in the scorecard, but they are important for public education and for generating income within the park. Human "interactions" with bison (i.e., viewing) are important because they further education and are a source of income within the park. Public access is an important educational opportunity for the public to be able to observe bison in their natural habitat. Public access is unrestricted; the park is open 24 hours a day, seven days a week, and bison are readily viewed from roads.

Bison played a large role in the way of life for native cultures, and continue to be an important facet of many tribes to this day. Not only are bison an important source of food, clothing, and other goods, but they play a central role in the cultures and religions of many native tribes. Hunting is not permitted in the park, but culled animals are distributed to tribes locally and beyond. The south unit of Badlands NP is located on the Pine Ridge Indian Reservation, but the Badlands bison herd is restricted to the north unit.

Sociopolitical Environment and Capacity

Another scorecard indicator that was beyond the scope of this assessment was sociopolitical environment and capacity, composed of four measures. These included a supportive legal and policy environment for ecological recovery, long-term security of recovery objectives, capacity to manage herds, and market incentives. While these measures are not biological in nature, they do directly impact the ecological recovery of the species and are therefore important for bison management.

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4.13. Swift Fox

4.13.1. Background and Importance

The swift fox (*Vulpes velox*) is a small-sized member of the dog family (Figure 4.13.1) (Egoscue 1979), typically weighing about two kilograms. Historically, they were thought to be common or locally abundant throughout much of the shortgrass and mixed-grass prairies of the Great Plains (Allardyce and Sovada 2003).

Figure 4.13.1. Swift fox fitted with a radio collar (Photo by NPS).

Swift foxes are mostly active at night, and spend the majority of the day on top of or in dens (Kitchen et al. 1999). They prey primarily on mammals (e.g., rabbits, small rodents, and prairie dogs), but also eat birds, insects, and vegetation (Hillman and Sharps 1978, Egoscue 1979). Their main predators are coyotes (Allardyce and Sovada 2003). Adults typically form monogamous pairs that mate for life, annually producing a litter of about four pups.

Swift foxes need denning sites year-round, and will change den locations frequently to reduce the risk of predation and perhaps to avoid parasites (Tannerfeldt et al. 2006). They can dig their own dens, but will often enlarge the burrows of other species, primarily prairie dogs (Egoscue 1979). Swift foxes are often associated with prairie dogs, which also serve as an important prey source in many areas (Hillman and Sharps 1978).

Twenty four National Park Service (NPS) units are located within the historic range of the swift fox (Moehrenschlager et al. 2008). The distribution of swift foxes is generally poorly understood, although research efforts to map locations throughout the potential range are underway. Even within National Park lands, swift foxes may be present but not documented. Prior to 2001, it was thought that no NPS sites had swift foxes (Licht 2002). Later surveys reported that, while there were no confirmed records of swift foxes on NPS lands, 14 park units potentially had swift foxes present (Moehrenschlager et al. 2008). Badlands NP is one of two units for which swift foxes are now confirmed to be present (NPS 2016), the other being the nearby Agate Fossil Beds National Monument (Graetz et al. 1995).

The NPS reintroduced a swift fox family to Badlands NP in 1987 from the nearby Pine Ridge Reservation (Consolo 1987), but failed to establish a population. Additional reintroductions were accomplished from 2003–2006 with 114 individual foxes brought from Colorado and Wyoming (Nevison et al. 2015).

The swift fox is one of four native species that has been reintroduced to Badlands NP in an effort to restore the native prairie ecosystem, the others being the black-footed ferret (*Mustela nigripes*), bighorn sheep (*Ovis canadensis*), and American bison (*Bison bison*). The Park Service is dedicated to protecting swift foxes, and has partnered with South Dakota State University on several research projects aimed at improving knowledge on swift fox populations in the region (Nevison et al. 2015). Badlands NP has a freely available online lesson plan for students, using real data from swift fox reintroductions (https://www.nps.gov/badl/learn/education/classrooms/swiftfoxdata.htm).

Regional Context

While swift foxes may have been common at one time, populations were reduced in the early 1900's due to conversion of native prairie to agriculture, incidental take from predator control aimed primarily at coyotes and wolves, and unregulated hunting and trapping. Their historic range coincided with that of black-tailed prairie dogs (*Cynomys ludovicianus*), whose reduced range may also have contributed to declines in swift foxes because of reduced prey availability and changes to habitat quality. There were no reports of swift foxes in South Dakota from 1914–1966, and there were only occasional reports from 1966–1975 (Hillman and Sharps 1978). Swift foxes were first confirmed again in South Dakota in the 1970s on the Pine Ridge Reservation (Hillman and Sharps 1978).

The 1972 federal restrictions on poisons used to kill coyotes and prairie dogs is one change that has allowed fox populations to rebound slowly. Information on the current population trend of swift foxes is generally lacking, but they appear to be more widespread than previously thought. A region-wide recovery was observed in the 1950s–1970s (Egoscue 1979).

The western half of South Dakota may contain suitable swift fox habitat (Figure 4.13.2). The best available information on current swift fox distribution indicates that they are found in only a small portion of suitable habitat in the state (Figure 4.13.3). In recent years, many states have undertaken efforts to map the current distribution and abundance of this species.

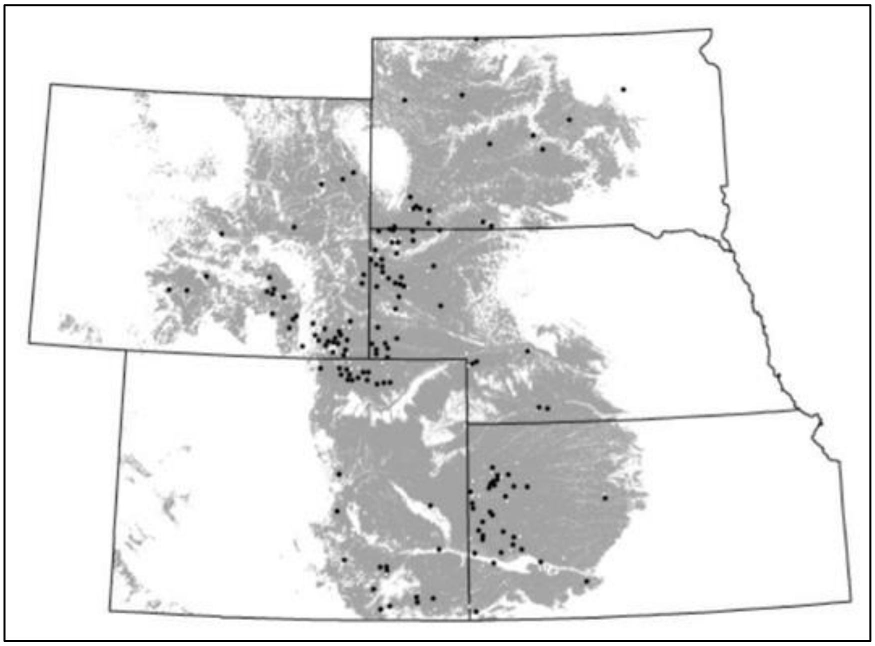

Figure 4.13.2. Predictive distribution of swift fox in Wyoming, Colorado, South Dakota, Nebraska, and Kansas (Beauvais et al. 2003). Gray depicts areas of land cover types associated with swift fox (e.g., mixed-grass prairie) and with suitable biophysical characteristics (e.g., elevation, precipitation). Circles are known occurrences that were used in model development and validation.

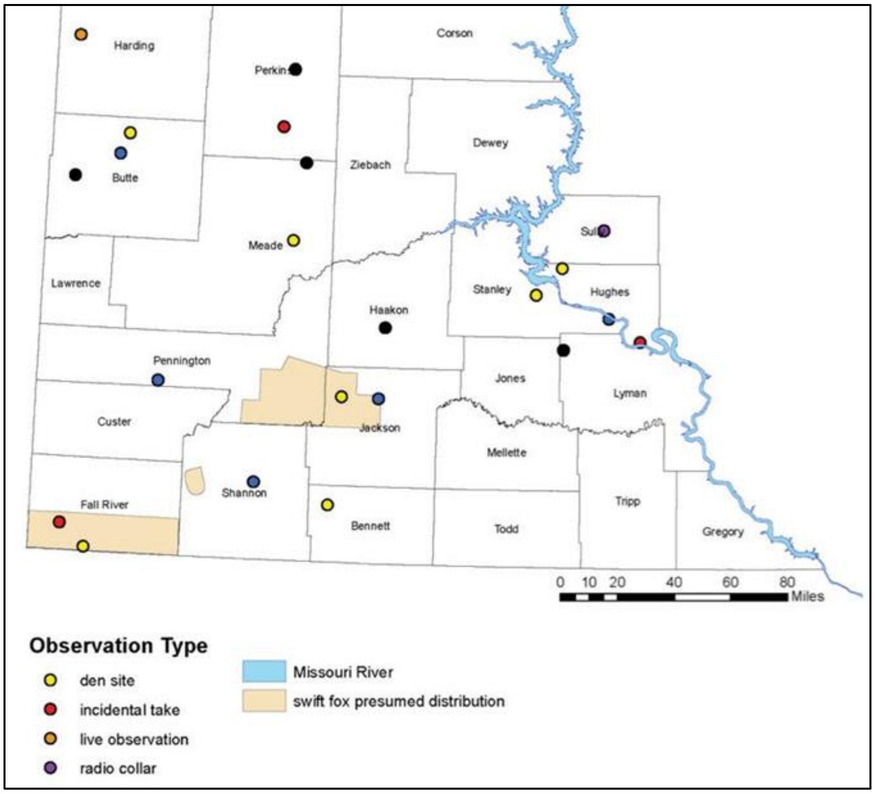

Figure 4.13.3. Estimated distribution of swift fox in South Dakota (Stukel 2015).

Swift foxes now occupy approximately 40% of their former range (Sovada et al. 2009; Figure 4.13.4). They exist in isolated populations in Canada and Montana, and fragmented populations in the United States. Researchers identified about seven genetically distinct populations (Schwalm et al. 2014).

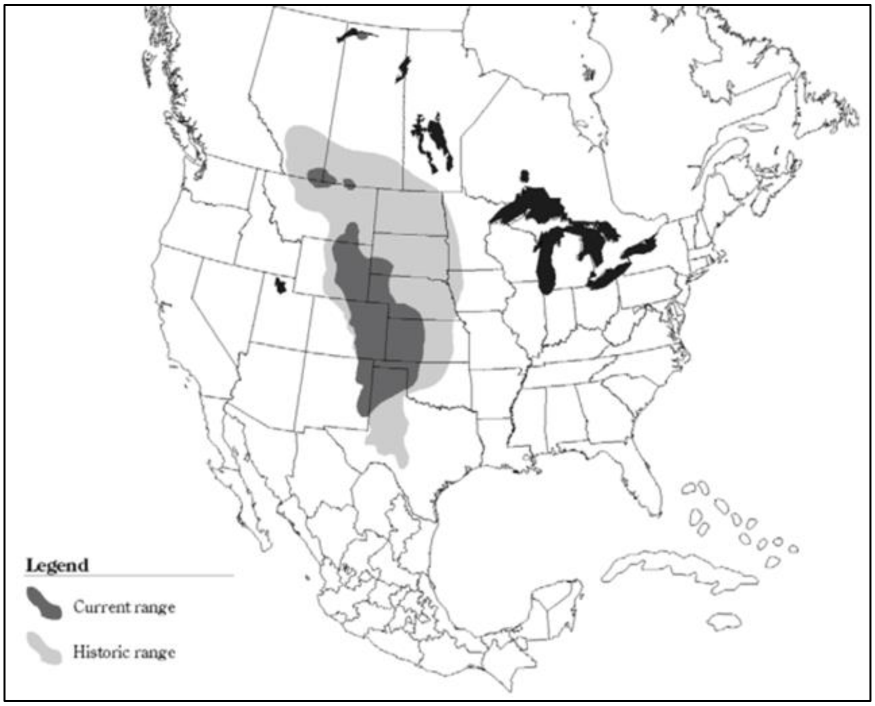

Figure 4.13.4 Current and historic distribution of swift fox in North America (Cotterill 1997).

4.13.2. Resource Standards

The International Union for the Conservation of Nature (IUCN) lists the swift fox as a species of least concern (Moehrenschlager et al. 2008), but it is listed as endangered in Canada. The status of swift fox in the United States has been revised numerous times since the inception of the Endangered Species Act. The northern subspecies of swift fox was listed as endangered in 1970, but this designation was removed in 1980. The species was later declared “warranted but precluded” by higher listing priorities in 1995 (USFWS 1995), but was removed from the candidate list in 2001 (USFWS 2001). The BLM designates them as a sensitive species. Swift fox has been listed as state threatened in South Dakota since 1978.

The Swift Fox Conservation Team was formed in 1994 as a collaborative effort to protect the swift fox and keep them off the endangered species list (Dowd Stukel et al. 2003). They conduct research and monitoring and produce a bi-annual report to share information on the status of this species.

4.13.3. Methods

Indicators, Measures, and Data Sources

We evaluated overall swift fox condition based on the individual condition of one main indicator: population viability. To assign a condition to this indicator, we examined population growth rate. Potential conditions were: *Resource in Good Condition*, *Warrants Moderate Concern*, and *Warrants Significant Concern*. The single indicator condition was the same as the overall swift fox condition.

Indicator: Population Viability

The population of swift foxes at Badlands is important for the overall recovery of the species in South Dakota. Population viability analyses estimate the chances that a population will persist for a given period of time. These analyses incorporate information on demographic, environmental, and genetic parameters, while incorporating the effect of random events.

Measure of Population Viability: Population Growth Rate

One of the elements of a population viability analysis is an estimate of population growth rate. To calculate populate growth rates through a population viability analysis, researchers collect data on birth rate, death rate, and reproductive rate for a population. Positive population growth rates mean that the population is growing, whereas populations with a negative growth rate decline. A growth rate of zero means that the population is not changing in overall size.

The Badlands swift fox population was recently reintroduced (2003–2006) and is part of a larger effort to restore swift fox to South Dakota and across the entirety of their former range. Therefore, we considered positive population growth to indicate Resource in Good Condition and negative growth to Warrant Significant Concern (Table 4.13.1). While it may seem natural to assign the condition Warrants Moderate Concern to a population with no growth rate, population in good condition can have similar numbers from year to year. Over multiple years, a trend is likely to emerge that indicates growth, decline, or statistically unchanging population size.

Table 4.13.1. Swift fox condition categories for population growth rate.

Resource condition		**Population growth rate**
Warrants significant concern	🔴	Negative population growth
Warrants moderate concern	🟡	–
Resource in good condition	🟢	Positive population growth

Data Collection

Data for this assessment came primarily from the dissertation of Sasmal (2011), the result of a collaborative project between Badlands National Park and South Dakota State University. The population viability assessment was conducted with seven years of demographic data (Sasmal 2011; 2003–2009) for populations located within the 1,800 square kilometer study area (23% managed by NPS; Russell 2006).

Quantifying Swift Fox Condition, Confidence, and Trend

Indicator Condition

To assess swift fox condition, we used the recovery goal of establishing a self-sustaining population. We used only one measure for the indicator, so the condition of that measure was the condition of the indicator. Potential condition categories were *Warrants Significant Concern*, *Warrants Moderate Concern*, and *Resource in Good Condition*.

Indicator Confidence

Confidence ratings were based on the quality of data and expert opinion. We gave a rating of *High* confidence when monitoring was on site or nearby, data were collected recently, the data were collected methodically, and the data were sufficient to calculate a population viability analysis (Morris and Doak 2002). We indicated a *Medium* confidence when monitoring was not nearby, data were not collected recently, data collection was not repeatable or methodical, or the data were insufficient to conduct a solid population viability analysis. We assigned *Low* confidence ratings when there were no good data sources to support the condition.

Indicator Trend

Potential trend categories were *Improving*, *Unchanging*, or *Deteriorating*. To calculate a trend estimate, we needed to have data that were collected similarly over multiple years. If there were no data available that met these requirements, we indicated that trend was *Not Available* for that indicator.

Overall Swift Fox Condition

To assess overall swift fox condition, we used the single measure of population growth rate; the condition of this indicator was, therefore, the overall condition of swift foxes at Badlands NP (Table 4.13.2).

Table 4.13.2. Summary of swift fox indicators and measures.

Indicator	Measure	Condition	Confidence	Trend	Condition rationale
Population viability	Population growth rate	Warrants significant concern	High	Not available	Swift fox population growth rate from 2003–2009 was -0.47; this value placed population viability in the *Warrants Significant Concern* category. Confidence was *High* and trend was *Deteriorating*

Overall Swift Fox Confidence

We used the single measure of population growth rate to assess overall swift fox confidence; the confidence in this indicator was the overall confidence for swift fox.

Overall Swift Fox Trend

We used the single measure of population growth rate to assess overall swift fox trend; the trend of this indicator was the overall trend for swift fox.

4.13.4. Swift Fox Conditions, Confidence, and Trends

Population Viability

🔴

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

Condition

To assign a condition for population viability, we used published data collected in Badlands and surrounding areas from 2003–2009. The population growth rate during this time period was negative (r = -0.47; Sasmal 2011). This value placed population viability of swift foxes for Badlands NP in the *Warrants Significant Concern* category.

Sasmal (2011) conducted population viability analysis on data collected from 2003–2009 for the reintroduced swift fox population at Badlands NP and the surrounding area. She predicted that the swift fox population at Badlands NP and surrounding areas had a 100% chance of extinction by 2019 if population decline continued at the rate of 47% per year. While swift foxes have been observed denning near the park, no recent swift fox den activity has been reported in Badlands NP (E. Childers, personal communication, 25 April 2016). However, a small number of foxes have been observed within park boundaries in recent years (S. Nevison, personal communication, 6 May 2016). The lack of current den activity, combined with the devastating effects of plague on prairie dog and potentially other rodent populations (see section 4.13.5 Stressors), suggests that the population growth rate is unlikely to have improved since 2009.

Researchers found that the driving factor of poor persistence in swift fox populations was the high mortality (low survival) rates of adults and pups. The annual survival probability of pups was 0.47 ± 0.10 SE and 0.27 ± 0.08 for yearlings and adults (Sasmal et al. 2016). They suggested that the most efficient way to maintain a stable population would be to decrease mortalities rates.

Confidence

Sasmal (2011) constructed population viability analysis using demographic rates and sensitivity analyses from seven years of data from Badlands National Park, surrounding areas, and the literature. The results from this analysis were corroborated by ongoing work at Badlands NP and observations by biologists (E. Childers, personal communication, 25 April 2016), so the confidence was *High*.

Trend

The negative growth rate is, inherently, a deteriorating trend. This calculation, coupled with the confidence of biologists that populations have declined, suggests that trend is deteriorating, but trend data were *Not Available.*

Swift Fox Overall Condition

Table 4.13.3. Swift fox overall condition.

Indicators	Measures	Condition
Population viability	- Population growth rate	🔴

The overall swift fox condition was the same as the single indicator condition, which placed the condition of swift foxes at Badlands National Park in the *Warrants Significant Concern* category.

Confidence

Confidence was *High* for overall swift fox condition.

Trend

The swift fox population has declined, but overall trend data for swift fox condition were *Not Available*.

4.13.5. Stressors

Prairie dog decline and plague

Swift foxes may use a variety of habitats provided that they contain adequate denning sites and afford good visibility of approaching predators. In Badlands NP, female swift foxes use grasslands, sparse vegetation, and prairie dog colonies in proportion to their availability, while avoiding other habitat types (Figure 4.13.5; Sasmal et al. 2011). Monitoring data for Badlands NP on grassland and sparse vegetation habitat types were not available, but we had access to information on prairie dog colonies, which we discuss in further detail in this NRCA (Chapter 4.10.).

Swift foxes are often associated with prairie dog colonies (Lomolino and Smith 2004), and populations of swift foxes may decline with declines in prairie dogs (Kotliar et al. 1999). Prairie dogs constitute a large proportion of the swift fox diet in South Dakota (Hillman and Sharps 1978, Uresk and Sharps 1986). Prairie dog colonies attract more species of small mammals (Shipley and Reading 2006) and higher densities of prey species such as deer mice (*Peromyscus maniculatus*), northern grasshopper mice (*Onychomys leucogaster*), and horned larks (*Eremophila alpestris*; Agnew et al. 1986). Changes in vegetation structure (i.e., reduced vegetation height) on colonies may also attract swift foxes. Swift fox prefer to den on or near prairie dog colonies (Kintigh and Andersen 2009). For all of these reasons, prairie dog colonies are important for swift foxes.

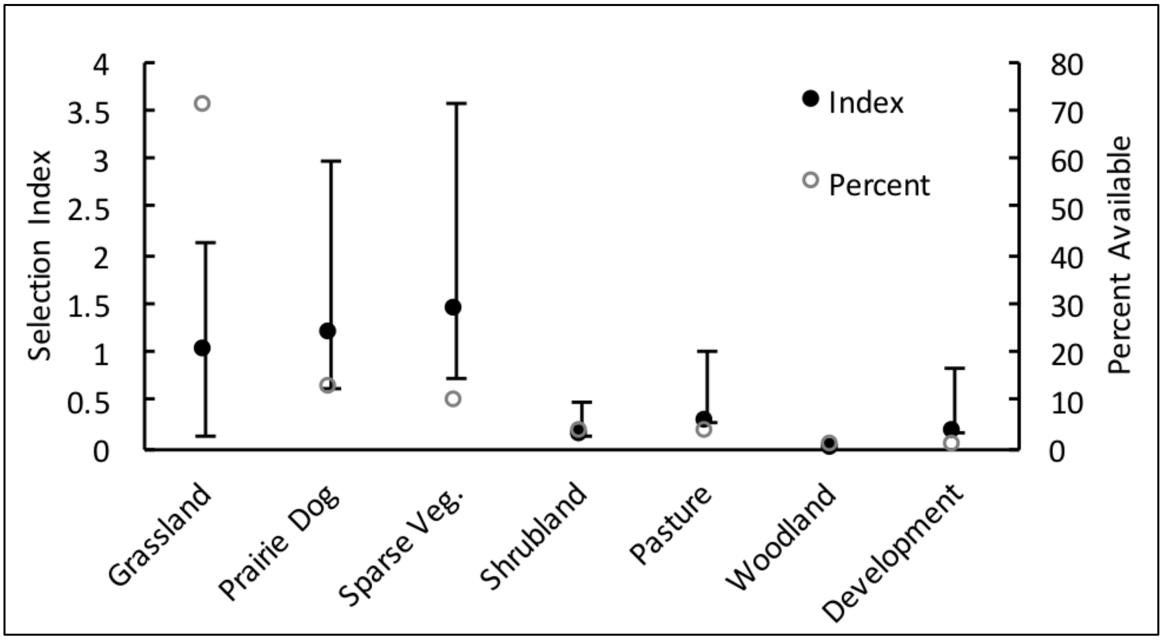

Figure 4.13.5. Habitat selection indecies for swift foxes versus percentage of totally study area land in each habitat type. Left axis: The black dots show habitat selection indices and their 90% confidence intervals. Values significantly greater than one indicate strong habitat preferences, values with confidence intervals including one indicate habitat use that is proportional to habitat availability, and values significantly less than one indicate habitat avoidance. In this case, areas of shrubland, pasture, and development were statistically avoided. Right axis: The gray circles show the proportion of the total study area in each habitat type (data from Sasmal et al. 2011).

The goals set by the Swift Fox Conservation Team include maintaining or restoring swift fox populations "throughout at least 50 percent of the suitable habitat available" (Dowd Stukel 2011). In 2015, there were 910 hectares (2,250 acres) of active prairie dog colonies within Badlands NP (Figure 4.13.6). The latest estimate of suitable prairie dog habitat (based on land cover and slope characteristics) from 2007 was 24,215 hectares (NPS 2007). Therefore, 3.8% of suitable habitat was occupied by prairie dogs in 2015. Suitable habitat for black-tailed prairie dogs is nearly the same as that for swift foxes for a number of reasons: 1) they have overlapping habitat needs. Both species require the same kinds of soil suitable for their burrows and dens (Reading and Matchett 1997, Harrison and Whitaker-Hoagland 2006); 2) they are attracted to the same vegetation structure. Both species seek out areas of high visibility (i.e., open areas of short grasses, or areas of grasses that can be maintained through clipping by prairie dogs); 3) Prairie dogs are a prey source. Prairie dogs remain active during the winter, and thus serve as a reliable, abundant source of prey for swift foxes; 4) Prairie dog burrows provide shelter. Swift foxes may make extensive use of prairie dog burrows.

Figure 4.13.6. Image of researchers collecting flea samples. Swift foxes harbor fleas that may transmit plague. Here researchers collect flea samples that will be tested for the plague bacterium, *Yersina pestis* (Photo by Sarah Nevison).

Sylvatic plague is a threat to prairie dogs and associated species, like swift foxes, in Badlands NP. A reduction in prairie dog acreage is a reduction in the amount and quality of swift fox habitat. Plague is a non-native, generalist disease that is highly lethal for black-tailed prairie dogs. Plague may have reached South Dakota around the early 2000s when it was first detected in the southwestern part of the state. Prairie dog colonies in nearby Conata Basin (Buffalo Gap National Grassland) and Badlands NP (Conata Basin/Badlands) were expanding until plague outbreaks occurred in 2008 and 2009, respectively.

We examined 16 years of mapped colonies to determine a trend in black-tailed prairie dog acreage (Figure 4.13.7). From 2000–2007, all colonies in the north unit were mapped every two years (one half surveyed in the first year, one half surveyed in the second). Therefore, acreage estimates for any given year represent the colonies mapped in that year plus the previous year. Since 2008, annual maps have included all colonies; this change in mapping extent was due to the reduced number and area of colonies.

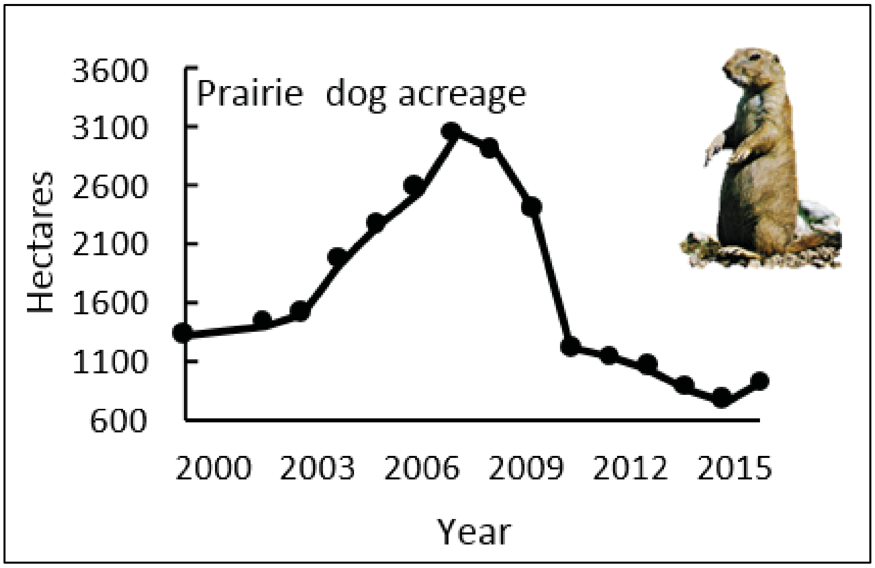

Figure 4.13.7. Trend in the amount of habitat occupied by black-tailed prairie dogs in the north unit of Badlands NP. Occupancy peaked in 2007. Plague was first detected in the region in 2005 and in Badlands in 2009. Acreage was not available for 2001.

We fit one linear and three nonlinear models to the data. We selected a quadratic model as the best fit for the data based on significance and model improvement ($R^2 = 0.6266$, df = 12, $P < 0.01$). The slope of the trend line following plague was negative, so the trend for this aspect of swift fox habitat was deteriorating. The single most influential cause of these declines in prairie dog populations was plague.

There are no diseases currently recognized as having significant impacts on swift fox populations (Pybus and Williams 2003). While plague antibodies have been detected in swift foxes (McGee et al. 2006, Salkeld et al. 2007), swift foxes are not thought to develop infectious plague or clinical signs of infection (Pybus and Williams 2003). The role of swift foxes in the transmission of plague is unclear. A study in New Mexico showed that the majority of swift foxes had one or more species of fleas known to carry plague (Figure 4.13.6), concluding that all foxes should be considered “potential carriers” (Harrison et al. 2003). A study in Colorado showed that plague antibody prevalence was tied to plague outbreaks (Salkeld et al. 2007). While foxes carried fleas that are known to transmit plague, these fleas did not test positive for plague (Salkeld et al. 2007). Nevertheless, researchers concluded that swift foxes may play a role in plague dynamics. The potential role of swift foxes in plague dynamics as potential sources of infected fleas is therefore a potential stressor as well as a data gap.

The primary strategy for controlling plague outbreaks is “dusting” burrow entrances with insecticide to kill the fleas that transmit plague. Dusting has been used at Badlands NP annually since plague was first detected in the region. Dusting, while largely successful, is not a panacea for black-tailed prairie dog recovery. Fleas have begun to show signs of resistance to the current dusting insecticide (deltamethrin; E. Childers, personal communication, 24 November 2015), so the success of longer-term dusting efforts hinges on finding an alternative insecticide. Dusting is also an expensive endeavor ($16.30 per acre in 2015; Griebel 2015). Historically, funding for dusting in Badlands came from recreational fee demonstration funds. The NPS did not renew this funding in 2015, and funding for 2016 is uncertain (E. Childers, personal communication, 24 November 2015).

Researchers with the USGS are investigating the viability of an oral vaccine bait for prairie dogs (U.S. Geological Survey 2013). 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.

Competition with other species

Coyotes are the principle cause of mortality for swift foxes range-wide (Figure 4.13.8; Allardyce and Sovada 2003). In Badlands NP, 43% of mortalities of known cause were attributed to coyotes (Sasmal et al. 2016). In other regions, coyotes may account for as much as 89% of swift fox deaths (Kamler et al. 2003). These mortalities are the result of competition rather than predation, as coyotes do not typically consume swift foxes (Kitchen et al. 1999). While data on coyote densities are lacking, nearby (~80 kilometers) coyotes populations declined from 2003–2005 (Chronert et al. 2007). Research in Colorado showed that coyotes and swift foxes show a high degree of spatial and temporal overlap in their home ranges, but the majority of mortalities by coyotes occurred outside of the home range of swift fox (Kitchen et al. 1999). Conversely, swift fox home ranges in Texas generally did not overlap with those of coyotes, and the majority of mortalities occurred close to swift fox dens (Kamler et al. 2003). Historically, wolves may have exerted some level of population control on coyotes, but they have been absent from these ecosystems for nearly a century.

Figure 4.13.8. Image of a coyote. Coyotes are common residents of Badlands National Park and are an important source of swift fox mortality (Photo by Dakota McCoy, NPS).

Vehicle Mortalities

Vehicle collisions are another important source of mortalities in swift foxes, particularly for dispersing juveniles (Sovada et al. 1998). Dispersal at Badlands occurs in September and October (Sasmal et al. 2016), during which time about 18% of the annual traffic volume passes through the park. A total of 394,332 vehicles entered the park in 2015 (https://irma.nps.gov). Park traffic is concentrated along two main travel corridors: pavement is limited to the Loop Load/Highway 240, and the Rim Road is a gravel route that runs along the northern border of the park. Vehicles may present impediments to movement and dispersal as well as cause a significant number of direct mortalities. Of 75 mortalities for which the cause could be determined from 2003–2009 in and around Badlands NP, 42 (56%) were attributed to vehicle collisions (Sasmal et al. 2016). Unfortunately, foxes may actually select den sites near roads (Hillman and Sharps 1978) or in areas of high road density (Kintigh and Andersen 2009). It is possible that foxes use roads as movement and dispersal corridors (Kintigh and Andersen 2009), thereby exposing them to vehicle traffic.

4.13.6. Data Gaps

Any rigorous data on population parameters, preferably with estimates of associated error, such as abundance, density, occupancy, reproduction, survival, mortality, population growth, or distribution from in and around the park would be informative. Most if not all of these population measures are being studied as part of ongoing research being conducted by the NPS and South Dakota State University (2014–2016); Nevison et al. (2015) at South Dakota State have the following objectives:

> *"…to (a) document the current distribution of swift foxes across southwestern South Dakota, (b) document active dens to determine reproductive rates, (c) determine survival and cause-specific mortality, and (d) assess the presence of swift fox in areas affected by plague."*

Additionally, information on the population size and trend of coyotes could be helpful to managers. The role swift foxes play in plague transmission, if any, has yet to be elucidated.

Genetics

Research on the genetic health of swift foxes is ongoing. The latest genetic analysis was conducted with samples from 2003–2009 (Sasmal et al. 2013). Releases of swift foxes occurred from 2003–2006. Swift foxes typically live for four or five years, so genetic summaries for purely wild-born foxes are not yet available. Ongoing collection of genetic samples should allow for future temporal comparisons of swift fox genetic diversity.

The results of the 2003–2009 genetic data indicated high levels of heterozygosity (Table 4.13.4). This is at least partly a result of the fact that animals were recently introduced from multiple populations, thus providing a boost of genetic diversity. Note that that genetic diversity is often reduced following population declines, such as that seen in the Badlands NP population.

Table 4.13.4. Comparison of observed genetic heterozygosities for different populations of swift foxes and related species of North American canids. Swift foxes exhibited a high level of average genetic heterozygosity with a large range of variability compared to other populations and species. Ho = observed genetic heterozygosity, SD = standard deviation, range = minimum and maximum observed heterozygosities. Descriptions of each population are given in the notes, with sampling dates in parentheses.

Common name	Scientific name	Location	Ho	Sd	Range	Source	Notes
Swift fox	*Vulpes velox*	South Dakota	0.75	0.17	0.30 – 0.92	Sasmal et al. 2013	Recently reintroduced (2003-2009)
		Colorado	0.78	0.16	0.32 – 0.91	Sasmal et al. 2013	Resident population
		Wyoming	0.75	0.17	0.35 – 0.91	Sasmal et al. 2013	Resident population
		Colorado	0.54	0.15	0.31 – 0.79	Kitchen et al. 2005	Resident population (1997-2000)
		MT/Canada	0.68	0.05	0.60 – 0.76	Cullingham and Moehrenschlager 2013	First reintroduction 1983 (2001-2006)
		Rangewide	0.61	0.07	0.50 – 0.68	Schwalm et al. 2014	Resident populations (1996-2008)
Kit fox	*V. macrotis*	California	0.39	0.07	0.28 – 0.50	Schwartz et al. 2005	Endangered subspecies
Coyote	*Canis latrans*	California	0.76	–	0.39 – 0.95	Williams et al. 2003	Population experiencing removals
Gray wolf	*C. lupus*	Montana	0.68	0.07	0.55 – 0.80	Forbes and Boyd 1996	Naturally colonized populations
		Alberta	0.55	–	–	Forbes and Boyd 1996	Source population

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4.14. Bats

4.14.1. Background and Importance

Bats have many important ecological roles and are one of the most diverse groups of mammals (Nowak and Walker 1994), accounting for about 20% of all mammal species globally (1,200). These winged mammals consume thousands of pounds of insects annually (Cleveland et al. 2006, Boyles et al. 2011), including some damaging agricultural pests, thereby saving billions of dollars in agricultural costs (Boyles et al. 2011). In some regions, bats are critical for the propagation of many plants (Howe and Smallwood 1982, Fujita and Tuttle 1991). Even bat guano (droppings) provides unique habitat to some specialist organisms (Mulec et al. 2016). Some bats are considered by researchers to be keystone species (Mello et al. 2015), a species that has a much greater effect on its ecosystem than would be expected given its biomass, and can be bioindicators of the health of a broad range of organisms (Jones et al. 2009).

Townsend’s big-eared bat, a species found in Badlands NP. Photo by NPS (2002).

Bats have not benefited from the charismatic appeal associated with many other organisms (Martin-Lopez et al. 2007) and have suffered population declines (Frick et al. 2010) due to white nose syndrome (WNS), a disease accompanied by a distinctive white fungal growth across the nose and muzzle of infected bats. White nose syndrome is an exotic disease first documented in New York State in 2007 and most likely originating in Europe (Warnecke et al. 2012). The disease is now widespread throughout eastern and central North America and, at the time of this assessment, had recently been identified in a small brown bat (*Myotis lucifgus*) in Cascade Mountains of northwestern Washington State.

National Park Service lands are important reference and monitoring sites for bat populations. The NPS is dedicated to protecting bats and their habitat; at the time of this assessment, over 40 parks were host to at least 43 projects to protect bats and gain insight into white nose syndrome (NPS 2015). Among NPS units that have caves, mines, and old buildings for roosting, about 40 of the 47 resident of U.S. bat species occur on NPS land (NPS 2015).

Regional Context

Thirteen bat species, of which eight species are fully resident and three are resident in the summer, are known to occur throughout South Dakota (Table 4.14.1; South Dakota Bat Working Group 2004, 2014). Eleven bat species are found in Badlands NP (Licht 2016) and three of these species are of particular concern to the state, receiving a listing as high priority Species of Greatest Conservation Need in the South Dakota State Wildlife Action Plan (SDGFP 2014). Additional bat species have a Special Species Status (BLM 2009) for the state, Sensitive Species designation for the region, and/or a federal listing under the Endangered Species Act (ESA) (16 USC § 1531–1544 1973).

Table 4.14.1. Bats found in South Dakota and resident status. Conservation status is included for species of concern at state and/or federal status. At the state level, species may be classified as Species of Greatest Conservation Need (SGCN) by South Dakota Game, Fish, and Parks with the ranks 1, 2a, 2b, or 3; a rating of 1 indicates an existing mandate for recovery, 2a indicates a regionally or globally imperiled species and SD is important range, 2b indicates a regionally or globally secure species and SD is important existing range, and 3 indicates species that are inherently vulnerable (SDGFP 2014) Additionally, USDI Bureau of Land Management (BLM) designates special status specific to the state. Federal designations include those overseen by the U.S. Fish & Wildlife Service (USFWS) under the Endangered Species Act (ESA). The USDA Forest Service (USFS) also assigns sensitive status on a regional scale; Badlands NP is in Region 2 (Rocky Mountain Region).

Common name	Scientific name	Resident status	Conservation status
Pallid bat	*Antrozous pallidus*	Possible	–
Townsend's big-eared bat[A]	*Corynorhinus townsendii pallescens*	Resident	SGCN 3 (SDGFP), Special Status (BLM), Sensitive (Region 2, USFS)
Big brown bat[A]	*Eptesicus fuscus*	Resident	–
Spotted bat	*Euderma maculatum*	Possible	Special Status (BLM), Sensitive (Region 2, USFS)

[A] Species known or suspected to be present at Badlands NP, also shown in bold text.

Table 4.14.1 (continued). Bats found in South Dakota and resident status. Conservation status is included for species of concern at state and/or federal status. At the state level, species may be classified as Species of Greatest Conservation Need (SGCN) by South Dakota Game, Fish, and Parks with the ranks 1, 2a, 2b, or 3; a rating of 1 indicates an existing mandate for recovery, 2a indicates a regionally or globally imperiled species and SD is important range, 2b indicates a regionally or globally secure species and SD is important existing range, and 3 indicates species that are inherently vulnerable (SDGFP 2014) Additionally, USDI Bureau of Land Management (BLM) designates special status specific to the state. Federal designations include those overseen by the U.S. Fish & Wildlife Service (USFWS) under the Endangered Species Act (ESA). The USDA Forest Service (USFS) also assigns sensitive status on a regional scale; Badlands NP is in Region 2 (Rocky Mountain Region).

Common name	Scientific name	Resident status	Conservation status
Eastern red bat[A]	*Lasiurus borealis*	Summer resident	–
Hoary bat[A]	*Lasiurus cinereus cinereus*	Summer resident	Sensitive (Region 2, USFS)
Silver-haired bat[A]	*Lasionycteris noctivagans*	Summer resident	SGCN 3 (SDGFP)
Western small-footed Myotis[A]	*Myotis ciliolabrum*	Resident	–
Long-eared Myotis	*Myotis evotis*	Resident	Special Status (BLM)
Little brown Myotis[A]	*Myotis lucifugus*	Resident	Petitioned for ESA listing
Northern long-eared Myotis[A]	*Myotis septentrionalis*	Resident	Threatened (USFWS); SGCN 3 (SDGFP)
Indiana bat	*Myotis sodalist*	Possible	–
Fringed Myotis[A]	*Myotis thysanodes*	Resident	SGCN 2a (SDGFP), Special Status (BLM), Sensitive (Region 2, USFS)
Long-legged Myotis[A]	*Myotis volans*	Resident	–
Evening bat	*Mycticeius humeralis*	Summer resident	–
Tri-colored bat (Eastern pipistrelle)[A]	*Perimyotis (Pipistrellus) subflavus subflavus*	Resident	Petitioned for ESA listing
Mexican free-tailed bat	*Tadarida brasiliensis mexicana*	Possible	–

[A] Species known or suspected to be present at Badlands NP, also shown in bold text.

At the time of this assessment, Badlands was confirmed as home to at least six species of bat and suspected to host five additional species (Licht 2016). Of the 11 species confirmed or suspected in the park, seven have special conservation status from the State of South Dakota, BLM, USFS, and/or USFWS under ESA. At the time of this assessment, two species (little brown myotis and tri-colored bat) were being petitioned for listing under ESA.

Resource Standards

South Dakota's State Wildlife Action Plan (SDGFP 2014) prioritizes three of the 11 bat species at Badlands NP for conservation as Species of Greatest Conservation Need (SGCN), but criteria for population size and habitat requirements do not exist. Northern myotis (*Myotis septentrionalis*) is listed as Threatened under ESA, but a recovery plan has not yet been developed.

4.14.2. Methods

Indicators and Measures

We assessed overall bat condition based on the condition of each bat species known or suspected to be present at Badlands NP and the status of white nose syndrome in and around the park.

Bat Species

Many bat species share ecological traits and behavioral patterns (e.g., roost during the day, emerge at dusk, hunt using echolocation), but even closely related species can have different roosting preferences, foraging characteristics, and geographic ranges. To gain a full understanding of bat community condition at Badlands NP, we assessed each bat species as separate indicators. The measures of these indicators were the growth rate of that indicator species and the state and federal levels of concern pertaining to conservation of that species. We describe these measures in detail for Townsend’s big-eared bat only, but we applied them to all indicator bat species.

Indicator: Townsend’s Big-eared Bat

Townsend’s big-eared bat inhabits western North America, from southern Mexico to British Columbia, Canada, and from California to Oklahoma with several more eastern populations in Arkansas and Virginia (Figure 4.14.1) (*Corynorhinus townsendii townsendii*). This species is resident in South Dakota and hibernates in caves and other large, open environments in a variety of ecosystems (WGFD 2010). These bats are sensitive to light and will relocate to a new roosting site if disturbed during the day (Arroyo-Cabrales and Álvarez-Castañeda 2008d). Townsend’s big-eared bats can tolerate extremely cold conditions and, therefore, roost in colder environments that may help them to be less susceptible to WNS than other species (I. Abernethy, personal communication, 26 August 2016).

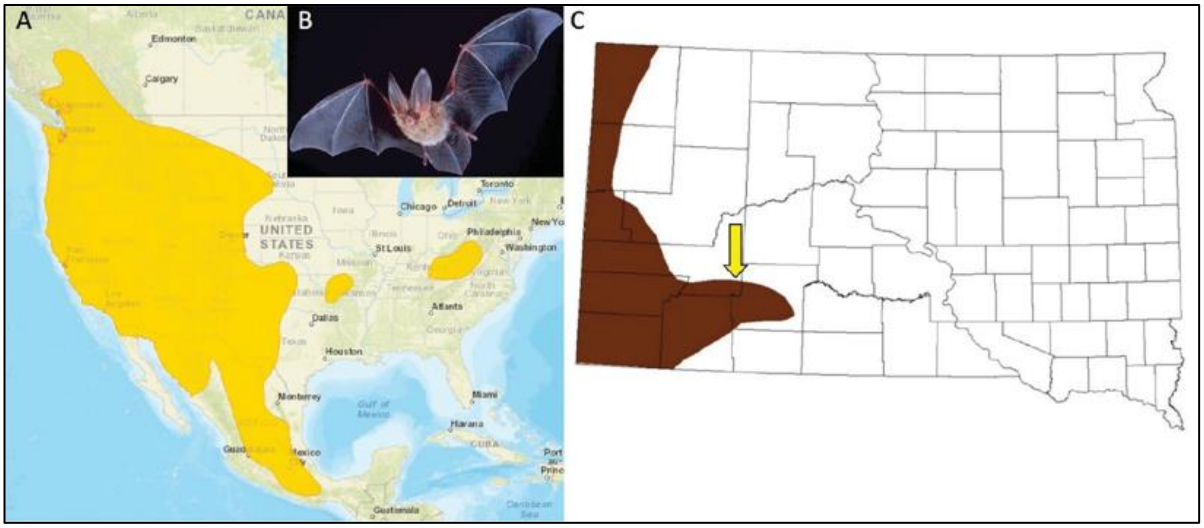

Figure 4.14.1. Distribution for the Townsend's big-eared bat. Townsend's Big-eared Bat is (A) distributed throughout western North America (IUCN 2016) and (B) is identifiable by its large ears (photo courtesy of BLM 2002). The range of this species in South Dakota (C) includes Badlands NP, indicated by the yellow arrow (adapted from SDGFP 2014).

Indicator: Big Brown Bat

Big brown bats (*Eptesicus fuscus*) are resident year-round in South Dakota. This species inhabits North America, Central America, and northern South America (Figure 4.14.2). Big brown bats are fairly tolerant of cold winter conditions and, at least in part because of this tolerance, are habitat generalists; this species hibernates in various natural and human-made hibernacula (Miller et al. 2008). Individuals roost in buildings, storm sewers, caves, trees cavities, and a variety of other environments (Miller et al. 2008).

Figure 4.14.2. Distribution for the big brown bat. The big brown bat is (A) distributed throughout western North America (IUCN 2016) and (B) has a strong jaw that allows it to forage on a variety of insects (photo by NPS 2008).

Indicator: Eastern Red Bat

Eastern red bats (*Lasiurus borealis*) are migratory bats, summering in South Dakota and moving south to warmer climates in the winter (South Dakota Bat Working Group 2004). This species inhabits central and eastern North America (Figure 4.14.3). Eastern red bats roost in dense foliage (Arroyo-Cabrales et al. 2016), primarily in hardwood forests but possibly also in riparian corridors (WGFD 2010). This species is vulnerable to habitat loss and wind energy development (WGFD 2010). The eastern red bat may be less susceptible to white nose syndrome that many other bats because it migrates and is active most of the year (I. Abernethy, personal communication, 26 August 2016).

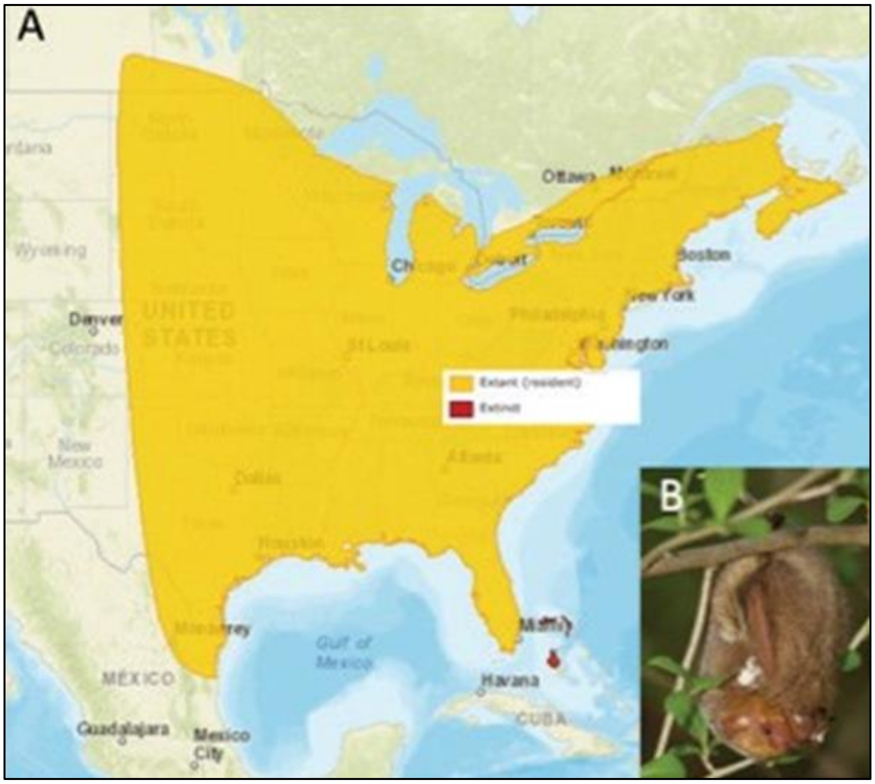

Figure 4.14.3. Distribution for the eastern red bat. The eastern red bat is (A) distributed throughout eastern North America (IUCN 2016) and (B) roosts in dense foliage (photo by Chris Harshaw 2010).

Indicator: Hoary Bat

The hoary bat (*Lasiurus cinereus*) is widely distributed throughout North and South America (Figure 4.14.4). Hoary bats migrate and are common inhabitants in South Dakota during the summer months. This species tends to roost in dense foliage and may be found in trees at the edge of clearings, though are also occasionally found deep within forests (Gonzalez et al. 2016). Hoary bats are solitary animals, though will forage in groups (Gonzalez et al. 2016).

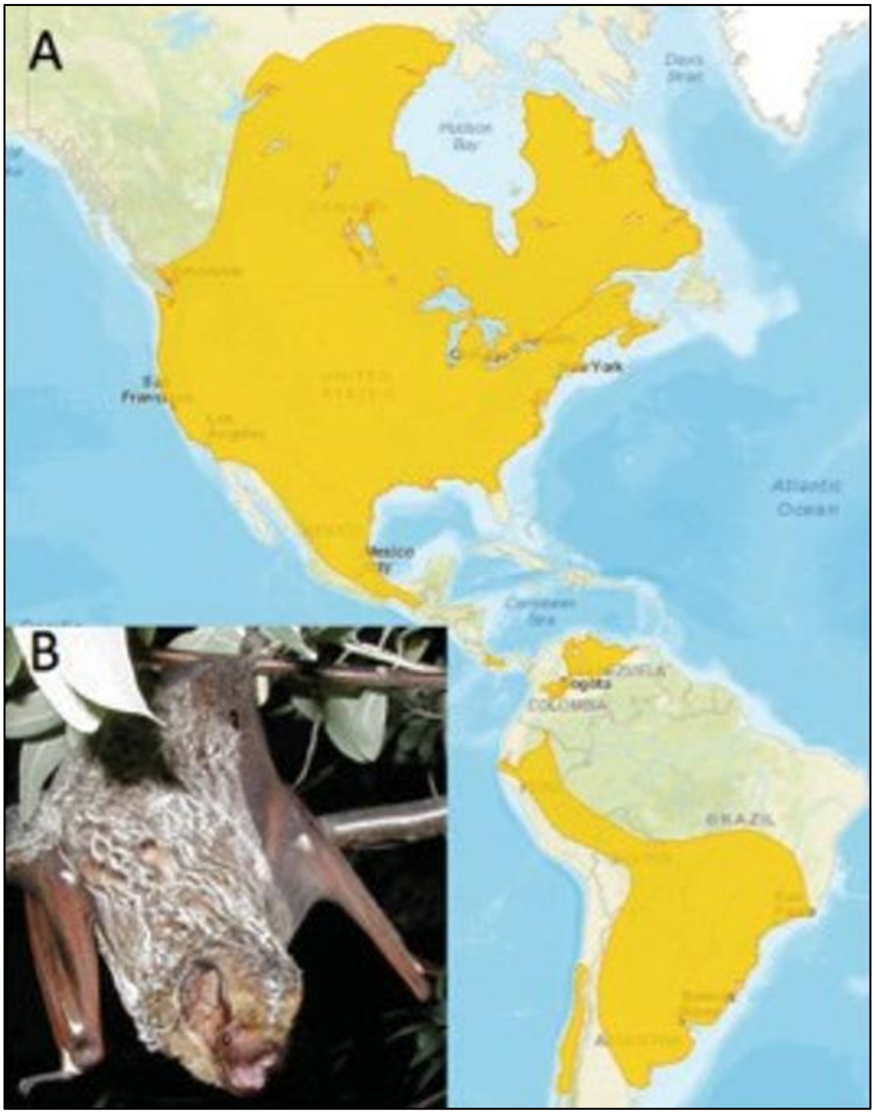

Figure 4.14.4. Distribution for the hoary bat. The hoary bat is (A) distributed throughout North and South America (IUCN 2016) and (B) roosts in defense foliage (photo by Paul Cryan 2013).

Indicator: Silver-haired Bat

The silver-haired bat (*Lasionycteris noctivagans*) is widely distributed throughout North America (Figure 4.14.5). Silver-haired bats migrate and inhabit South Dakota during the summer months. This species roosts behind loose tree bark and in hollow snags, leaving these sites to forage over short distances to catch moths, flies, and beetles (Arroyo-Cabrales et al. 2008a). Silver-haired bats may be less susceptible to white nose syndrome that many other bats because they migrate and are active most of the year (I. Abernethy, personal communication, 26 August 2016).

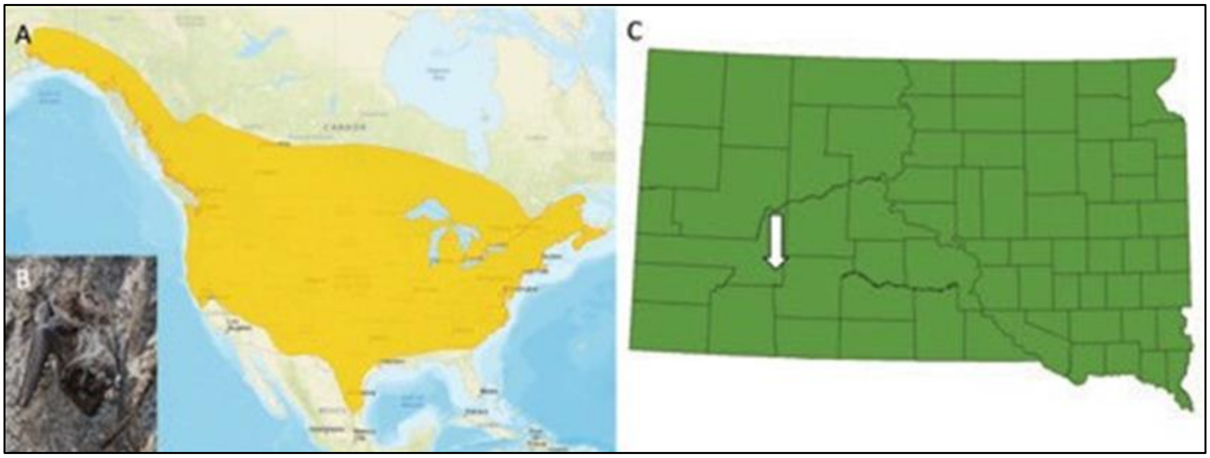

Figure 4.14.5. Distribution for the silver-haired bat. The silver-haired bat is (A) distributed throughout North America (IUCN 2016) and (B) roosts in trees, often behind loose bark (photo by Sally King, NPS). The range of this species in South Dakota (C) includes Badlands NP, indicated by the white arrow (adapted from SDGFP 2014).

Indicator: Small-footed Myotis

Small-footed myotis (*Myotis ciliolabrum*) is a resident species in South Dakota. This species inhabits North America, with a range stretching from New Mexico to Alberta (Figure 4.14.6). Associated with a broad range of arid and rocky ecosystems, small-footed myotis tend to use tight crevices and cracks for roosting during the day and will use caves and tunnels for winter hibernacula (Arroyo-Cabrales and Álvarez-Castañeda 2008e).

Figure 4.14.6. Distribution for the small-footed myotis. The small-footed myotis is (A) distributed throughout North America (IUCN 2016) and (B) is a resident of Wyoming (photo by Drew Stokes, USGS).

Indicator: Northern Long-eared Myotis

Northern long-eared myotis (*Myotis septentrionalis*) are residents in South Dakota, with a range that stretches from Yukon to Nova Scotia, Canada, and south into Alabama (Figure 4.14.7). Northern long-eared myotis roost in a variety of forest environments, particularly boreal forests, during the summer and use caves and other hibernacula during the winter (Arroyo-Cabrales and Álvarez-Castañeda 2008a). This species has experienced substantial declines in population numbers throughout the eastern part of its range, due to its susceptibility to WNS (USFWS 2016), and is listed as a Threatened species under ESA (50 CFR Part 17 2016).

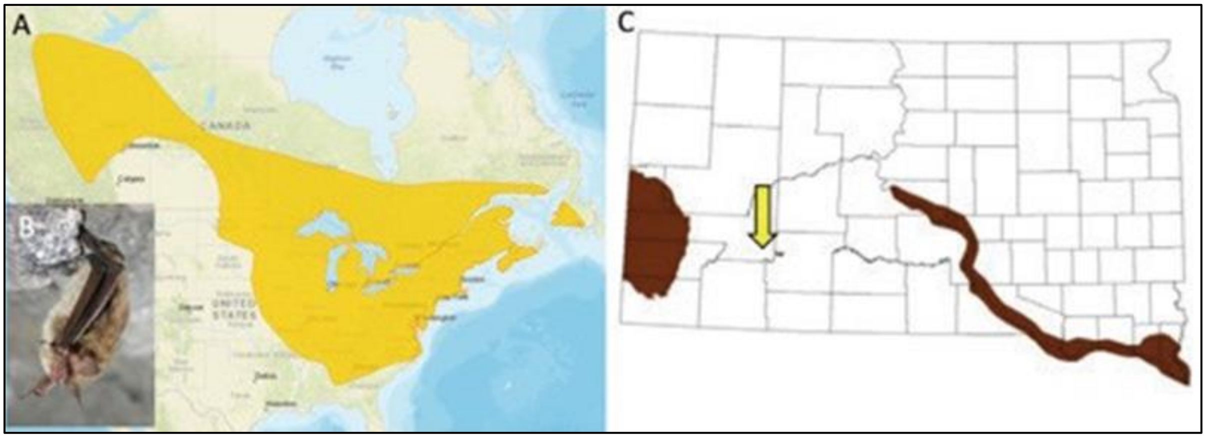

Figure 4.14.7. Distribution for the Northern long-eared myotis. Northern long-eared myotis are (A) distributed throughout North America (IUCN 2016) and (B) are threatened due to their susceptibility to white-nose syndrome (photo by Al Hicks USFWS 2007). The range of this species in South Dakota (C) includes Badlands NP, indicated by the yellow arrow (adapted from SDGFP 2014).

Indicator: Little Brown Myotis

Little brown myotis (*Myotis lucifugus*) have a broad distribution throughout North America, extending into northern Alaska (Figure 4.14.8). While this species uses human structures extensively for roosting, it is still affected by anthropogenic activities (WGFD 2010). Additionally, the little brown myotis is susceptible to WNS and has experienced population declines in the northeastern U.S. because of the disease (Arroyo-Cabrales and Álvarez-Castañeda 2008b). The little brown myotis is currently being petitioned for listing under the Endangered Species Act. This species roosts in wooded areas near open water (Arroyo-Cabrales and Álvarez-Castañeda 2008b, WGFD 2010).

Figure 4.14.8. Distribution for the little brown myotis. The little brown myotis is (A) distributed throughout North America (IUCN 2016) and (B) is susceptible to white nose syndrome (photo by Marvin Moriarity USFWS 2009).

Indicator: Fringed Myotis

Fringed myotis (*Myotis thysanodes*) occur in western North America, from British Columbia through southern Mexico (Figure 4.14.9). This species inhabits a variety of dry conifer and shrubland environments, and uses diverse roosts from rock crevices and tree cavities to buildings and mines during the summer (Arroyo-Cabrales and de Grammont 2008, WGFD 2010).

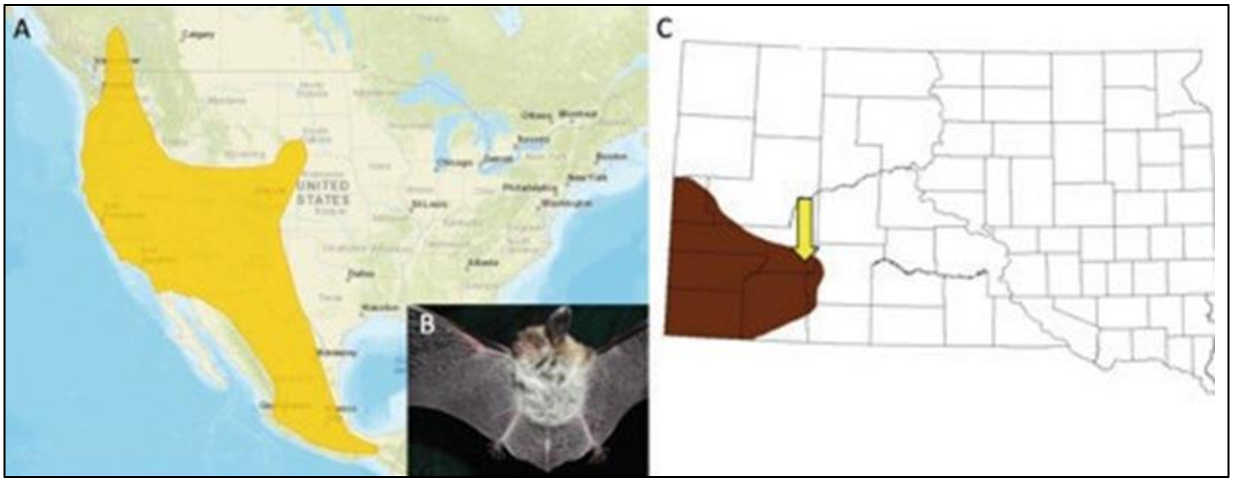

Figure 4.14.9. Distribution for the fringed myotis. The fringed myotis is (A) distributed throughout North America (IUCN 2016), is (B) of medium size, and has long ears (photo by USGS). The range of this species in South Dakota (C) includes Badlands NP, indicated by the yellow arrow (adapted from SDGFP 2014).

Indicator: Long-legged Myotis

Long-legged myotis (*Myotis volans*) have a broad range through western North America (Figure 4.14.10) and frequently occur in large colonies of 2,000–5,000 individuals (Arroyo-Cabrales and Álvarez-Castañeda 2008c). This species inhabits forested environments and roosts in crevices during summer days, while typically hibernating in caves during the winter (Arroyo-Cabrales and Álvarez-Castañeda 2008c, WGFD 2010).

Figure 4.14.10. Distribution for the long-legged myotis. The long-legged myotis is (A) distributed throughout North America (IUCN 2016) and (B) forages for a short period of time each night (photo by Dan Neubaum, USGS).

Indicator: Tri-colored Bat

Tri-colored bats (*Perimyotis* [*Pipistrellus*] *subflavus subflavus*) typically occur throughout eastern North American (Figure 4.14.11) and are resident species in South Dakota. This species roosts in foliage of trees, in rock crevices, and in buildings and caves; they are usually found near water and in forest edges or openings (Arroyo-Cabrales et al. 2008b).

Figure 4.14.11. Distribution for the tri-colored bat. The tri-colored bat is (A) distributed throughout North America (IUCN 2016) and (B) is a resident of South Dakota (photo by USFWS).

Measure of All Indicator Bat Species: Population Growth Rate (λ)

One basic way to measure the health of a species is to monitor how the number of individuals change over time. A population, a group of individuals of the same species that interact with each other, is an ideal unit for tracking these changes. Population growth rate (lambda or λ) for bats, a group that reproduces annually and typically have few young (Racey and Entwistle 2000), should be calculated over discrete time intervals to include new offspring. When $\lambda = 1$, the population is stable, with no increases or decreases per year. If $\lambda = 1.1$, the population has experienced a 10% increase per year, and if $\lambda = 0.9$ then the population has experienced a 10% decline each year.

Increases in population size ($\lambda > 1$) usually indicate that the population is healthy and sufficient resources exist to support growth. We assigned the condition, *Resource in Good Condition* when a population was increasing (Table 4.14.2). A relatively stable number of individuals ($\lambda = 1$) can also indicate a healthy population that fluctuates around a maximum capacity; unchanging population size also received the condition, *Resource in Good Condition*. While it may seem natural to assign the condition *Warrants Moderate Concern* to a population with no growth rate, population in good condition can have similar numbers from year to year. Populations with declining numbers ($\lambda < 1$) are usually not in good condition; we assigned the condition, *Warrants Significant Concern* in this case. We did not assign the condition, *Warrants Moderate Concern*, to any value of growth rate.

Table 4.14.2. Bat condition categories for growth rate (**λ**).

Resource condition		Growth rate (λ)
Warrants significant concern	🔴	< 1
Warrants moderate concern	🟡	NA
Resource in good condition	🟢	≥ 1

While two years of data can give a growth rate, lambda (λ) is best calculated based on a minimum of three years; annual variance in resource availability and random differences in birth and death rates change λ from year to year. Confidence in the overall growth estimate increases with additional years of survey data.

Measure of All Indicator Bat 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). For any bat species listed under the ESA, we gave that indicator the condition *Warrants Significant Concern* (Table 4.14.3). To receive an ESA listing, species must be considered in a petition process. For any species currently being considered through a listing petition, we gave the condition *Warrants Moderate Concern.* In South Dakota, the State Wildlife Action Plan (SDGFP 2014) designates Species of Greatest Conservation Need (SGCN) as high priority for conservation focus. The USDA Forest Service and Bureau of Land Management also maintain sensitive species lists (USDA Forest Service 2015, BLM 2009). For species with an SGCN or sensitive species status, we gave the condition as *Warrants Moderate Concern*. Species without conservation priority status received the condition, *Resource in Good Condition*.

Table 4.14.3. Bat condition categories for level of conservation concern.

Resource condition		Conservation priority or protection
Warrants significant concern	🔴	Listing under ESA
Warrants moderate concern	🟡	Considered for listing under ESA; State or regional conservation priority
Resource in good condition	🟢	No listing, listing consideration, or special conservation status

Environmental Characteristics

Indicator: Exposure to White-nose Syndrome

White-nose syndrome (WNS) is an emerging disease caused by a fungus, which has resulted in massive population declines of bats in North America since 2006 (USFWS 2011). The fungus, *Geomyces destructans*, is native to Europe and was probably accidentally introduced to North America (Cryan et al. 2013); while the disease has been confirmed in several bat species in Europe, no evidence exists for massive mortality events there (Foley et al. 2011). Hibernating bats are more susceptible to infection than migratory bats, though the specific environmental factors that best determine susceptibility are not well understood (USFWS 2011). Infected individuals exhibit white fungus around the muzzle, wings, and ears, lending the disease its name (see Figure 4.14.8B). Mortality occurs when infected bats are more active during winter, depleting fat stores quickly.

Millions of bats have been lost due to WNS (White-nose Syndrome 2016), putting once-common species at risk. If WNS were to infect bats in South Dakota, the consequent loss could be substantial. At the time of this report, the closest confirmed infection to South Dakota was in Iowa and the closest suspected infection was in eastern Nebraska (Figure 4.14.12).

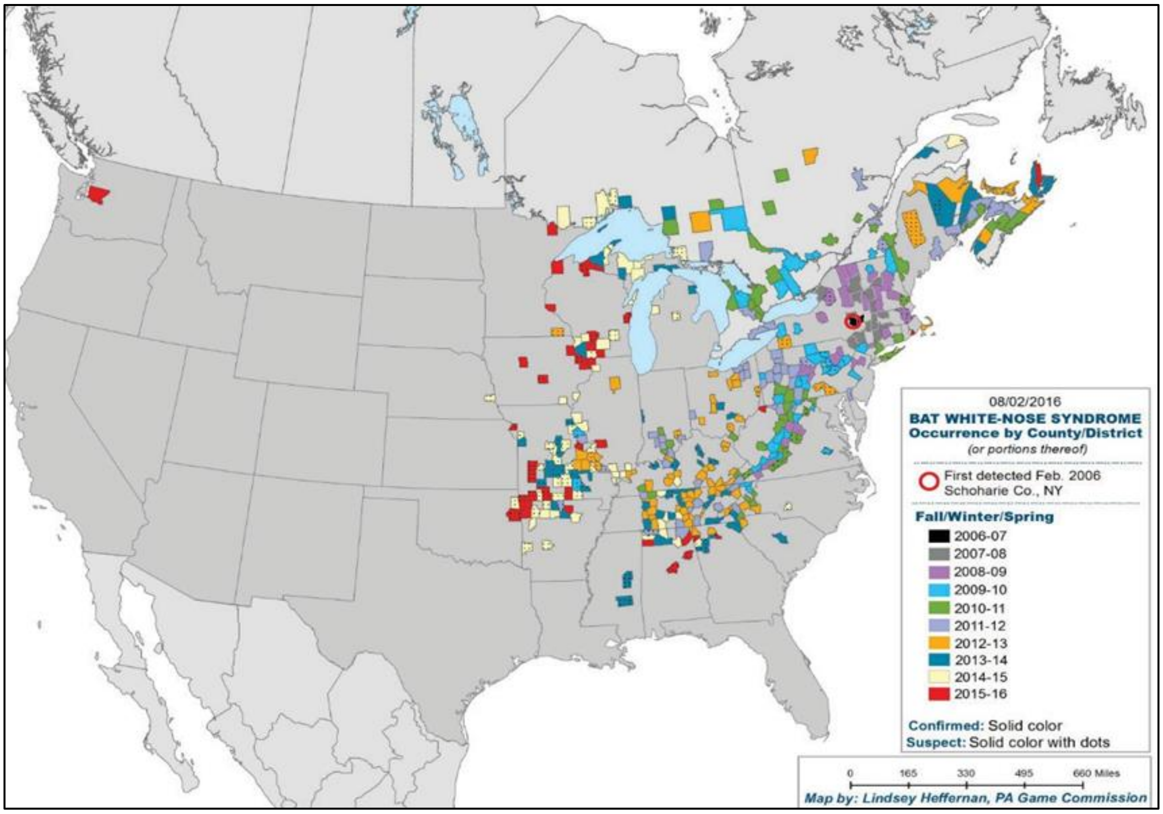

Figure 4.14.12. Confirmed and suspected infections of white-nose syndrome, color-coded by year from first detection in 2006 through August 2, 2016 (White-Nose Syndrome 2016).

Measure of Exposure to White-nose Syndrome: Presence, Absence, or Proximity

The Wyoming Bat Working Group wrote a strategic plan for managing WNS and developed a three-stage alert system (Abel and Grenier 2012). We have used their criteria to create condition categories for this assessment; if South Dakota adopts a separate management plan, these categories may need some revision. If WNS detection was > 250 miles from the South Dakota border, we gave the condition, *Resource in Good Condition.* If WNS was < 250 miles from the state border but not yet in South Dakota, we assigned the condition, *Warrants Moderate Concern.* If WNS was detected within the state, we gave the condition, *Warrants Significant Concern* (Table 4.14.4).

Table 4.14.4. Bat condition categories for exposure to White-nose Syndrome (WNS)

Resource condition		Distance of WNS from Wyoming
Warrants significant concern	🔴	Within South Dakota border
Warrants moderate concern	🟡	< 250 miles but not within South Dakota Border
Resource in good condition	🟢	> 250 miles

Data Collection and Sources

Data Management and Availability

For this assessment we used data collected by Licht (2016) at Badlands NP in 2015, the Species of Greatest Conservation Need list in the State Wildlife Action Plan for South Dakota (SDGFP 2014), sensitive species lists for Region 2 of the Forest Service (USDA Forest Service 2015) and for Montana/Dakota by BLM (BLM 2009), and expert opinion.

Quantifying Bat Condition, Confidence, and Trend

Indicator Condition

To quantify bat 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 rigorously. 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 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. For qualitative data, we assigned a *High* confidence if more than one source indicated a similar condition. 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. For qualitative data, we assigned

Medium confidence if only one source indicated a condition. *Low* confidence was assigned when there were no reliable data sources to support the condition.

Indicator Trend

Potential trend categories were *Improving, Unchanging*, or *Deteriorating*. To assign a trend to population growth rate (λ) for any bat species, we required at least three years of abundance data for that species. White-nose syndrome can spread quickly and is likely to cause precipitous population declines if bats become infected (USFWS 2011); two years of mortality and infection data should be sufficient to calculate a conservative trend. 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 Bat Condition, Trend, and Confidence

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

4.14.3. Bats Conditions, Confidence, and Trends

Bat recordings at stationary points occurred at 12 recording stations in 2014 and 11 stations in 2015. Mobile surveys occurred twice in 2014 and twice in 2015 on three monitoring routes at Badlands NP (Licht 2016). The average number of bat detection per night per stationary point was 983 in 2014 and 1149 in 2015, and the average number of bat detections on mobiles surveys was 40 bats in 2014 and 58 in 2015 (Licht 2016). Locations with many bat detections tended to be in close proximity to a water body. These data indicated that Badlands NP has a diverse bat community, with some interannual variation in community abundance, but abundance estimates were unavailable for individual bat species. We, therefore, used these data to confirm presence at the site and deferred to listing status to generate a condition for each indicator species (Table 4.14.5). If an index of abundance (for example, number of detections of bat species X per time unit Y) were formalized, managers could apply the index to these data as a baseline to detect changes in relative abundance over time and compare the two monitoring methods (stationary points and mobiles surveys).

Table 4.14.5. Summary bat indicators and measures.

Indicator	Measure	Condition	Confidence	Trend	Condition rationale
Townsend's big-eared bat	Population growth rate (λ)	Warrants moderate concern	High	Not available	–
	Level of conservation concern	Warrants moderate concern	High	Not available	Townsend's big-eared bat was listed as a level 3 SGCN and as a sensitive species by both BLM and the Forest Service.
Big brown bat	Population growth rate (λ)	Resource in good condition	Medium	Not available	–
	Level of conservation concern	Resource in good condition	Medium	Not available	The big brown bat was not a listed species of concern

Table 4.14.5 (continued). Summary bat indicators and measures.

Indicator	Measure	Condition	Confidence	Trend	Condition rationale
Eastern red bat	Population growth rate (λ)	Resource in good condition	Medium	Not available	–
	Level of conservation concern	Resource in good condition	Medium	Not available	The eastern red bat was not a listed species of concern.
Hoary bat	Population growth rate (λ)	Warrants moderate concern	Medium	Not available	–
	Level of conservation concern	Warrants moderate concern	Medium	Not available	The hoary bat was listed as a sensitive species in the Rocky Mountain Region by the Forest Service
Silver-haired bat	Population growth rate (λ)	Warrants moderate concern	Medium	Not available	–
	Level of conservation concern	Warrants moderate concern	Medium	Not available	The silver-haired bat was listed as a level 3 SGCN.
Small-footed myotis	Population growth rate (λ)	Resource in good condition	Medium	Not available	–
	Level of conservation concern	Resource in good condition	Medium	Not available	The small-footed myotis was not a listed species of concern.
Little brown myotis	Population growth rate (λ)	Warrants moderate concern	Medium	Not available	–
	Level of conservation concern	Warrants moderate concern	Medium	Not available	The little brown myotis was being considered for ESA listing.
Northern long-eared myotis	Population growth rate (λ)	Warrants significant concern	High	Not available	–
	Level of conservation concern	Warrants significant concern	High	Not available	Northern long-eared myotis was a federally-listed Threatened species and level 3 SGCN.
Fringed myotis	Population growth rate (λ)	Warrants moderate concern	High	Not available	–
	Level of conservation concern	Warrants moderate concern	High	Not available	Fringed myotis was listed as a level 2a SGCN and as a sensitive species by both BLM and the Forest Service.

Table 4.14.5 (continued). Summary bat indicators and measures.

Indicator	Measure	Condition	Confidence	Trend	Condition rationale
Long-legged myotis	Population growth rate (λ)	Resource in good condition	Medium	Not available	–
	Level of conservation concern	Resource in good condition	Medium	Not available	The long-legged myotis was not a listed species of concern.
Tri-colored bat	Population growth rate (λ)	Warrants moderate concern	Medium	Not available	–
	Level of conservation concern	Warrants moderate concern	Medium	Not available	The tri-colored bat was being petitioned for ESA listing at the time of this assessment
White-nose syndrome	Population growth rate (λ)	Resource in good condition	High	Unchanging	–
	Level of conservation concern	Resource in good condition	High	Unchanging	At the time of this assessment, white-nose syndrome was > 250 miles from the South Dakota border, with the nearest suspected occurrence > 350 miles (560 kilometers) away in eastern Nebraska. The nearest confirmed occurrences were in Iowa and Missouri.

Townsend's Big-eared Bat (*Corynorhinus townsendii pallescens*)

🟡

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

Condition

Townsend's big-eared bat was listed as a level 3 SGCN and as a sensitive species by both BLM and the US Forest Service. Condition of this indicator species was *Warrants Moderate Concern.*

Confidence

Abundance data were not available for Townsend's big-eared bat, but at the time of this assessment the bat appeared on multiple sensitive species lists. Confidence was *High*.

Trend

Trend was *Not Available*.

Big Brown Bat (*Eptesicus fuscus*)

🟢

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

Condition

The big brown bat was confirmed present at Badlands NP, but abundance data were not available. This species did not appear on special conservation list at the state, regional, or federal level, so the condition of the big brown bat was *Resource in Good Condition.*

Confidence

Abundance data were not available for big brown bat and at the time of this assessment the species did not appear on regulatory or special conservation lists. Confidence was *Medium*.

Trend

Trend was *Not Available.*

Eastern Red Bat (*Lasiurus borealis*)

🟢

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

Condition

The eastern red bat was confirmed present at Badlands NP, but abundance data were not available. This species did not appear on special conservation list at the state, regional, or federal level, so the condition of this bat was *Resource in Good Condition.*

Confidence

Abundance data were not available for the eastern red bat and this species did not appear on regulatory or special conservation lists. Confidence was *Medium*.

Trend

Trend was *Not Available*.

Hoary Bat (*Lasiurus cinereus cinereus*)

●

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

Condition

The hoary bat was listed as a sensitive species in the Rocky Mountain Region by the Forest Service. Condition of this indicator species was *Warrants Moderate Concern.*

Confidence

Abundance data were not available for this bat, but at the time of this assessment the species appeared on one sensitive species list. Survey data from Badlands NP in 2014–2015 confirmed that this species was present. Confidence was *Medium*.

Trend

Trend was *Not Available.*

Silver-haired Bat (*Lasionycteris noctivagans*)

●

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

Condition

The silver-haired bat was listed as a level 3 SGCN. Condition of this indicator species was *Warrants Moderate Concern.*

Confidence

Abundance data were not available for this bat, but at the time of this assessment the species appeared on one sensitive species list. Additionally, survey data from Badlands NP from 2014–2015 confirmed that this species was present. Confidence was *Medium*.

Trend

Trend was *Not Available*.

Small-footed Myotis (*Myotis ciliolabrum*)

🟢

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

Condition

The small-footed myotis did not appear on special conservation list at the state, regional, or federal level, so the condition of this bat was *Resource in Good Condition.*

Confidence

Abundance data were not available for the small-footed myotis and this species did not appear on regulatory or special conservation lists. Small-footed myotis were confirmed present at Badlands NP in 2014–2015. Confidence was *Medium*.

Trend

Trend was *Not Available*.

Little Brown Myotis (*Myotis lucifugus*)

🟡

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

Condition

At the time of this assessment, the little brown myotis was being petitioned for ESA listing. Condition of this indicator species was *Warrants Moderate Concern.*

Confidence

Abundance data were not available for this bat, but at the time of this assessment the little brown myotis was being petitioned for federal regulatory listing lists. Confidence was *Medium*.

Trend

Trend was *Not Available*.

Northern Long-eared Myotis (*Myotis septentrionalis*)

🔴

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

Condition

At the time of this assessment, the northern long-eared myotis was a federally-listed Threatened species under ESA and was listed as a level 3 SGCN. Condition of this indicator species was *Warrants Significant Concern*.

Confidence

Abundance data were not available for northern long-eared myotis, but at the time of this assessment the bat was federally listed and appeared on a state-level sensitive species lists. Confidence was *High*.

Trend

Trend was *Not Available*.

Fringed Myotis (*Myotis thysanodes*)

🟡

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

Condition

Fringed myotis was listed as a level 2a SGCN and as a sensitive species by both BLM and the Forest Service. Condition of this indicator species was *Warrants Moderate Concern*.

Confidence

Abundance data were not available for fringes myotis, but at the time of this assessment the bat appeared on multiple sensitive species lists. Confidence was *High*.

Trend

Trend was *Not Available*.

Long-legged Myotis (*Myotis volans*)

🟢

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

Condition

Long-legged myotis did not appear on special conservation list at the state, regional, or federal level, so the condition of this bat was *Resource in Good Condition*.

Confidence

Abundance data were not available for the long-legged myotis and this species did not appear on regulatory or special conservation lists. Long-legged myotis were confirmed present at Badlands NP in 2014–2015. Confidence was *Medium*.

Trend

Trend was *Not Available*.

Tri-colored Bat (*Perimyotis subflavus subflavus*)

🟡

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

Condition

The tri-colored bat was being petitioned for ESA listing at the time of this assessment. Condition of this indicator species was *Warrants Moderate Concern*.

Confidence

Abundance data were not available for the tri-colored bat, but at the time of this assessment the species was under petition for ESA listing. Confidence was *Medium*.

Trend

Trend was *Not Available*.

White-nose Syndrome

⇔

Condition: Resource in Good Condition
Confidence: High
Trend: Unchanging

Condition

At the time of this assessment, white-nose syndrome was > 250 miles from the South Dakota border, with the nearest suspected occurrence > 350 miles (560 kilometers) away in eastern Nebraska and the nearest confirmed occurrences in Iowa and Missouri (Figure 4.14.12). Because these occurrences were > 250 miles from the South Dakota border, the condition for WNS at Fort Laramie NHS was *Resource in Good Condition*.

Confidence

White nose syndrome is an emerging disease of national concern and is monitored closely by government and non-government agencies (e.g., USFWS 2011, Abel and Grenier 2012, White-Nose Syndrome 2016). Beginning in 2010, White-Nose Syndrome.org (2016) has published WNS occurrence maps that include the new detections as they are reported each summer; no occurrences have been detected within South Dakota at the time of this assessment. Confidence was *High*.

Trend

White-nose syndrome was not present at Badlands NP at the time of this assessment, nor had it been present previously detected in South Dakota. Trend was *Unchanging*.

Bat Overall Condition

Table 4.14.6. Bat overall condition.

Indicators	**Measures**	**Condition**
Townsend's Big-eared Bat (*Corynorhinus townsendii pallescens*)	- Population growth rate - Level of conservation concern	🟡
Big Brown Bat *Eptesicus fuscus*)	- Population growth rate - Level of conservation concern	🟢
Eastern Red Bat (*Lasiurus borealis*)	- Population growth rate - Level of conservation concern	🟢
Hoary Bat (*Lasiurus cinereus cinereus*)	- Population growth rate - Level of conservation concern	🟡

Table 4.14.6 (continued). Bat overall condition.

Indicators	**Measures**	**Condition**
Silver-haired Bat (*Lasionycteris noctivagans*)	• Population growth rate • Level of conservation concern	🟡
Small-footed Myotis (*Myotis ciliolabrum*)	• Population growth rate • Level of conservation concern	🟢
Little Brown Myotis (*Myotis lucifugus*)	• Population growth rate • Level of conservation concern	🟡
Northern Long-eared Myotis (*Myotis septentrionalis*)	• Population growth rate • Level of conservation concern	🔴
Fringed Myotis (*Myotis thysanodes*)	• Population growth rate • Level of conservation concern	🟡
Long-legged Myotis (*Myotis volans*)	• Population growth rate • Level of conservation concern	🟢
Tri-colored Bat (*Perimyotis subflavus subflavus*)	• Population growth rate • Level of conservation concern	🟡
White-nose Syndrome	• Presence, absence, or proximity	🟢⇔
Overall condition for all indicators and measures		🟡

Condition

Overall bat condition was determined by the average of the indicator conditions. We summarized the condition, confidence, and trend for each indicator, and assigned condition points. The score for overall bat condition was 66 points, which placed bat condition at Badlands NP in the *Warrants Moderate Concern* category.

Confidence

The score for overall confidence was also 66 points, which met the criteria for *Medium* confidence in overall bat condition.

Trend

Trend was Unchanging for WNS, but unavailable for the other indicators. Overall trend for bat condition was *Not Available*.

4.14.4. Stressors

Badlands NP has a relatively large number of bat species and bat occurrences (Licht 2016), but a number of stressors threaten the health of these bats and South Dakota bats in general. The South Dakota Bat Management Plan (South Dakota Bat Working Group 2004) and State Wildlife Action Plan (SDGFP 2014) identify key these threats to South Dakota bats as insect control programs, mine closures that neglect to mitigate for potential use by bats, and vandalism to roosting sites and hibernacula. Additional threats may be some recreational activities such as rock climbing (and spelunking where caves are present), and wind energy development (South Dakota Bat Working Group 2013). While not all of these threats are relevant to management activities in Badlands NP, land use practices in the surrounding area could affect bats within the park unit.

For most bats, summer day roosts and winter hibernacula are likely to be the most limiting factors for population size (I. Abernethy, personal communication, 24 August 2016). Recovery criteria for bat species listed under the Endangered Species Act have focused on the protection of these habitat features, but designating critical habitat for bats can increase vandalism and these criteria are, therefore, not always regulated (e.g., 50 CFR Part 17 2016). This change in regulation may increase the importance of protecting bat habitat in protected areas.

White-nose syndrome is one of the greatest threats to bats (SDGFP 2014, White-Nose Syndrome 2016). Though the disease has not yet appeared in South Dakota, or within 250 miles of the state border, it may appear in the next few years. Methods to prevent infection and spread of WNS have not yet been developed, though humans should take great care to reduce the possibility of spreading WNS (White-Nose Syndrome 2016).

4.14.5. Data Gaps

To detect a change in local bat populations, the most practical approach would be to derive an abundance index from acoustic monitoring (I. Abernethy, personal communication, 26 August 2016). For example, a bat abundance index could be the number of recordings from a species per unit time; repeated annually, this approach could reveal relative changes in bat numbers.

Environmental testing for WNS, including soil sampling and hibernacula testing, could give some advance notice of the presence of the disease (I. Abernethy, personal communication, 24 August 2016).

Acknowledgments

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4.15. Rocky Mountain Bighorn Sheep

4.15.1. Background and Importance

Bighorn sheep (*Ovis canadensis*) are native to western North America and exhibit a patchy distribution over what was once a more continuous range (Figure 4.15.1). There are several subspecies of bighorn sheep; the badlands or Audubon’s bighorn (*Ovis c. auduboni*) was historically found in the badlands region, but went extinct by 1925. The NPS introduced the Rocky Mountain bighorn sheep (*Ovis c. canadensis*; hereafter “bighorn sheep,” Figure 4.15.2) to Badlands NP in 1964.

Figure 4.15.1. Bighorn sheep at Badlands National Park (Photo by Dudley Edmondson, NPS).

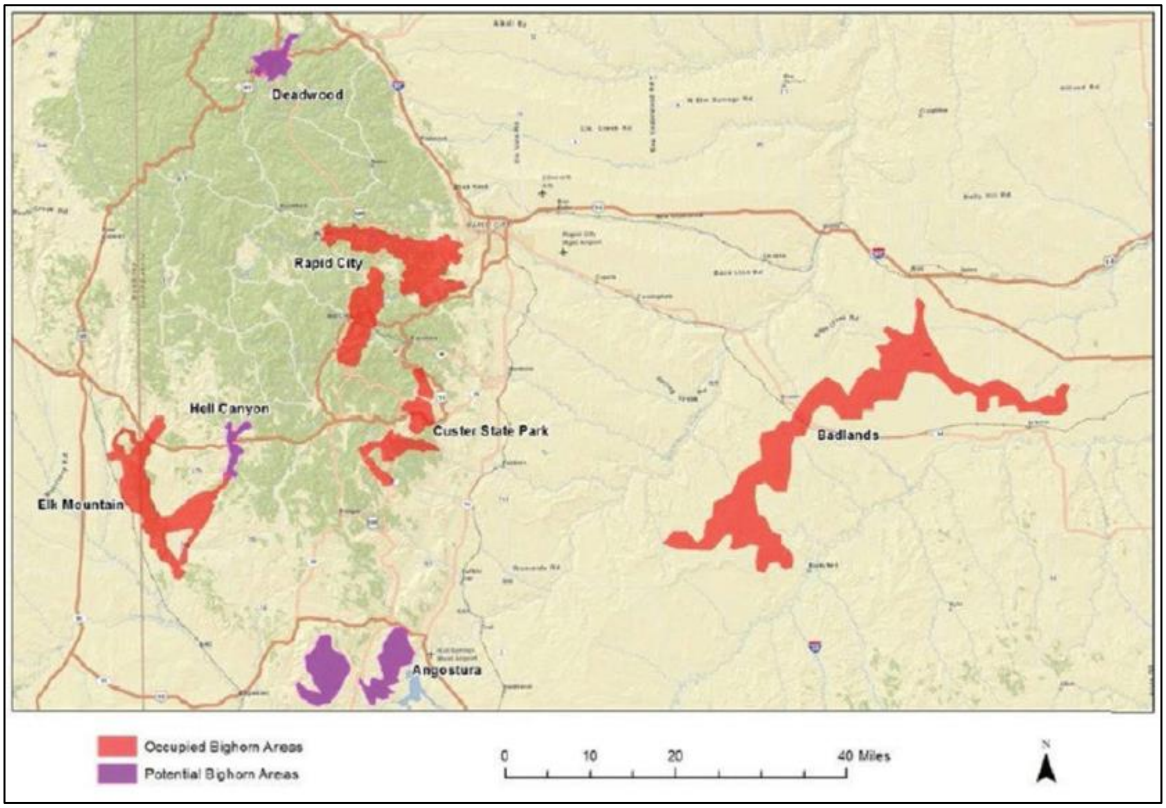

Figure 4.15.2. Bighorn sheep distribution throughout North America (Source: Wikipedia).

Bighorn sheep populations have a tenuous hold in many areas, largely owing to disease susceptibility. Studies show that bighorn populations inhabiting larger areas, kept at greater distances from domestic sheep, exhibiting longer migratory movements, and in larger herds are more likely to persist (Singer et al. 2001). It is generally accepted that disease is the main threat to wild sheep populations, and that management efforts aimed at mitigating the frequency and severity of disease outbreaks are a conservation priority (Gross et al. 2000).

Regional Context

At the time of this assessment, there were four main herds of bighorn sheep in South Dakota (Figure 4.15.3), including the herd at Badlands NP, which accounted for roughly a quarter of the total bighorn population in the state (SDGFP 2013).

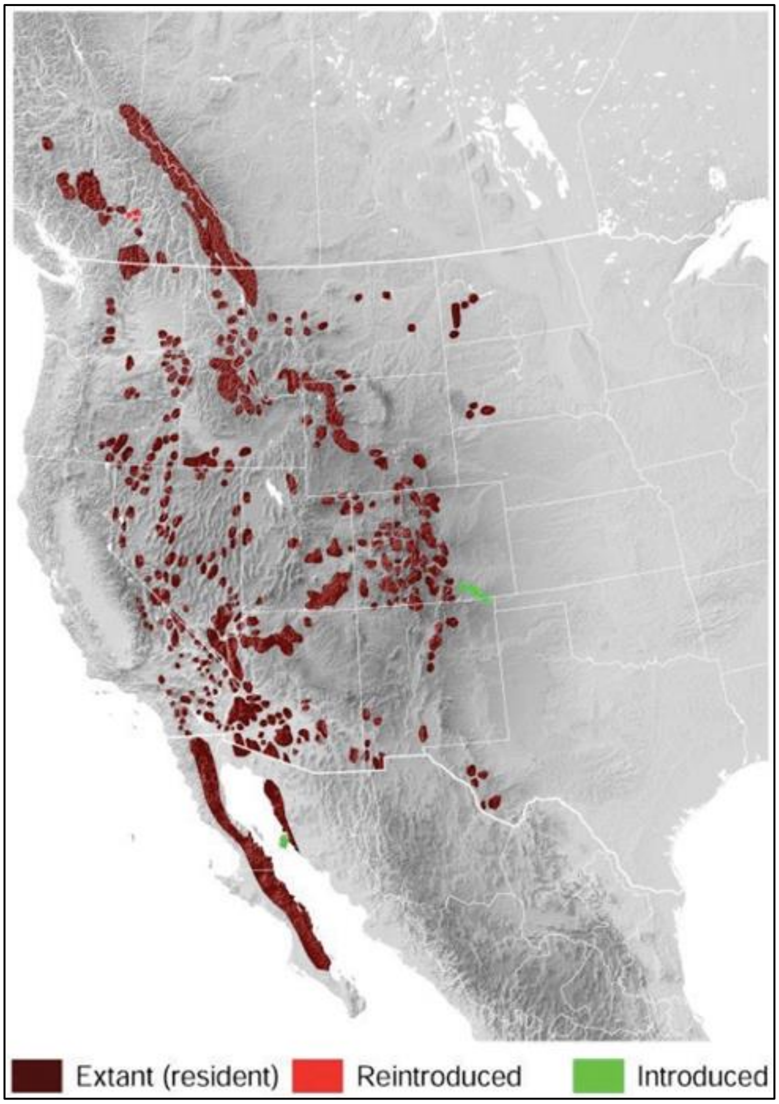

Figure 4.15.3. Current and proposed distribution of bighorn sheep in South Dakota (SDGFP 2013).

National Park Service lands are important reference and monitoring sites for animal populations, and the NPS is dedicated to protecting bighorn sheep and their habitat.

4.15.2. Resource Standards

Region 2 of the USDA Forest Service (USFS) has designated Rocky Mountain bighorn sheep a sensitive species (USFS 2016). Sensitive species status means that bighorn sheep are emphasized in USFS planning and management activities to ensure their conservation.

There is a limited quota for hunting bighorn sheep in South Dakota, and residents currently harvest 2–5 rams annually from the Black Hills population (SDGFP 2016a). South Dakota Game Fish and Park (SDGFP) instituted a cooperative program with landowners in the Black Hills to install fencing meant to reduce disease transmission from domestic to wild sheep (SDGFP 2016b).

4.15.3. Methods

Indicators and Measures

We assessed overall bighorn sheep condition based on two indicators: population viability and population size.

Indicator: Population viability

Population viability analyses allow managers to estimate the chances that a population will persist for a given period of time. These analyses can incorporate information on demographic, environmental, and genetic parameters, plus the effects of random events. The more information that can be included in these analyses, the more robust the prediction can be. In the long term, population viability analyses can incorporate climatic variation to understand how populations may respond to good and bad years, as well as indicate the sensitivity of overall population growth to the survival of specific age classes (Morris and Doak 2002).

Measure of Population Viability: Population Growth Rate (λ)

Population growth rate (lambda or λ) for bighorn sheep, a species that reproduces annually and typically has few young, should be calculated over discrete time intervals to include new offspring. When $\lambda = 1$, the population is stable, with no increases or decreases per year. If $\lambda = 1.1$, the population has experienced a 10% increase per year, and if $\lambda = 0.9$ then the population has experienced a 10% decline each year.

Increases in population size ($\lambda > 1$) usually indicate that the population is healthy and sufficient resources exist to support growth. We assigned the condition, *Resource in Good Condition* when a population was increasing. A relatively stable number of individuals ($\lambda = 1$) can also indicate a healthy population that fluctuates around a maximum capacity; unchanging population size also received the condition, *Resource in Good Condition*. Populations with declining numbers ($\lambda < 1$) are usually not in good condition; we assigned the condition, *Warrants Significant Concern* in this case. We did not assign the condition, *Warrants Moderate Concern*, to any value of growth rate (Table 4.15.1). It may seem natural to assign the condition *Warrants Moderate Concern* to a population with no growth rate, but populations in good condition can have similar numbers from year to year.

Table 4.15.1. Rocky mountain bighorn sheep condition categories for population growth rate (λ).

Resource condition		Population growth rate (λ)
Warrants significant concern	🔴	< 1
Warrants moderate concern	🟡	NA
Resource in good condition	🟢	≥ 1

While two years of data can give a growth rate, lambda (λ) is best calculated based on a minimum of three years; annual variance in resource availability and random differences in birth and death rates change λ from year to year. Confidence in the overall growth estimate increases with additional years of survey data.

Indicator: Population Size

One basic way to measure the health of a species is to monitor how the number of individuals changes over time. A population, a group of individuals of the same species that interact with each other, is an ideal unit for tracking these changes.

Measure of Population Size: Minimum Population Count

Population size is a reasonably good predictor of population persistence of bighorn sheep. One estimate of minimum viable population size was 125 animals (Van Dyke et al. 1983; original citation Trefethen 1975), although the basis for this suggestion is unknown. Empirical studies of bighorn herds in the southwestern United States showed that populations of 50 or fewer animals went extinct within 50 years, while populations with more than 100 animals persisted for at least 70 years (Berger 1990). Studies of genetic viability suggested that a minimum of 150 animals are necessary for a herd to be self-sustaining (Wockner et al. 2003). Simulations of population persistence suggest that larger populations of 250+ animals were more likely to recover rapidly following an epizootic die-off (Singer et al. 2001).

Broadly, the main management goal for the introduced population of bighorn sheep at Badlands is to restore a native species. The current estimate of carrying capacity for the Badlands NP herd is 150–200 bighorn sheep (E. Childers, personal communication, 27 September 2016). A previous estimate of 300 for carrying capacity was based on a GIS analysis conducted in 1995 (E. Childers, personal communication, 27 September 2016). It is important to note that while population viability estimates suggest the need for herds to be large to be self-sustaining (> 100 bighorn sheep), it is of course necessary that the habitat be capable of supporting these herds.

We assigned the condition, *Resource in Good Condition* when a population met the management suggestion of Singer et al. (2001). A herd of this size should be capable of persisting in the face of a disease outbreak. A herd less than 250 but greater than 100 animals should be capable of persisting in the absence of disease; we assigned the herd *Warrants Moderate Concern* in this case. Populations smaller than 100 animals are unlikely to persist, and those that require periodic augmentation cannot be considered fully restored; we assigned the condition, *Warrants Significant Concern* in this case (Table 4.15.2).

Table 4.15.2. Rocky mountain bighorn sheep condition categories for population size.

Resource condition		**Minimum population count**
Warrants significant concern	🔴	Herd size < 100 or not self-sustaining without augmentation
Warrants moderate concern	🟡	Herd currently self-sustaining, but herd size < 250
Resource in good condition	🟢	Herd size > 250

Data Collection and Sources

Data on bighorn sheep came from the NPS (Bessken 1990, Roghair 2015) and a dissertation conducted at Badlands NP (Zimmerman 2008).

Quantifying Bighorn Sheep Condition, Confidence, and Trend

Indicator Condition

To quantify bighorn sheep 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 rigorously. 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 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 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 reliable data sources to support the condition.

Indicator Trend

Potential trend categories were *Improving*, *Unchanging*, or *Deteriorating*. To assign a trend to population growth rate (λ) or herd unit size, we required at least three years of abundance 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 Bighorn Sheep 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 bighorn sheep condition, trend, and confidence.

4.15.4. Rocky Mountain Bighorn Sheep Conditions, Confidence, and Trends

Population Viability

◌

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

Condition

The last published population growth rate for bighorn sheep in the North Unit of Badlands NP was 1.18, which placed bighorn sheep in *Good Condition*.

Confidence

The last estimate of population growth rate for Badlands NP was an average calculated from 1987–1997. Because this estimate is two decades old, confidence was *Low*.

Trend

Trend data were *Not Available* for population growth of the Badlands NP bighorn sheep herd.

Population Size

⇧

Condition: Warrants Moderate Concern
Confidence: High
Trend: Unchanging

Condition

Twenty-two animals were introduced in 1964 (Bessken 1990). In response to findings that the founding population experienced both demographic and genetic bottlenecks (Ramey et al. 2000), the herd was later augmented in 2004 by 23 individuals (Zimmerman 2008). The most recent estimate of minimum herd size of Badlands bighorn sheep was 151 individuals in 2015 (Roghair 2015). This placed population size in the *Moderate Concern* category.

Confidence

Abundance data for Badlands NP were obtained from minimum population size estimates from NPS and the literature. Confidence was *Medium* because the data were collected regularly, but not in a way that allows for calculating the precision of estimates.

Trend

The bighorn sheep herd at Badlands National Park has been *Improving* through the combination of herd augmentation and the absence of disease epizootics (Figure 4.15.4).

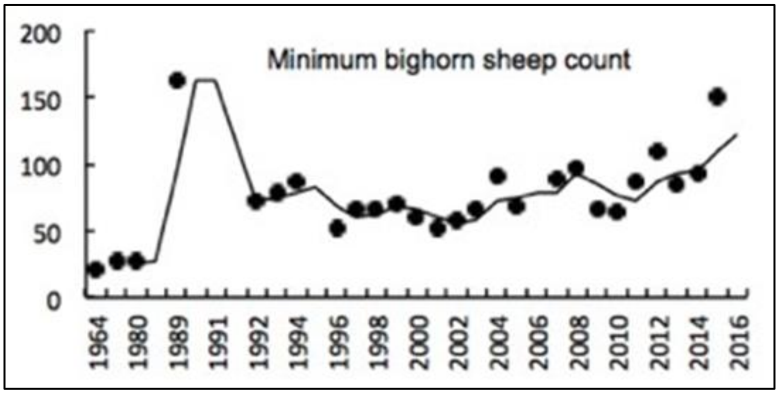

Figure 4.15.4. Minimum population size of the Badland National Park bighorn sheep herd since the time of first introduction. The line is a moving average calculated over a three-year interval; ewes typically first reproduce in their second or third year. Twenty-two individuals were introduced to the park in 1964. Disease reduced the herd in the late 1990s. The herd was augmented with 23 individuals in 2004.

Rocky Mountain Bighorn Sheep Overall Condition

Table 4.15.3. Rocky mountain bighorn sheep overall condition.

Indicators	Measures	Condition
Population viability	- Population growth rate	🟢
Population size	- Minimum population size	⬆

Table 4.15.3 (continued). Rocky mountain bighorn sheep overall condition.

Indicators	**Measures**	**Condition**
Overall condition for all indicators and measures		⇧

Condition

Overall bighorn sheep condition was determined by the average of the indicator conditions. We summarized the condition, confidence, and trend for each indicator, and assigned condition points. The score for overall bighorn sheep condition was 75 (*Resource in Good Condition*) for Badlands NP (Table 4.15.4).

Table 4.15.4. Summary bighorn sheep indicators and measures.

Indicator	**Measure**	**Condition**	**Confidence**	**Trend**	**Condition Rationale**
Population viability	Population growth rate (λ)	Good	Low	Not available	The 10-year average λ = 1.18 for 1997, this placed population viability in *Good Condition*. Confidence was *Low* because this estimate was out-of-date. Trend was *Not Available*.
Population size	Minimum population count	Moderate	Medium	Improving	The minimum population count in 2015 was 151 bighorn sheep, placing population size in *Moderate Condition*. Confidence was *Medium* because minimum population counts may not be accurate estimates of population size. Trend was *Improving*.

Confidence

The score for overall confidence was 25 points, which met the criteria for *Low* confidence in overall bighorn sheep condition.

Trend

Trend was unavailable for population growth, although the herd is generally growing. The trend for herd size was *Improving*. Overall trend for bighorn sheep condition was *Improving*.

4.15.5. Stressors

Habitat Quality

The availability of water and high quality forage are two factors contributing to the carrying capacity of the Badlands bighorn herd. Bighorn sheep prefer water sources near (typically < 0.5 kilometers) “escape terrain” (VanDyke et al. 1983). They spend the majority of their time within 1.6 kilometers of water (VanDyke et al. 1983). Given the scarcity of freshwater at Badlands NP, the carrying capacity of the bighorn herd is likely limited largely by water availability. The NPS has proposed the construction of additional water sources for bison (NPS 2015), which has the potential to increase the carrying capacity of the bighorn sheep herd. The current estimate of carrying capacity is 150 – 200 animals.

Access to high quality forage areas is not generally the main limiting factor for bighorn sheep populations. However, sheep prefer open areas of short vegetation (VanDyke et al. 1983), which historically would have been maintained through bison and fire in the badlands region. The bison herd at Badlands NP may help to maintain forage quality for bighorn sheep. It is unclear whether controlled burns may benefit bighorn sheep at Badlands NP (Moses et al. 1994).

Disease

Pneumonia outbreaks threaten the viability of bighorn sheep populations throughout their range (Bighorn Sheep Disease Research Consortium 2016). Epizootics in wild sheep are typically caused by contact with domestic sheep or goats (Figure 4.15.5). Cattle and bison, but not domestic sheep, are grazed on lands adjacent to Badlands NP. About half of the herd was lost to *Pasteurella* infection in 1967, shortly after the herd was introduced and at a time when animals were maintained in an enclosure (Bourassa 2001). There were additional disease epizootics in 1982, and again in the early 1990s (Ramey et al. 2000). There have not been any issues with pneumonia in recent years.

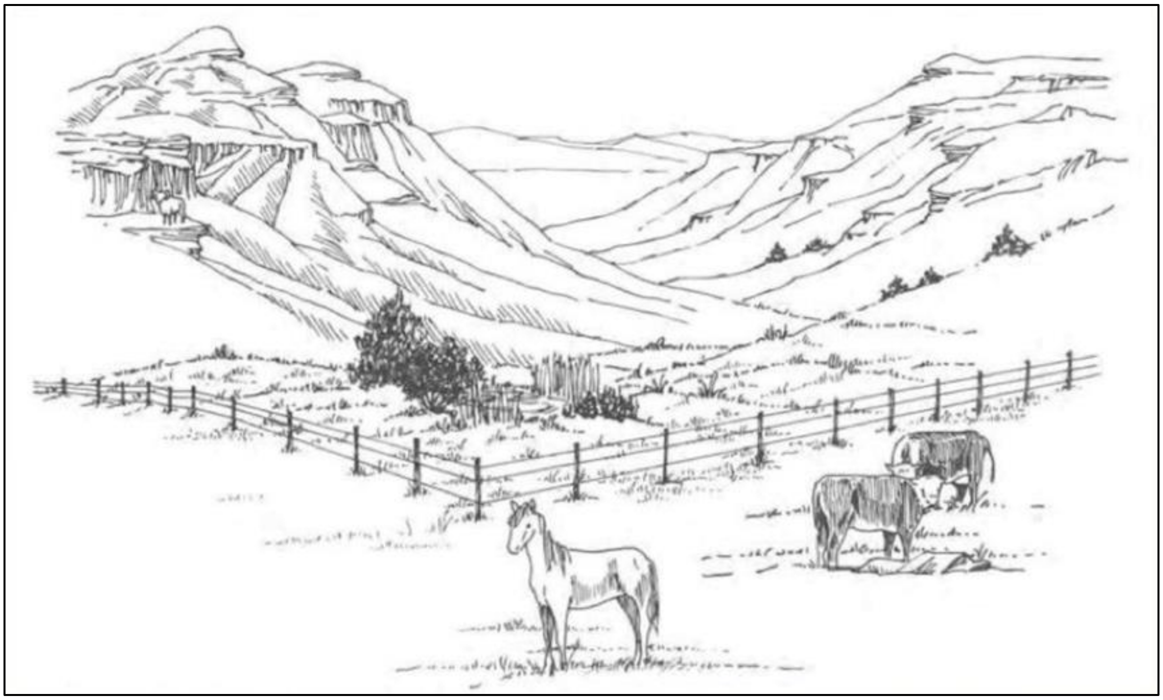

Figure 4.15.5. Illustration of fencing. Fencing can be used to effectively manage disease transmission between livestock and bighorn sheep (VanDyke et al. 1983).

Epizootic hemorrhagic disease (EHD) is transmitted by gnats and mosquitoes. Infected ungulates may present a wide variety of clinical symptoms, often leading to death. Although sheep are considered to rarely present clinical sings of EHD, the disease was detected in 1997 in a dead bighorn sheep at Badlands NP (NPS 1997).

Although the Badlands bighorn herd is currently considered "disease free," NPS has funded a bighorn disease study starting in 2016 (Eddie Childers, personal communication, 27 September 2016). The goals of the project are to "assess potential disease pathogens currently in the resident bighorn sheep population, giving a baseline for disease exposure, and evaluate vital rates and demography of bighorn sheep" (Stafford and Childers 2016). Biologists also plan to examine survival and reproduction, movements, and the presence of livestock around the park.

Population Fragmentation

Populations of bighorn sheep are fragmented throughout their range. The Badlands herd is isolated from natural immigration and emigration. Fragmentation of bighorn sheep populations may impede the recovery of a given herd exposed to disease outbreaks or other population stressors (Singer et al. 2001).

4.15.6. Data Gaps

Any rigorous data on population parameters, preferably with estimates of associated error, such as abundance, density, occupancy, reproduction, survival, mortality, population growth, or distribution from in and around the park would be informative. Ongoing studies of collared animals in and around Badlands NP can begin to fill these gaps in population data.

Acknowledgments

- Eddie Childers
- Kit Bramblee (NPS)

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4.16. Bobcat

4.16.1. Background and Importance

Bobcat (*Lynx rufus*; Figure 4.16.1) are the most widely distributed native cats in North America (Figure 4.16.2). Bobcat are adaptable to a wide variety of habitat types, from deserts to forests (Rolley and Warde 1985, Delibes and Hiraldo 1987), consuming prey as diverse as birds, hares, and the occasional scavenged moose (Litvaitis et al. 1986). Because of their value as a furbearer species, bobcat nearly went extinct in the eastern U.S. by the mid-1900s (Litvaitis et al. 2006). Federal legislation and state-level management restored the species to self-sustaining populations by the early 1990s.

Figure 4.16.1. Bobcat at Badlands National Park (Photo by Teri Stoia, NPS).

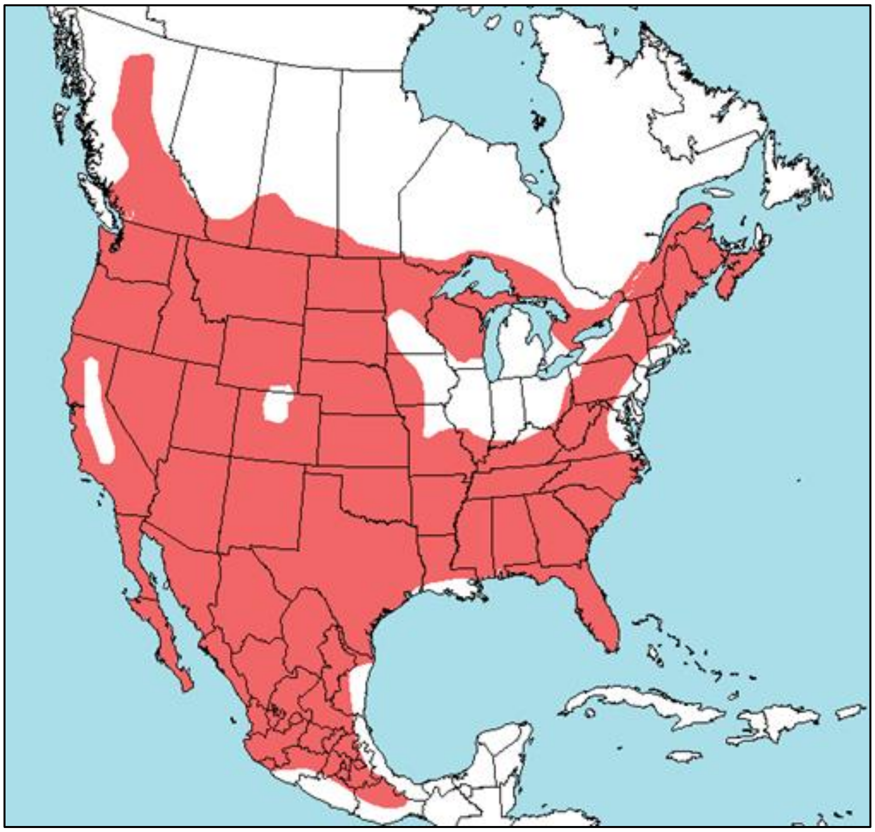

Figure 4.16.2. Bobcat distribution throughout North America (Source: Smithsonian).

<u>Regional Context</u>

In the 1960s, some data indicated that bobcat populations were declining in the western U.S. (Nunley 1978), but more recent evidence suggests that bobcat have been increasing throughout their native range (Roberts and Crimmins 2010). National Park Service lands are important reference and monitoring sites for animal populations, and the NPS is dedicated to protecting bobcat and their habitat.

Bobcat at Badlands National Park. Photo by Teri Stoia, NPS (2010).

4.16.2. Resource Standards

The bobcat is classified as a furbearer in South Dakota, and may be trapped with a license (SDGFP 2016).

4.16.3. Methods

Indicators and Measures

We assessed overall bobcat condition based on population viability. Ideally, mangers could also consider population size as an indicator of bobcat condition, because a growing population may still be in poor condition if only a few individuals are responsible for that growth. At the time of this assessment, however, we were unable to identify estimates of minimum number of individuals required for a population to be self-sustaining. We instead present available population data, describe how population size contributes to bobcat condition, and outline major considerations for using population size as an indicator (See section on Population Size and Density).

Population Size and Density

Population size is an important indicator of condition because populations must have a minimum number of individuals to persist. Below a critical number, which depends on species, habitat, land use, and various other biological and management factors, populations become imperiled and likely to disappear in the near future. Populations should be managed to stay above this critical number (Morris and Doak 2002). The composition of age classes and the sex ratio are also important and may need to be considered as measures of population size in the future, though we do not discuss those measures here.

An empirical study of minimum viable population size occurred with a reintroduction of 32 bobcat to Cumberland Island, Georgia (Diefenbach et al. 1993, 2015) from 1988–1989. Initial population viability estimates predicted that this population had 0.32 probability of persisting > 100 years and 0.73 probability of surviving for > 50 years, likely going extinct after about 65 years due to environmental variation and problems arising from inbreeding (Diefenbach 2015). Recent estimates of population size and inbreeding indicated that additional introductions to this population would be necessary for the population to persist (Diefenbach 2015). Also, the starting population size of 32 individuals may simply be insufficient to persist over years of environmental and demographic stochasticity (Morris and Doak 2002). This study is relevant to South Dakota populations of bobcat in considering genetic diversity and dispersal potential, though the available home range sizes are much smaller than those currently available to bobcat in the intermountain west.

In South Dakota, population estimates for bobcat (≥ 1 year of age) grew from 90 to 262 from 2013–2015 within a 20,402 square kilometer study area (Tycz 2016). Empirical estimates of bobcat population size were unavailable for Badlands NP, however we estimated potential population size using two different metrics: observed home range sizes in Badlands NP (Mosby 2011) and observed densities in western South Dakota (Tycz 2016). Badlands NP includes 982 square kilometers, and female home range size in the park averaged 26.7 square kilometers (Mosby 2011). Using data from the Mosby (2011) study, we estimated a potential population size in the park: assuming no overlap in female home ranges—and without consideration for resource availability—a maximum of 36 females could coexist in the park. This calculation yields a population density of 3.7 females/100 square kilometers, which is more than twice as high as densities observed in western South Dakota (1.8 bobcat/100 square kilometers). Badlands NP may be able to support higher densities of bobcat than typically observed in western South Dakota (excluding the Black Hills), but individuals may also be restricted to localized areas in the park. These densities are a starting point to identifying carrying capacity and population viability within Badlands NP.

The data for South Dakota, coupled with the intensive bobcat population study from the very different Cumberland Island environment, suggest that a minimum viable population size is somewhere between 32 and 90. These numbers must be considered in the context of available area for dispersal, requisite home range size, and supporting environment.

Indicator: Population Growth

One basic way to measure the health of a species is to monitor how the number of individuals' changes over time, then use the observed rate of change to get a sense of population trajectory. A population, a group of individuals of the same species that interact with each other, is an ideal unit for tracking these changes.

Measure of Population Viability: Population Growth Rate (λ)

Population growth rate (lambda or λ) for bobcat should be calculated over discrete time intervals to include new offspring. When $\lambda = 1$, the population is stable, with no increases or decreases per year. If $\lambda = 1.1$, the population has experienced an average 10% increase per year, and if $\lambda = 0.9$ then the population has experienced an average 10% decline each year.

Increases in population size ($\lambda > 1$) usually indicate that the population is healthy and sufficient resources exist to support growth. We assigned the condition, *Resource in Good Condition* when a population was increasing. A relatively stable number of individuals ($\lambda = 1$) can also indicate a healthy population that fluctuates around a maximum capacity; unchanging population size also received the condition, *Resource in Good Condition*. Populations with declining numbers ($\lambda < 1$) are usually not in good condition; we assigned the condition, *Warrants Significant Concern* in this case.

We did not assign the condition, *Warrants Moderate Concern*, to any value of growth rate (Table 4.16.1). It may seem natural to assign the condition *Warrants Moderate Concern* to a population with no growth rate, but populations in good condition can have similar numbers from year to year.

Table 4.16.1. Bobcat condition categories for population growth rate (λ).

Resource condition		Population growth rate (λ)
Warrants significant concern	🔴	< 1
Warrants moderate concern	🟡	NA
Resource in good condition	🟢	≥ 1

While two years of data can give a growth rate, lambda (λ) is best calculated based on a minimum of three years; annual variance in resource availability and random differences in birth and death rates change λ from year to year. Confidence in the overall growth estimate increases with additional years of survey data.

Data Collection and Sources

Data on bobcat were collected in Badlands NP and western South Dakota from 2006–2009 (Mosby 2011), and outside of the park from 2013–2016 (Tycz 2016).

Quantifying Bobcat Condition, Confidence, and Trend

Indicator Condition

To quantify bobcat condition, we identified indicators, measures, and condition categories based on the scientific literature, regulatory standards, and expert opinion. We prioritized data collected most recently and rigorously.

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 reliable data sources to support the condition.

Indicator Trend

Potential trend categories were *Improving, Unchanging*, or *Deteriorating*. To assign a trend to population growth rate (λ) or herd unit size, we required at least three years of abundance 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 Bobcat Condition, Trend, and Confidence

We used one indicator to assess condition of bobcat at Badlands NP. Overall condition depended on the condition, confidence, and trend of that indicator.

4.16.4. Bobcat Conditions, Confidence, and Trends

Bobcat Overall Condition

Table 4.16.2. Bobcat overall condition.

Indicators	Measures	Condition
Population viability	• Population growth rate	⇧

Condition

Overall condition depended on population growth. In Badlands NP, bobcat had low survivorship (0.43) from 2008–2011, but population growth rate was unavailable because total population sizes were not available. Further, this data came from a study of only 10 collared animals. Data from outside of the park and west of the Missouri River (excluding the Black Hills), showed population size estimates for South Dakota: 450 in 2013, 839 in 2014, and 1315 in 2015 (Tycz 2016). Growth rate (λ) calculated from these estimates was 1.7, which indicates an increasing population. Based on strong, positive regional population growth rate estimates, bobcat condition was *Resource in Good Condition.*

Confidence

Data were collected for western South Dakota, including area to the north of Badlands NP but not specifically in the park. Bobcat are protected within the park, but the population growth evident in the data presented here occurred outside Badlands NP in spite of harvest pressure. While individuals move across park boundaries and may be harvested on those edges, the bobcat population in the park is likely to be more protected that those outside park boundaries. Data were limited and not collected recently in the park (B. Kenner, personal communication, 12 December 2016). Confidence was *Low*.

Trend

The bobcat population in western South Dakota increased in size from 2013–2015. Trend was *Improving.* See Table 4.16.3 for a summary of bobcat condition.

Table 4.16.3. Summary bobcat indicator and measure.

Indicator	Measure	Condition	Confidence	Trend	Condition rationale
Population viability	Population growth rate (λ)	Resource in good condition	Medium	Not available	Growth rate was > 1, indicating an increasing population, but data were not available within the park.

4.16.5. Stressors

Prey availability

Bobcat diet is typically dominated by lagomorphs but bobcat will take other small mammals (Delibes and Hiraldo 1987), and prairie dogs may be an important component of winter diet in Badlands NP (Licht 2010). Plague has caused declines in prairie dogs, which may reduce prey availability.

Disease

Plague not only causes loss of prey, but could also affect bobcat in Badlands NP. Bobcat are susceptible to the bacterium (e.g., Salkeld and Stapp 2005) and could face impacts from plague.

Competition

Bobcat may compete with coyotes for habitat and resources (Litvaitis and Harrison 1989), and when coyote numbers increase in and around Badlands NP that could negatively impact bobcat populations. While detailed data do not exist on for recent coyote numbers, coyote populations do seem to be growing (E. Childers, personal communication 31 October 2016). Additionally, bobcat are a furbearer species that are hunted in South Dakota, and pelts are financially valuable. Harvest pressure around the edge of the park could affect the population in Badlands NP (E. Childers, personal communication 29 September 2016).

4.16.6. Data Gaps

Any rigorous data on population parameters, preferably with estimates of associated error, such as abundance, density, occupancy, reproduction, survival, mortality, population growth, or distribution from in and around the park would be informative. Ongoing studies of collared animals in and around Badlands NP can begin to fill these gaps in population data.

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4.17. Mule Deer

4.17.1. Background and Importance

Mule deer (*Odocoileus hemionus*; hereafter “deer”, Figure 4.17.1), named for their large ears, are native to western North America and are concentrated in the Rocky Mountain region, ranging from Alaska through the Rockies to northern Mexico and southern Baja (Reid 2006). This ungulate has experienced population fluctuations throughout its range over at least a century (Forrester and Wittmer 2013), and has drawn the attention of conservation and hunting groups. Variably harsh winters, changes in resource availability (Monteith et al. 2014), and land use alteration (Sawyer et al.

2006) may be contributing factors to these vacillations, though proximate causes are likely to vary with region and herd size (Forrester and Wittmer 2013).

Figure 4.17.1. Mule deer at Badlands National Park (Photo by Lee McDowell, NPS).

Regional Context

The Great Plains ecoregion is the easternmost portion of mule deer range (Figure 4.17.2), comprising shrub steppe and mixed- or shortgrass prairie (Ricketts 1999). Deer populations nearly went extinct within the region by the 1900s, following heavy consumption during exploration in the 1800s, but are now common in the Great Plains (Fox et al. 2009). South Dakota deer populations were high in the mid-2000s, but at the time of this assessment population numbers were below management goals for most herd units (SDGFP 2016b). The most recent estimate of mule deer numbers in South Dakota was 81,000–152,000 (Mule Deer Working Group 2016).

Figure 4.17.2. Mule deer distribution throughout North America (Source: Wikipedia).

National Park Service lands are important reference and monitoring sites for animal populations, and the NPS is dedicated to protecting mule deer and their habitat. Three mule deer herd units overlap portions of Badlands NP: 02C, 39A, and 65A. The herd units surrounding Badlands NP are managed for hunting and for non-consumptive wildlife-viewing (SDGFP 2016b). Deer are managed by NPS within Badlands NP boundaries, and hunting is not allowed within the park.

4.17.2. Resource Standards

No regulatory standards existed for mule deer at the time of this assessment, though South Dakota Game, Fish, and Parks sets herd unit goals for population size; hunting licenses are issued based on projected population growth rates and management goals (SDGFP 2016b). These management approaches do not apply directly to the herd within Badlands NP, but may affect the resident herd as animals cross back and forth across park boundaries.

4.17.3. Methods

Indicators and Measures

We assessed overall mule deer condition based on two indicators: population growth and population size.

Indicator: Population Viability

One basic way to measure the health of a species is to monitor how the number of individuals changes over time. A population, a group of individuals of the same species that interact with each other, is an ideal unit for tracking these changes. Population viability analyses allow managers to estimate the chances that a population will persist for a given period of time. These analyses can incorporate information on demographic, environmental, and genetic parameters, plus the effects of random events. The more information that can be included in these analyses, the more robust the prediction can be. In the long term, population viability analyses can incorporate climatic variation to understand how populations may respond to good and bad years, as well as indicate the sensitivity of overall population growth to the survival of specific age classes (Morris and Doak 2002).

Measure of Population Viability: Population Growth Rate (λ)

Population growth rate (lambda or λ) for deer, a species that reproduces annually and typically has few young, should be calculated over discrete time intervals to include new offspring. When $\lambda = 1$, the population is stable, with no increases or decreases per year. If $\lambda = 1.1$, the population has experienced a 10% increase per year, and if $\lambda = 0.9$ then the population has experienced a 10% decline each year.

Increases in population size ($\lambda > 1$) usually indicate that the population is healthy and sufficient resources exist to support growth. We assigned the condition, *Resource in Good Condition* when a population was increasing (Table 4.17.1). A relatively stable number of individuals ($\lambda = 1$) can also indicate a healthy population that fluctuates around a maximum capacity; unchanging population size also received the condition, *Resource in Good Condition*. Populations with declining numbers ($\lambda < 1$) are usually not in good condition; we assigned the condition, *Warrants Significant Concern* in this case. We did not assign the condition, *Warrants Moderate Concern*, to any value of growth rate. It may seem natural to assign the condition *Warrants Moderate Concern* to a population with no growth rate, but populations in good condition can have similar numbers from year to year.

Table 4.17.1. Mule deer condition categories for population growth rate (λ).

Resource condition		**Population growth rate (λ)**
Warrants significant concern	🔴	< 1
Warrants moderate concern	🟡	NA
Resource in good condition	🟢	≥ 1

While two years of data can give a growth rate, lambda (λ) is best calculated based on a minimum of three years; annual variance in resource availability and random differences in birth and death rates change λ from year to year. Confidence in the overall growth estimate increases with additional years of survey data. Data for survival rates and numbers of individuals within multiple age classes would give a more comprehensive picture of long term population viability.

Indicator: Population Size

Population size is an important indicator of condition because populations must have a minimum number of individuals to persist. Below a critical number, which depends on species, habitat, land use, and various other biological and management factors, populations become imperiled and likely to disappear in the near future. Population should be managed to stay above this critical number (Morris and Doak 2003). The composition of age classes and the sex ratio are also important and may need to be considered as measures of population size in the future, though we do not discuss those measures here.

Measure of Population Size: Herd Unit Size

As a game species that does not have special conservation status, mule deer herds are largely managed through hunting season projections and licenses issued by South Dakota Game, Fish, and Parks. Management goals for population size in herd units are set to incorporate deer harvest each year (Table 4.17.2).

Table 4.17.2. Mule deer condition categories for herd unit size.

Resource condition		Herd unit size
Warrants significant concern	🔴	Below park management goal
Warrants moderate concern	🟡	Statistically same as park management goal
Resource in good condition	🟢	Above park management goal

Data Collection and Sources

Data Management and Availability

Data specific to Badlands NP were unavailable, but we discuss stressors based on data for South Dakota that are relevant to the park.

Quantifying Mule Deer Condition, Confidence, and Trend

Indicator Condition

To quantify mule deer 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 rigorously. 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 mule deer 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 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 reliable data sources to support the condition.

Indicator Trend

Potential trend categories were *Improving*, *Unchanging*, or *Deteriorating*. To assign a trend to population growth rate (λ) or herd unit size, we required at least three years of abundance 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 Mule Deer Condition, Trend, and Confidence

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

4.17.4. Mule Deer Conditions, Confidence, and Trends

Population Viability

●

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

Condition

South Dakota’s Game, Fish and Parks divides mule deer into data analysis units (DAU) for monitoring purposes. DAU4 contains a total of 14 individual herds (Figure 4.17.3), and three of these (02C, 39A, and 65A) overlap with portions of Badlands NP. South Dakota Game, Fish and Parks provided a growth rate estimate for DAU4 (K. Robling, personal communication, 4 November 2016). The derived population growth rate of DAU4 was 1.24 ± 0.07 in 2016, placing population viability in *Resources in Good Condition*.

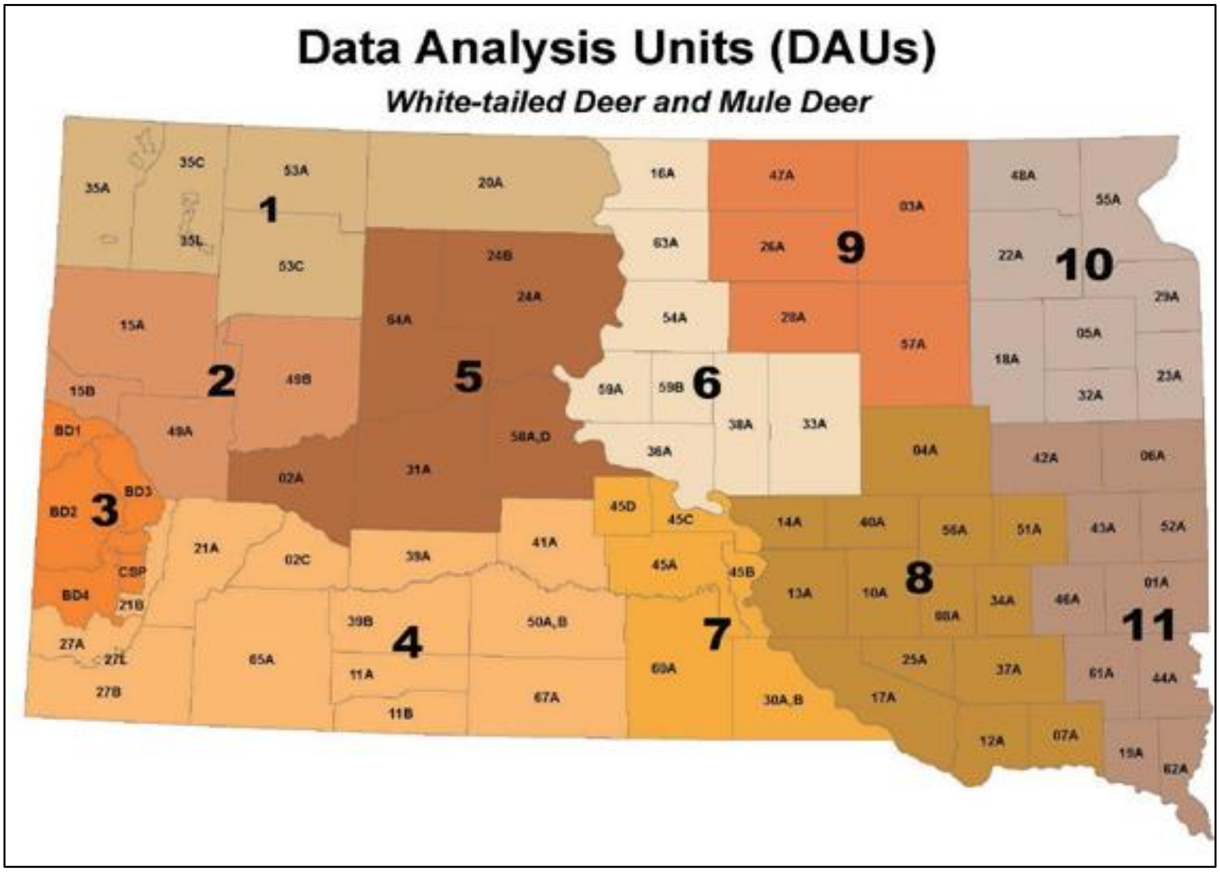

Figure 4.17.3. Herd and data analysis units used in the calculated of population growth rates for mule deer. The data analysis units are the larger, color-coded number series. Each herd unit is labeled individually.

Mule deer survival monitoring began in Badlands National Park in 2015 (SDGFP 2015) and data were not yet available at the time of this assessment.

Confidence

Population growth rate data were not available for Badlands NP, specifically, although we believe that a herd unit is an appropriate level of analysis. The reported population growth rate was calculated over a large area that may not necessarily reflect the status of the local herd units. We do not know how data were collected or how lambda was calculated, so confidence was *Low*.

Trend

Trend data were *Not Available* for Badlands NP, although the statewide trend has been declining since 2010, with limited evidence for recent increases in the past two years (Mule Deer Working Group 2016). In 2016, population growth rates for the various “data analysis units” in South Dakota ranged from 1.09–1.34 (Mule Deer Working Group 2016).

Population Size

◌

Condition: Not Available
Confidence: Low
Trend: Not Available

Condition

Condition of population size for Badlands mule deer was *Not Available*. We had two years of data on the composition of one herd (02C), but we did not have resource standards that would allow us to rate the condition of herd unit 02C, but have provided the herd composition data (Table 4.17.3).

Table 4.17.3. Herd composition of mule deer unit 02C, one of three units overlapping Badlands NP.

Year	Unit	Bucks	Does	Fawns	Fawns per 100 Does	Bucks per 100 Does
2015	02C	34	39	32	0.82	0.87
2016	02C	25	71	44	0.62	0.35

Confidence

Abundance data were not available for Badlands NP. Confidence was *Low*.

Trend

Trend was *Not Available*.

Mule Deer Overall Condition

Table 4.17.4. Mule deer overall condition.

Indicators	Measures	Condition
Population viability	• Population growth rate	🟢
Population size	• Number of individuals	◌
Overall condition for all indicators and measures		🟢

Condition

Overall mule deer condition was determined by the average of the indicator conditions. We summarized the condition, confidence, and trend for each indicator, and assigned condition points (Table 4.17.5). The overall condition of mule deer was *Resource in Good Condition* for Badlands NP.

Table 4.17.5. Summary mule deer indicators and measures.

Indicator	**Measure**	**Condition**	**Confidence**	**Trend**	**Condition rationale**
Population viability	Population growth rate (ʎ)	Resource in good condition	Low	Not available	Population growth rate was 1.24, warranting *Good Condition*. Confidence was *Low* because the data were not collected on-site, and trend was *Not Available*.
Population size	Herd unit size	Not available	Low	Not available	Population size for mule deer was *Not Available*.

Confidence

The score for overall confidence was also 0 points, which met the criteria for *Low* confidence in overall mule deer condition.

Trend

Trend was unavailable for all indicators. Overall trend for mule deer condition was *Not Available*.

4.17.5. Stressors

Development

Perhaps the largest impact of human disturbance on mule deer is through the indirect effects of energy development on migration routes (Hebblewhite 2011). Mule deer are capable of migrating over great distances (100+ miles), and are known to alter their migratory behaviors in the face of energy development (Sawyer et al. 2013). The large-scale impacts of energy development on mule deer are poorly understood, but likely include threats to critical migration corridors. To the knowledge of regional experts, herds in South Dakota do not cover the same migratory mileage as observed in Wyoming (J. Kanta, personal communication, 16 September 2016), but these developments could negatively affect resident herds and herds moving across shorter distances. The proposed expansion of nearby wind energy (Figure 4.17.4) may have unintended consequences for mule deer populations in protected areas such as Badlands NP.

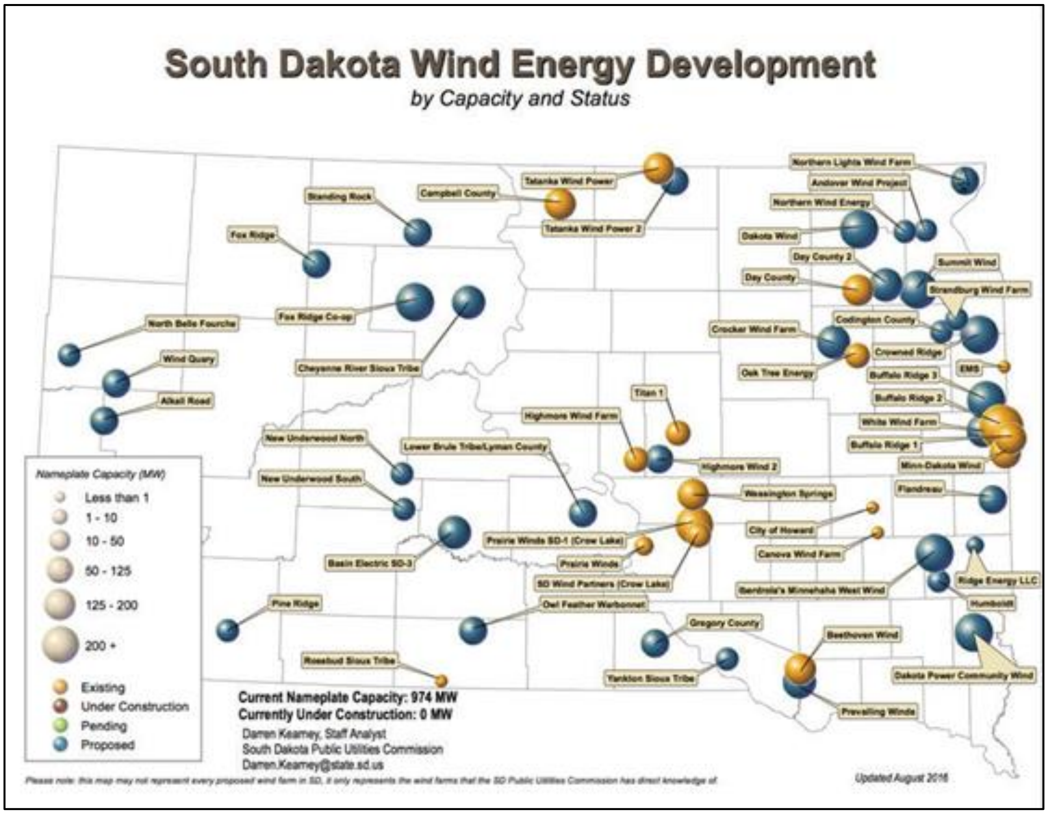

Figure 4.17.4. South Dakota wind energy developement by capacity and status. The footprint of wind energy is expanding westward into areas near Badlands National Park.

<u>Disease</u>

Chronic wasting disease (CWD) is characterized by prolonged weight loss resulting in eventual death. The disease is transmissible within members of the deer family, including white-tailed deer, which can also be found at Badlands NP. Chronic Wasting Disease is also capable of persisting in the environment (Haley and Hoover 2015), and crows feeding on carcasses may act as reservoir for the disease (Fischer et al. 2013). This disease was first detected in free-ranging animals in southwestern South Dakota in 2001, while the first incidence in farmed animals was in 1997 (SDGFP 2016a). While CWD has not officially been detected within any of the herds found within Badlands NP, it has been detected in Pennington County (Figure 4.17.5), within which the majority of the north unit of Badlands NP is situated.

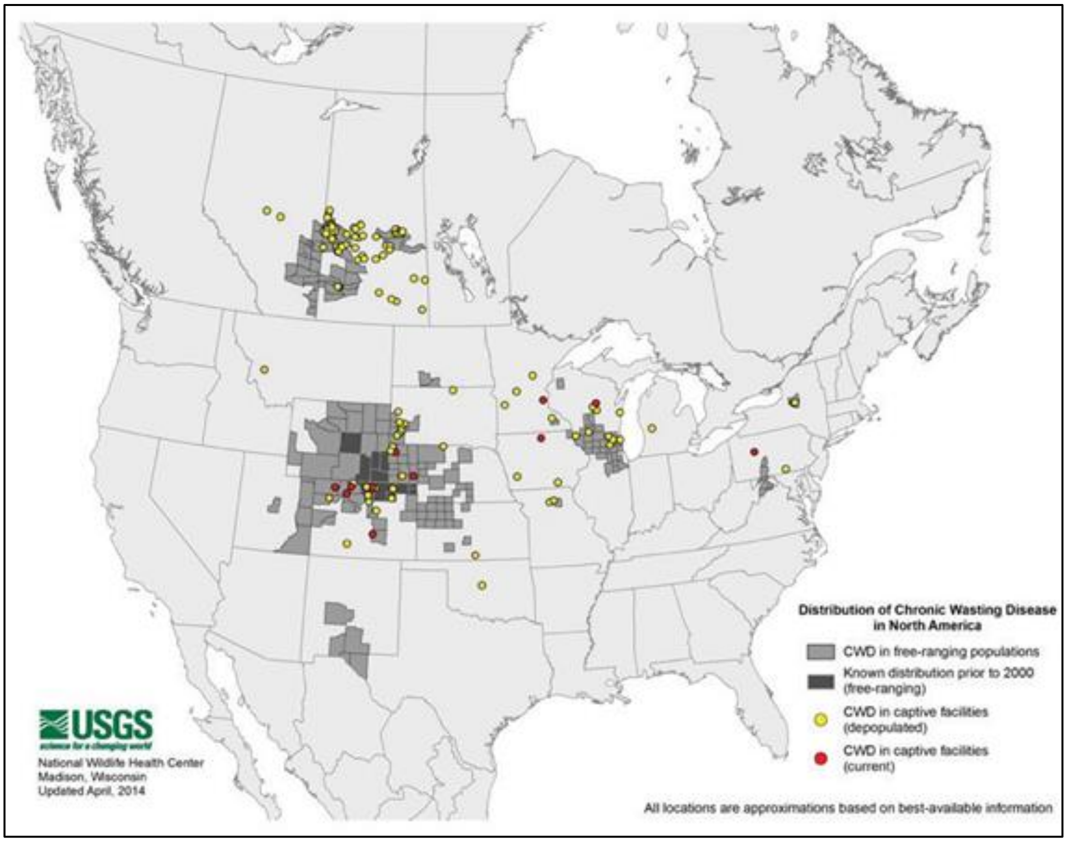

Figure 4.17.5. Distribution of chronic wasting disease in North America. Chronic wasting disease is known to occur in southwestern South Dakota, including Pennington County in which the north unit of Badlands NP resides.

4.17.6. Data Gaps

Any rigorous data on population parameters, preferably with estimates of associated error, such as abundance, density, occupancy, reproduction, survival, mortality, population growth, or distribution from in and around the park would be informative. Ongoing studies of collared animals in and around Badlands NP can begin to fill these gaps in population data.

Acknowledgments

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- John Kanta (South Dakota Game, Fish, and Parks)

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4.18. Herpetofauna

4.18.1. Background and Importance

Herpetofauna, a taxonomic grouping of amphibians and reptiles, are important organisms in a wide variety of ecosystems. Reptiles and amphibians are important prey for other organisms and are often considered to be indicators of ecosystem health (e.g., Welsh and Ollivier 1998, Dixon et al. 2011).

Reptiles and amphibians have experienced declines globally (Gibbon et al. 2000) and over a third of amphibians have become imperiled (Stuart et al. 2004). Amphibians have received attention from the conservation community due to their unprecedented declines (e.g., McCallum 2007, Norris 2007, Bishop et al. 2012) and the discovery of limb deformations in some populations (e.g., Schmidt 1997, Hecker and Sessions 2001), but reptiles have also been affected by land use change and disease. A global analysis found that of six taxonomic groups, including mammals and plants, reptiles had the greatest negative response to habitat loss (Mantyka-Pringle et al. 2012) due to lasting changes in prey and habitat (e.g., Suarez and Case 2002). In the short term, low availability of prey can manifest in increased stress levels (McCue and Pollock 2008), which decrease survival rates in lizards (Romero and Wikelski 2001) and lead to higher rates of disease and population declines in amphibians (Blaustein et al. 2012).

Prairie rattlesnake, a species present in Badlands NP. Photo by Reilly Dibner (2014).

National Park Service lands are important reference and monitoring sites for reptile and amphibian populations, especially considering the susceptibility of these groups to land use change. Many herpetofauna have minimum habitat area requirements (e.g., Semlitsch and Bodie 2003) that can guide management actions in NPS units in and around those habitats.

<u>Regional Context</u>

Thirty reptile species and 15 amphibian species are known to occur throughout South Dakota (Ballinger et al. 2000), of which eight amphibians (Table 4.18.1) and 12 reptiles (Table 4.18.2) were suspected or confirmed to occur in Badlands NP (NPS 2016a, 2016b). At the time of this assessment, two of these species were of particular concern to the state, receiving a listing as high priority Species of Greatest Conservation Need (SGCN) in the South Dakota State Wildlife Action Plan (SDGFP 2014). Additional species had special conservation status from USDI Bureau of Land

Management (BLM 2015), at the state level, and within the Rocky Mountain Region (Region 2) of the USDA Forest Service (USFS 2015).

Table 4.18.1. Amphibians known or suspected to be present at Badlands NP. Conservation status is included for species of concern at the state and/or federal level. At the state level, species may be classified as Species of Greatest Conservation Need (SGCN) by South Dakota Game, Fish, and Parks (SDGFP 2014). Additionally, USDI Bureau of Land Management (BLM) designates special status specific to the state. Federal designations include those overseen by the US Fish and Wildlife Service (USFWS) under the Endangered Species Act (ESA). The USDA Forest Service (USFS) also assigns sensitive status on a regional scale; Badlands NP is in Region 2 (Rocky Mountain Region).

Scientific name	Common name	Conservation status
Ambystoma tigrinum	Tiger salamander	–
Anaxyrus cognatus[A]	**Great plains toad**	Special Status (BLM)
Anaxyrus woodhousii[A]	**Woodhouse's toad**	–
Pseudacris maculata	Boreal chorus frog	–
Lithobates blairi	Plains leopard frog	Special Status (BLM), Sensitive (Region 2, USFS)
Lithobates catesbeianus	Bullfrog	–
Lithobates pipiens[A]	**Northern leopard frog**	Special Status (BLM)
Spea bombifrons	Plains spadefoot	Special Status (BLM)

[A] Species with confirmed presence, also shown in bold text.

Table 4.18.2. Reptiles known or suspected to be present at Badlands NP, and status in the park. Conservation status is included for species of concern at state and/or federal status.

Scientific name	Common name	Conservation status
Chelydra serpentina[A]	**Snapping turtle**	–
Chrysemys picta[A]	**Painted turtle**	–
Cnemidophorus sexlineatus	Six-lined racerunner	–
Coluber constrictor[A]	**Racer**	–
Crotalus viridis[A]	**Prairie rattlesnake**	–
Heterodon nasicus[A]	**Western hog-nosed snake**	Special Status (BLM)
Lampropeltis trangulum	Milk snake	Special Status (BLM)
Phrynosoma hernandesi	Short-horned lizard	Species of Greatest Conservation Need (SD), Special Status (BLM)
Pituophis catenifer	Gopher snake	–
Sceloporus undulatus	Fence lizard	–
Terrapene ornate	Western box turtle	Species of Greatest Conservation Need (SD)
Thamnophis radix[A]	**Western garter snake**	–

[A] Species with confirmed presence, also shown in bold text.

4.18.2. Resource Standards

National standards for the protection of most reptiles and amphibians are lacking. Habitat protection guidelines exist for species currently listed in the Endangered Species Act (16 USC § 1531 et seq. 1973), if recovery plans have been completed. At the time of this assessment, however, no herpetofauna known to occur in South Dakota or Badlands NP had federal protection (USFWS 2016).

4.18.3. Methods

Indicators and Measures

We assessed overall herpetofauna condition based on the condition of each reptile and amphibian species known or suspected to be present at Badlands NP.

Herpetofauna Species

To gain a full understanding of herpetofauna community condition at Badlands NP, we assessed each reptile and amphibian species as separate indicators. The measures of these indicators were the growth rate of that indicator species and the state and federal levels of concern pertaining to conservation of that species. We describe these measures in detail for tiger salamander (*Ambystoma tigrinum*) only, but we applied them to all indicator herpetofauna species.

Indicator: Tiger Salamander

Tiger salamanders (*Ambystoma tigrinum*) inhabit North America, from southern Mexico to southern Canada and from the east to west coast (Figure 4.18.1). This species is one of the largest amphibians in the U.S. and is common throughout South Dakota (Fischer et al. 1999b). Tiger salamanders breed in ponds and migrate to terrestrial habitat, foraging mostly at night (Stebbins 2003).

Figure 4.18.1. Tiger salamander (Photo by G. Bartolotti 2013).

Indicator: Great Plains Toad (Anaxyrus cognatus)

The Great Plains toad (*Anaxyrus cognatus*) is common in the central U.S., and widespread throughout South Dakota (Figure 4.18.2). This species breeds in ponds, ephemeral pools, and flooded areas in a variety of arid and semi-arid environments (IUCN 2015a).

Figure 4.18.2. Great Plains toad (Photo by USFWS 2014).

Indicator: Woodhouse's Toad (Anaxyrus woodhousii)

Woodhouse's toad (*Anaxyrus woodhousii*) is widespread across the central U.S. and presumed to occur in most of South Dakota (Ballinger et al. 2000), burrowing underground when inactive (Hammerson and Santos-Barrera 2004). These toads (Figure 4.18.3) breed in relatively still water in a wide variety of water bodies (Stebbins 2003).

Figure 4.18.3. Woodhouse's toad (Photo by L.A. Dawson 2007).

Indicator: Boreal Chorus Frog (Pseudacris maculata)

Boreal chorus frogs (*Pseudacris maculata*) persist from the southwestern U.S. north to central Yukon and Northwest Territories in Canada (Figure 4.18.4). This species inhabits areas near permanent water sources, usually at the edge of a wetland, pond, or wet meadows (IUCN 2015c). Boreal chorus frogs breed in shallow waters with emergent vegetation in open areas and occasionally in deeper pools in forested areas (Stebbins 2003).

Figure 4.18.4. Boreal chorus frog (Photo by Wikimedia Commons 2006).

Indicator: Plains Leopard Frog (Lithobates blairi)

The range of the plains leopard frog (*Lithobates blairi*) includes the central U.S., reaching north into southern South Dakota (Figure 4.18.5). The species is widespread throughout the range, but some populations have experienced declines, and the status of the species is unknown in many locations

(IUCN 2014). Plains leopard frogs inhabit prairie and desert grassland, and can occasionally be found in oak woodlands (Stebbins 2003).

Figure 4.18.5. Plains leopard frog (Photo by D. Becker 2009).

Indicator: Bullfrog (Lithobates catesbeianus)

Bullfrogs (*Lithobates catesbeianus*) are native to eastern North America but introduced to western North America (Figure 4.18.6); west of the continental divide, this species has had a negative effect on native amphibians (e.g., Pearl et al. 2004). Bullfrogs inhabit a wide variety of environments, from reservoirs to brackish ponds to irrigation ditches (IUCN 2015d).

Figure 4.18.6. Bullfrog (Photo by J. Tuszynski 2012).

Indicator: Northern Leopard Frog (Lithobates pipiens)

Northern leopard frogs (*Lithobates pipiens*) have a broad distribution across northern and central North America (Figure 4.18.7), inhabiting grasslands, shrublands, and forests; this species is particularly well adapted to the cold (Stebbins 2003). Some populations have declined, particularly in the Rocky Mountains, and can no longer be found in parts of the range (Hammerson et al. 2004).

Figure 4.18.7. Northern leopard frog (Photo by M. Swarnyk 2014).

Indicator: Plains Spadefoot Toad (Spea bombifrons)

The plains spadefoot toad (*Spea bombifrons*) is widespread across the central U.S. (Figure 4.18.8) and inhabits shrubland and grasslands, usually in semi-arid environments (IUCN 2015b). This species tends to breed in temporary waters, usually shallow pools and flooded areas (Stebbins 2003).

Figure 4.18.8. Plains spadefoot toad (Photo by S. Trauth n.d.).

Indicator: Snapping Turtle (Chelydra serpentina)

Snapping Turtles (*Chelydra serpentina*) are widespread throughout central and eastern North America (Figure 4.18.9), inhabiting a large variety of environments from rivers to marshes to reservoirs (van Dijk 2016a). Snapping turtles are generalist consumers, feeding on birds, fish, amphibians, aquatic plants, and small mammals (Stebbins 2003).

Figure 4.18.9. Snapping turtle (Photo by Dakota L. 2011).

Indicator: Painted Turtle (Chrysemys picta)

Painted turtles (*Chrysemys picta*) are common throughout the U.S. and South Dakota (Ballinger et al. 2000). These turtles (Figure 4.18.10) inhabit a variety of water bodies, though prefer relatively still water (van Dijk 2016b).

Figure 4.18.10. Painted turtle (Photo by W.L. Franch, USFWS 2013).

Indicator: Six-lined Racerrunner (Aspidoscelis [formerly Cnemidophorus] sexlineatus)

Six-lined racerrunners (*Aspidoscelis sexlineatus*) reach southern South Dakota at the northern portion of their range (Ballinger et al. 2000); these lizards (Figure 4.18.11) inhabit open areas with sun exposure (Hammerson et al. 2007a).

Figure 4.18.11. Six-lined racerunner (Photo by H. Hillewaert 2011).

Indicator: Eastern Racer (Coluber constrictor)

Eastern racers (*Coluber constrictor*) are widespread throughout the U.S., inhabiting a variety of habitats in both mountainous and lowland areas (Hammerson et al. 2013). These snakes favor grassy environments (Figure 4.18.12) near lizard basking sites, a common prey item (Stebbins 2003).

Figure 4.18.12. Eastern racer (Photo by WikimediaCommons 2003).

Indicator: Prairie Rattlesnake (Crotalus viridis)

Prairie Rattlesnakes (*Crotalus viridis*) are common throughout western South Dakota, especially in grasslands, shrubby areas (Figure 4.18.13), and prairies; rocky outcroppings are a particularly favored habitat (Ballinger et al. 2000).

Figure 4.18.13. Prairie rattlesnake (Photo by R. Dibner 2014).

Indicator: Western Hog-nose Snake (Heterodon nasicus)

Western hog-nose snakes (*Heterodon nasicus*) range from southern Canada to the southern U.S., are concentrated in the Great Plains (Stebbins 2003), and are common in South Dakota (Ballinger et al. 2000). This snake (Figure 4.18.14) inhabits open prairies, grasslands, and floodplains (Stebbins 2003).

Figure 4.18.14. Western hog-nosed snake (Photo by WikimediaCommons 2010).

Indicator: Milk Snake (Lampropeltis triangulum)

Milk Snakes (*Lampropeltis triangulum*) inhabit South Dakota west of the Missouri River (Ballinger et al. 2000). This species (Figure 4.18.15) is most common in short-grass prairie, sagebrush, rocky hillsides, and open woodlands (Stebbins 2003).

Figure 4.18.15. Milk snake (Photo by D. Avi 2007).

Indicator: Short-horned Lizard (Phrynosoma hernandesi)

Short-horned lizards (*Phrynosoma hernandesi*) have a broad distribution throughout the western U.S., ranging from Mexico to southern Canada. These lizards (Figure 4.18.16) inhabit a variety of environments including sagebrush, short-grass prairie, and open woodlands; populations can persist at elevations of over 3,300 meters (11,000 feet).

Figure 4.18.16. Greater short-horned lizard (Photo by R. Dibner 2014).

Indicator: Gopher Snake (Pituophis catenifer)

Gopher snake (*Pituophis catenifer*) are common throughout the U.S. and South Dakota (Ballinger et al. 2000, Stebbins 2003). These snakes (Figure 4.18.17) occur in a wide variety of environments, from open brushland to grassland (Stebbins 2003).

Figure 4.18.17. Gopher snake (Photo by G. Clark 2006).

Indicator: Fence Lizard (Sceloporus undulatus)

Fence lizards (*Sceloporus undulatus*) occur in the southeast U.S. (Stebbins 2003), with the northern part of the range extending into South Dakota (Ballinger et al. 2000). These lizards prefer open, sunny areas (Figure 4.18.18) in a variety of habitats (Hammerson et al. 2007b).

Figure 4.18.18. Western fence lizard (Photo by C. Bass 2008).

Indicator: Western Box Turtle (Terrapene ornata)

Western box turtles (*Terrapene ornata*) inhabit sandy areas in southwestern South Dakota (Ballinger et al. 2000). This turtle (Figure 4.18.19) is terrestrial, inhabiting grassland, sparse shrubland, and open woodland (Stebbins 2003).

Figure 4.18.19. Western box turtle (Photo by P. Feller 2009).

Indicator: Western Garter Snake (Thamnophis radix)

Western garter snakes (*Thamnophis radix;* Figure 4.18.20) are common throughout South Dakota, inhabiting grassy areas next to water bodies (Ballinger et al. 2012).

Figure 4.18.20. Western garter snake (Photo by K. Lundgren, USFWS 2014).

Measure of All Indicator Herpetofauna Species: Population Growth Rate (λ)

One basic way to measure the condition of a species is to monitor how the number of individuals changes over time. A population, a group of individuals of the same species that interact with each other, is an ideal unit for tracking these changes. Population growth rate (lambda or λ) for species that reproduce annually should be calculated over discrete time intervals to include new offspring. When $\lambda = 1$, the population is stable, with no increases or decreases per year. If $\lambda = 1.1$, the population has experienced an average 10% increase per year, and if λ = 0.9 then the population has experienced an average 10% decline each year.

Increases in population size (λ > 1) or a relatively stable number of individuals (λ = 1) usually indicate that the population is healthy and sufficient resources exist to support growth. We assigned the condition, *Resource in Good Condition,* when a population was increasing or stable (Table 4.18.3). Populations with declining growth rate (λ < 1) are usually not in good condition; we assigned the condition, *Warrants Significant Concern* in this case.

Table 4.18.3. Herpetofauna condition categories for growth rate (λ).

Resource condition		**Population growth rate (λ)**
Warrants significant concern	🔴	< 1
Warrants moderate concern	🟡	NA
Resource in good condition	🟢	≥ 1

While growth rate can be calculated from two years of population size data, lambda (λ) is best calculated based on a minimum of three years; annual variance in resource availability and random differences in birth and death rates change λ from year to year. Confidence in the overall growth estimate increases with additional years of survey data.

Measure of All Indicator Herpetofauna 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 US is a listing under the Endangered Species Act (ESA). For any herpetofauna species listed under the ESA, we gave that indicator the condition *Warrants Significant Concern* (Table 4.18.4). To receive an ESA listing, species must be considered in a petition process. For any species currently being considered through a listing petition, we gave the condition *Warrants Moderate Concern.* In South Dakota, the State Wildlife Action Plan (SDGFP 2014) designates Species of Greatest Conservation Need (SGCN) as high priority for conservation focus. The USFS and BLM also maintain sensitive species lists (USFS 2015, BLM 2009). For species with an SGCN or sensitive species status, we gave the condition as *Warrants Moderate Concern*. Species without conservation priority status received the condition *Resource in Good Condition*.

Table 4.18.4. Herpetofauna condition categories for level of conservation concern.

Resource condition		Conservation priority or protection
Warrants significant concern	🔴	Listing under ESA
Warrants moderate concern	🟡	Considered for listing under ESA; State or regional conservation priority
Resource in good condition	🟢	No listing, listing consideration, or special conservation status

Environmental Characteristics

Indicator: Exposure to Chytrid Fungus

Amphibian chytridiomycosis is an emerging disease caused by chytrid fungus (*Batrachochytrium dendrobatidis*), which has resulted in massive population declines of amphibians globally (Daszak et al. 1999, Stuart et al. 2004, Murray et al. 2009). The fungus is likely to have originated in Africa (Weldon et al. 2004) and its spread is associated with the disappearance of many species (e.g., Lips et al. 2006). Chytrid fungus affects amphibian skin, thickening the outer skin layer and disrupting the physiological processes that occur across the membrane; infections can cause osmotic imbalance and electrolyte loss that are lethal (Rosenblum et al. 2010). Researchers do not have a full understanding of spatial patterns in the spread of chytrid fungus (Kilpatrick et al. 2010) though species at high altitude seem to be more susceptible than species at low altitude (Kriger and Hero 2006), at least when considered with a seasonal temperature effect that keeps high elevation habitat cooler (the fungus reproduces more successfully at low temperatures). Additionally, infection is most likely to affect amphibians in permanent breeding habitats, rather than ephemeral streams or ponds (Kriger and Hero 2007).

Measure of Exposure to Chytrid Fungus: Presence, Absence, or Proximity

At the time of this assessment, no formal approaches existed for measuring the risk of chytrid fungus to amphibians in a given region. Further, data were sparse for South Dakota (Figure 4.18.21). The fungus affects some species and regions more than others (Kriger and Hero 2006, 2007, Olson et al. 2013). To quantify a level of risk to amphibians from chytrid fungus, we adopted an approach that has been developed for another emerging animal disease that have a variety of similarities and unresolved questions (Eskew and Todd 2013): White-nose Syndrome (WNS), a disease causing mass mortalities in bats. The approach for WNS involves using a three-stage alert system (Abel and Grenier 2012), with detection distance of the fungus from the state border determining the level of concern. The rate of spread for chytrid fungus is much slower than that of WNS, at a rate of at least 700 meters per year (Vredenburg et al. 2010), and possibly much quicker with anthropogenic movement of the diseases. We, therefore, modified the WNS three-stage alert system to apply to chytrid fungus and herpetofauna within Badlands NP. If chytrid fungus detection was > 50 miles from the Badlands border, we gave the condition, *Resource in Good Condition*. If the fungus was < 50 miles from the park border but not yet in the park, we assigned the condition, W*arrants Moderate Concern*. If chytrid fungus was detected within the park, we gave the condition, *Warrants Significant Concern* (Table 4.18.5).

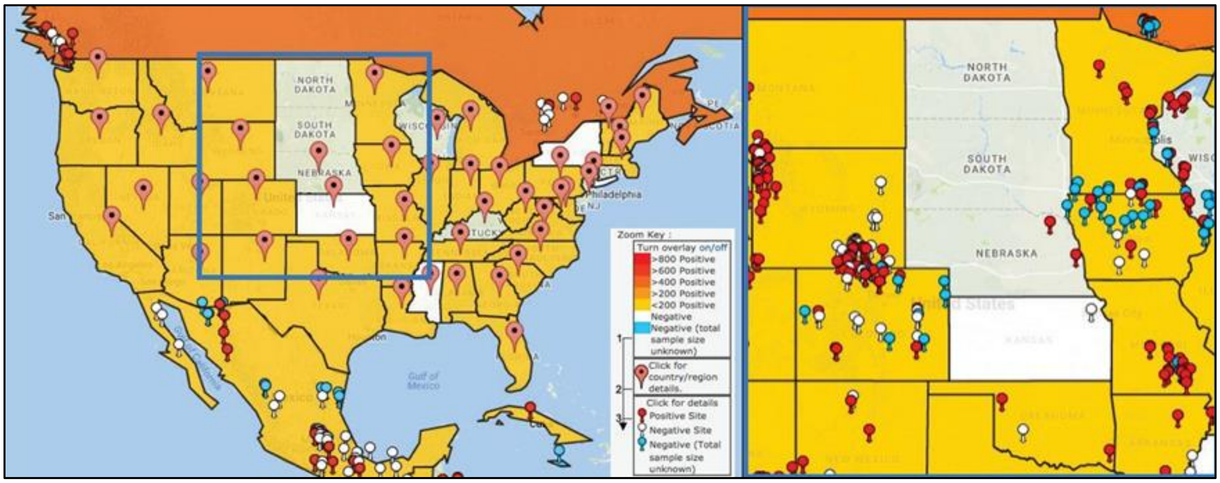

Figure 4.18.21. Confirmed positive and negative infections of chytrid fungus (Aanensen et al. 2016).

Table 4.18.5. Herpetofauna condition categories for exposure to chytrid fungus.

Resource condition		Distance of WNS from South Dakota
Warrants significant concern	🔴	Within Badlands NP border
Warrants moderate concern	🟡	< 50 miles from border but not within Badlands NP
Resource in good condition	🟢	> 50 miles from border of Badlands NP

Data Collection and Sources

Data Management and Availability

For this assessment we used data available from NPS natural resource inventory checklists (NPS 2008), field guides for reptiles and amphibians in South Dakota (Fischer et al. 1999a, Ballinger et al. 2000, Stebbins 2003, Bandas and Higgins 2004), reports to the wildlife management agency (Kerby 2011), the Species of Greatest Conservation Need list in the State Wildlife Action Plan for South

Dakota (SDGFP 2014), and sensitive species lists for Region 2 of the Forest Service (USFS 2015) and for Montana/Dakota by BLM (BLM 2009).

Quantifying Herpetofauna Condition, Confidence, and Trend

Indicator Condition

To quantify herpetofauna condition, we identified indicators, measures, and condition categories based on the scientific literature and expert opinion. We deferred to data collected most recently and rigorously. When quantitative data were available 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. If only qualitative data were available, we assigned condition based on expert opinion and the scientific literature.

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. For qualitative data, we assigned a *High* confidence if more than one source indicated a similar condition. 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. For qualitative data, we assigned *Medium* confidence if only one source indicated a condition, or if species suspected to occur within the park but not confirmed appeared on at least one sensitive species lists. We assigned a *Low* confidence when species were not confirmed within the park or there were no reliable data sources to support the condition.

Indicator Trend

Potential trend categories were *Improving*, *Unchanging*, or *Deteriorating*. To assign a trend to population growth rate (λ) for any reptile or amphibian species, we required at least three years of repeated abundance data for that species. Chytrid fungus can spread quickly and may cause precipitous population declines in some species but not others; three years of mortality and infection data may be sufficient to calculate a trend. 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 Herpetofauna Condition, Trend, and Confidence

If 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 herpetofauna condition, trend, and confidence. In the absence of adequate quantitative data, we assigned condition based on qualitative information, expert opinion, and consultation with NPS scientists (Table 4.18.6).

Table 4.18.6. Summary of herpetofauna indicators and measures.

Indicator	Measure	Condition	Confidence	Trend	Condition rationale
Tiger salamander	Population growth rate (λ)	Resource in good condition	Medium	Not available	–
	Level of conservation concern	Resource in good condition	Medium	Not available	Not a listed species of concern
Great plains toad	Population growth rate (λ)	Warrants moderate concern	Medium	Not available	–
	Level of conservation concern	Warrants moderate concern	Medium	Not available	Listed as a sensitive species by BLM
Woodhouse's toad	Population growth rate (λ)	Resource in good condition	Medium	Not available	–
	Level of conservation concern	Resource in good condition	Medium	Not available	Not a listed species of concern
Boreal chorus frog	Population growth rate (λ)	Resource in good condition	Low	Not available	–
	Level of conservation concern	Resource in good condition	Low	Not available	Not a listed species of concern
Plains leopard frog	Population growth rate (λ)	Warrants moderate concern	Low	Not available	–
	Level of conservation concern	Warrants moderate concern	Low	Not available	Listed species of concern by both BLM and the Forest Service
Bullfrog	Population growth rate (λ)	Resource in good condition	Low	Not available	–
	Level of conservation concern	Resource in good condition	Low	Not available	Not listed as a species of concern
Northern leopard frog	Population growth rate (λ)	Warrants moderate concern	Medium	Not available	–
	Level of conservation concern	Warrants moderate concern	Medium	Not available	Listed as a species of concern by BLM

Table 4.18.6 (continued). Summary of herpetofauna indicators and measures.

Indicator	Measure	Condition	Confidence	Trend	Condition rationale
Plains spadefoot toad	Population growth rate (λ)	Warrants moderate concern	Medium	Not available	–
	Level of conservation concern	Warrants moderate concern	Medium	Not available	Listed as a species of concern by BLM
Common snapping turtle	Population growth rate (λ)	Resource in good condition	Medium	Not available	–
	Level of conservation concern	Resource in good condition	Medium	Not available	Not listed as species of conservation concern
Painted turtle	Population growth rate (λ)	Resource in good condition	Medium	Not available	–
	Level of conservation concern	Resource in good condition	Medium	Not available	Not listed as species of conservation concern
Six-lined racerunner	Population growth rate (λ)	Resource in good condition	Low	Not available	–
	Level of conservation concern	Resource in good condition	Low	Not available	Not a listed species of concern
Eastern racer	Population growth rate (λ)	Resource in good condition	Medium	Not available	–
	Level of conservation concern	Resource in good condition	Medium	Not available	Not a listed species of concern
Prairie rattlesnake	Population growth rate (λ)	Resource in good condition	Medium	Not available	–
	Level of conservation concern	Resource in good condition	Medium	Not available	Not a listed species of concern
Western hog-nosed snake	Population growth rate (λ)	Warrants moderate concern	Medium	Not available	–
	Level of conservation concern	Warrants moderate concern	Medium	Not available	Listed as a species of concern by BLM

Table 4.18.6 (continued). Summary of herpetofauna indicators and measures.

Indicator	Measure	Condition	Confidence	Trend	Condition rationale
Milk snake	Population growth rate (λ)	Warrants moderate concern	Low	Not available	–
	Level of conservation concern	Warrants moderate concern	Low	Not available	Listed as a species of concern by BLM
Greater short-horned lizard	Population growth rate (λ)	Warrants moderate concern	Medium	Not available	–
	Level of conservation concern	Warrants moderate concern	Medium	Not available	Listed as a species of concern by BLM
Gopher snake	Population growth rate (λ)	Warrants moderate concern	Medium	Not available	–
	Level of conservation concern	Warrants moderate concern	Medium	Not available	Not listed species of concern
Chytrid fungus	Presence, absence, or proximity	Warrants significant concern	Medium	Not available	–
		Warrants significant concern	Medium	Not available	Chytrid fungus was present throughout South Dakota

4.18.4. Herpetofauna Conditions. Confidence, and Trends

Reptile and amphibian data were sparse for Badlands National Park. General occurrence data were available for some species throughout South Dakota, and we used range maps to identify areas of likely occurrence. Abundance data were unavailable for herpetofauna species within Badlands NP, but we were able to assign condition using range maps and qualitative data.

Tiger salamander (*Ambystoma tigrinum*)

●

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

Condition

Abundance data were not available for tiger salamanders. Tiger salamanders did not appear on special conservation list at the state, regional, or federal level, so the condition of the salamander was *Resource in Good Condition.*

Confidence

Tiger salamanders were confirmed present within Badlands NP. Confidence was *Medium*.

Trend

Trend was *Not Available.*

Great Plains Toad (*Anaxyrus cognatus*)

🟡

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

Condition

Abundance data for Great Plains toads were not available. This toad was listed as a species of conservation concern by BLM. Condition of the toad was *Warrants Moderate Concern.*

Confidence

Great Plains toads were confirmed present at Badlands NP. This toad was included on one sensitive species list and was confirmed present within the park. Confidence was *Medium*.

Trend

Trend was *Not Available.*

Woodhouse's Toad (*Anaxyrus woodhousii*)

🟢

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

Condition

Abundance data were not available for Woodhouse's toad. This species did not appear on special conservation list at the state, regional, or federal level, so the condition of the toad was *Resource in Good Condition.*

Confidence

Woodhouse's toad was confirmed present in Badlands NP. Confidence was *Medium*.

Trend

Trend was *Not Available.*

Boreal Chorus Frog (*Pseudacris maculata*)

🟢

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

Condition

Abundance data were not available for boreal chorus frogs. This species did not appear on special conservation lists at the state, regional, or federal level, so the condition of the toad was *Resource in Good Condition.*

Confidence

This frog was likely present in Badlands NP, though its presence had not been confirmed at the time of this assessment. Confidence was *Low*.

Trend

Trend was *Not Available.*

Plains Leopard Frog (*Lithobates blairi*)

🟡

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

Condition

Abundance data were not available for plains leopard frogs. This frog was listed as a sensitive species by both BLM and the Forest Service. Condition of this indicator species was *Warrants Moderate Concern.*

Confidence

These frogs were likely present in Badlands NP, though their presence had not been confirmed at the time of this assessment. Confidence was *Low*.

Trend

Trend was *Not Available.*

Bullfrog (*Lithobates catesbeianus*)

●

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

Condition

Abundance data were not available for bullfrogs. This species did not appear on special conservation lists at the state, regional, or federal level, so the condition of the toad was *Resource in Good Condition.*

Confidence

Bullfrogs were likely present in Badlands NP, though their presence had not been confirmed at the time of this assessment. Confidence was *Low*.

Trend

Trend was *Not Available.*

Northern Leopard Frog (*Lithobates pipiens*)

●

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

Condition

Abundance data were not available for northern leopard frogs. This frog was listed as a species of conservation concern by BLM. Condition of this indicator species was *Warrants Moderate Concern.*

Confidence

Northern leopard frogs were confirmed present in Badlands NP. Confidence was *Medium*.

Trend

Trend was *Not Available.*

Plains Spadefoot Toad (*Spea bombifrons*)

●

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

Condition

Abundance data were not available for plains spadefoot toads. This toad was listed as a species of conservation concern by BLM. Condition of this species was *Warrants Moderate Concern.*

Confidence

Plains spadefoot toads were confirmed present in Badlands NP. Confidence was *Medium*.

Trend

Trend was *Not Available.*

Common Snapping Turtle (*Chelydra serpentina*)

●

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

Condition

Abundance data were not available for snapping turtles. This species did not appear on special conservation list at the state, regional, or federal level, so the condition of the turtle was *Resource in Good Condition.*

Confidence

Snapping turtles were confirmed present within Badlands NP. Confidence was *Medium*.

Trend

Trend was *Not Available.*

Painted Turtle (*Chrysemys picta*)

●

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

Condition

Abundance data were not available for painted turtles. This species did not appear on special conservation lists at the state, regional, or federal level, so the condition of the turtle was *Resource in Good Condition.*

Confidence

Painted turtles were confirmed present in Badlands NP. Confidence was *Medium*.

Trend

Trend was *Not Available.*

Six-lined Racerunner (*Perimyotis subflavus subflavus*)

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

Condition

Abundance data were not available for six-lined racerunners. This lizard did not appear on special conservation lists at the state, regional, or federal level, so the condition of the species was *Resource in Good Condition.*

Confidence

Six-lined racerunners were likely present in Badlands NP, though their presence had not been confirmed at the time of this assessment. Confidence was *Low*.

Trend

Trend was *Not Available.*

Racer (*Coluber constrictor*)

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

Condition

Abundance data were not available for racers. This species did not appear on special conservation lists at the state, regional, or federal level, so the condition of the snake was *Resource in Good Condition.*

Confidence

Racers were confirmed present in Badlands NP. Confidence was *Medium*.

Trend

Trend was *Not Available.*

Prairie rattlesnake (*Crotalus viridis*)

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

Condition

Abundance data were not available for prairie rattlesnakes. This snake did not appear on special conservation lists at the state, regional, or federal level, so the condition of the species was *Resource in Good Condition.*

Confidence

Prairie rattlesnakes were confirmed present in Badlands NP. Confidence was *Medium*.

Trend

Trend was *Not Available.*

Western Hog-nosed Snake (*Heterodon nasicus*)

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

Condition

Abundance data were not available for western hog-nosed snake. This snake was listed as a species of conservation concern by BLM. Condition of the western hog-nosed snake was *Warrants Moderate Concern.*

Confidence

The western hog-nosed snake was confirmed present in Badlands NP. Confidence was *Medium*.

Trend

Trend was *Not Available.*

Mike Snake (*Lampropeltis trangulum*)

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

Condition

Abundance data were not available for milk snake. This snake was listed as a species of conservation concern by BLM. Condition of the milk snake was *Warrants Moderate Concern.*

Confidence

The milk snake was likely present in Badlands NP, though its presence had not been confirmed at the time of this assessment. Confidence was *Low*.

Trend

Trend was *Not Available.*

Greater Short-horned Lizard (*Phrynosoma hernandesi*)

●

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

Condition

Abundance data were not available for this greater short-horned lizard. This lizard was listed as a Species of Greatest Conservation Need by the state of South Dakota and as a species of conservation concern by BLM. Condition of the greater short-horned lizard was *Warrants Moderate Concern.*

Confidence

The greater short-horned lizard was likely present in Badlands NP, though its presence had not been confirmed at the time of this assessment. Confidence was *Low*.

Trend

Trend was *Not Available.*

Gopher Snake (*Pituophis catenifer*)

●

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

Condition

Abundance data were not available for gopher snakes. This snake did not appear on special conservation lists at the state, regional, or federal level, so the condition of the species was *Resource in Good Condition.*

Confidence

Gopher snakes were confirmed present in Badlands NP. Confidence was *Medium*.

Trend

Trend was *Not Available.*

Fence Lizard (*Sceloporus undulatus*)

🟢

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

Condition

Abundance data were not available for fence lizards. This lizard did not appear on special conservation lists at the state, regional, or federal level, so the condition of the species was *Resource in Good Condition.*

Confidence

Fence lizards were likely present in Badlands NP, though their presence had not been confirmed at the time of this assessment. Confidence was *Low*.

Trend

Trend was *Not Available.*

Western Box Turtle (*Terrapene ornate*)

🟡

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

Condition

Abundance data were not available for western box turtle. This turtle was listed as a Species of Greatest Conservation Need by the state of South. Condition of the western box turtle was *Warrants Moderate Concern.*

Confidence

The western box turtle was likely present in Badlands NP, though its presence had not been confirmed at the time of this assessment. Confidence was *Low*.

Trend

Trend was *Not Available.*

Western Garter Snake (*Thamnophis radix*)

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

Condition

Abundance data were not available for western garter snakes. This snake did not appear on special conservation lists at the state, regional, or federal level, so the condition of the species was *Resource in Good Condition.*

Confidence

Garter snakes were confirmed present within Badlands NP. Confidence was *Medium*.

Trend

Trend was *Not Available.*

Chytrid Fungus

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

Condition

Globally, amphibian populations have declined due to chytrid fungus, though it is unclear how chytridiomycosis has affected populations in South Dakota. At the time of this assessment, chytrid fungus was known to occur throughout South Dakota (Kerby 2011). Condition was *Warrants Significant Concern.*

Confidence

Sampling in this study was limited to a few species and, due to logistical complications, was not spread evenly across South Dakota. At the time of this assessment, sampling for Chytrid fungus had not occurred in or around Badlands NP. Confidence was *Low*.

Trend

Chytrid fungus was likely present at Badlands NP at the time of this assessment, though its consequences for amphibian populations are unknown in Badlands NP and across in South Dakota. Trend was *Not Available*.

Herpetofauna Overall Condition

Table 4.18.7. Herpetofauna overall condition.

Indicators	**Measures**	**Condition**
Tiger salamander (*Ambystoma tigrinum*)	• Population growth rate • Level of conservation concern	🟢
Great Plains Toad (*Anaxyrus cognatus*)	• Population growth rate • Level of conservation concern	🟡
Woodhouse's Toad (*Anaxyrus woodhousii*)	• Population growth rate • Level of conservation concern	🟢
Boreal Chorus Frog (*Pseudacris maculata*)	• Population growth rate • Level of conservation concern	🟢
Plains Leopard Frog (*Lithobates blairi*)	• Population growth rate • Level of conservation concern	🟡
Bullfrog (*Lithobates catesbeianus*)	• Population growth rate • Level of conservation concern	🟢
Northern Leopard Frog (*Lithobates pipiens*)	• Population growth rate • Level of conservation concern	🟡
Plains Spadefoot Toad (*Spea bombifrons*)	• Population growth rate • Level of conservation concern	🟡
Common Snapping Turtle (*Chelydra serpentina*)	• Population growth rate • Level of conservation concern	🟢
Painted Turtle (*Chrysemys picta*)	• Population growth rate • Level of conservation concern	🟢
Six-lined Racerunner (*Perimyotis subflavus subflavus*)	• Population growth rate • Level of conservation concern	🟢

Table 4.18.7 (continued). Herpetofauna overall condition.

Indicators	**Measures**	**Condition**
Racer (*Coluber constrictor*)	• Population growth rate • Level of conservation concern	🟢
Prairie rattlesnake (*Crotalus viridis*)	• Population growth rate • Level of conservation concern	🟢
Western Hog-nosed Snake (*Heterodon nasicus*)	• Population growth rate • Level of conservation concern	🟡
Mike Snake (*Lampropeltis trangulum*)	• Population growth rate • Level of conservation concern	🟡
Greater Short-horned Lizard (*Phrynosoma hernandesi*)	• Population growth rate • Level of conservation concern	🟡
Gopher Snake (*Pituophis catenifer*)	• Population growth rate • Level of conservation concern	🟢
Fence Lizard (*Sceloporus undulatus*)	• Population growth rate • Level of conservation concern	🟢
Western Box Turtle (*Terrapene ornate*)	• Population growth rate • Level of conservation concern	🟡
Western Garter Snake (*Thamnophis radix*)	• Population growth rate • Level of conservation concern	🟢
Chytrid Fungus	• Presence, absence, or proximity	🔴
Overall for all indicators and values		🟡

Condition

Overall herpetofauna condition was determined by qualitative information, expert opinion, and consultation with NPS scientists. Condition was unavailable for population growth rate due to a lack of data. Forty percent of species suspected or confirmed present at Badlands NP were listed as species of conservation concern. Due to the presence or suspected presence of so many listed species in the park, plus the presence of chytrid fungus in South Dakota, we assigned the condition, *Warrants Moderate Concern.*

Confidence

The lack of abundance data and the uncertainty about the presence of several species warranted a *Low* confidence in overall herpetofauna condition.

Trend

Trend was *Not Available* for any indicator. Overall trend for herpetofauna condition was *Not Available*.

4.18.5. Stressors

Most amphibians spend a significant proportion of their lives in water, and their skin structure allows for physiological processes to occur across the membrane when it is wet; these species are, therefore, especially sensitive to chemical contaminants in water bodies (Brühl et al. 2013). Toxins in the water can directly damage amphibian physiology (Mann et al. 2009), but they can alter ecosystem processes and affect amphibian communities indirectly as well (e.g., Rohr and Crumline 2005). Agricultural operations in the vicinity of the park could affect water quality (Baker et al. 2013). Even water quality in wilderness areas can be affected by air-borne pesticides (Marohasy and Abbot 2015).

Disease is also a major threat to amphibians. Chytrid fungus has been detected throughout South Dakota (Kerby 2011) and could be affecting amphibians in the park. Ranaviruses threaten amphibians as well as reptiles; these viruses cause general, systematic infections in afflicted individuals and result in mass mortalities in a variety of species (Gray et al. 2009).

Reptiles are particularly sensitive to habitat loss (e.g., Mantyka-Pringle, 2012) and amphibians also have specific habitat requirements. Good aquatic environments are requisite for the persistence of amphibian populations and some reptile populations within the park.

Potential changes in climate could affect both amphibian and reptile populations. For amphibians, a potentially warmer and drier climate could affect the availability of aquatic habitat. Additionally, chytrid fungus could respond to changes in climate. This fungus flourishes within a temperature range of 17–25°C (Piotrowski et al. 2004), and changes in average spring and summer temperature in South Dakota could affect the infection potential of chytrid fungus in Badlands NP amphibian populations. Reptiles and amphibians can also be affected by temperature changes at the developmental stage. Many herpetofauna have temperature-dependent sex determination, wherein a variety of thermal variables are responsible for the production of male or female offspring. Changes in the variability of temperatures, as well as mean temperatures can shift the ratio of males to females (Georges 2013).

4.18.6. Data Gaps

An updated comprehensive survey of all herpetofauna present in the park would be an important step to understanding condition of herpetofauna in Badlands NP. Additionally, repeated monitoring is critical to understanding if populations are changing within the park. Sampling for chytrid fungus within the park would elucidate how prevalent the disease really is in park populations.

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4.19. Invertebrate Pollinators

4.19.1. 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.

Melissa blue butterfly at Badlands NP. Photo by Cathy Bell, NPS (2013).

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 scare 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 a part of research programs at several national parks and pollinator education programs were growing at the time of this assessment (NPS 2016a).

Regional Context

Most South Dakota pollinators are native insects and honey bees (USDA-NRCS 2008), all of which require fairly undisturbed habitat and a variety of food sources. Badlands NP is home to a total of 69 confirmed species (NPS 2016b). Monarch butterflies (*Danaus plexippus*) feed on milkweed in the park (Figure 4.19.1A), where the species spends summer, two-tailed swallowtails (*Papilio multicaudata*) lay eggs on choke cherry and wild plum trees (Figure 4.19.1B), and melissa blue butterflies (*Plebejus melissa*) persist throughout the park (Marrone 2004, Figure 4.19.1C). While bumble bees (*Bombus* sp.) and other invertebrate pollinators are likely present (Koch et al. 2012) in Badlands NP, local census data are lacking for the park.

Figure 4.19.1. Butterfly species present at Badlands NP (Marrone 2004) include A) Monarch butterfly (*Danaus plexippus*), B) two-tailed swallowtails (*Papilio multicaudata*), C) and melissa blue butterflies (*Plebejus melissa*). Photos by K.D. Harrelson (2007), J. Williams (2006), and A. Reago and C. McClarren (2014), respectively.

4.19.2. 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 USC § 1531 et seq. 1973), if recovery plans have been completed. At the time of this assessment, however, recovery plans did not exist for the two listed species in South Dakota, Dakota skipper (*Hesperia dacotae*) and Poweshiek skipperling (*Oarisma poweshiek*) (USFWS 2016).

4.19.3. Methods

Indicators and Measures

We assessed invertebrate pollinator condition at Badlands NP 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 Badlands NP. The method for assign 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 (Marrone 2004), the Badlands NP webpage on butterfly species (NPS 2016b), 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 Badlands NP.

Quantifying Pollinator Condition, Confidence, and Trend

Indicator Condition

To quantify invertebrate pollinator condition, we used 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.

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 to calculate overall pollinator condition, trend, and confidence (Table 4.19.1). In the absence of adequate quantitative data, we assigned condition based on qualitative information, expert opinion, and consultation with NPS scientists.

Table 4.19.1. Summary invertebrate pollinator's indicators and measures.

Indicator	Measure	Condition	Confidence	Trend	Condition rationale
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.

4.19.4. Pollinator Conditions, Confidence, and Trends

Few data on pollinators were available for Badlands NP, though we were able to reference a butterfly census survey (Marrone 2004) and an updated park webpage (NPS 2016b) on butterflies in the park. Xerces Society Red Lists identified a number of species of concern in South Dakota and we were able to associate vulnerable status with a butterfly know to occur in Badlands NP, 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

Several butterfly species lists exist for Badlands NP (Marrone 2004, NPS 2016b), but no such list exists for other invertebrate pollinators. The most comprehensive butterfly survey we identified (Marrone 2004) involved a repeated census of species present at nine sampling sites throughout the park. This butterfly survey (Marrone 2004) included counts of butterfly species at different locations, using baited traps and observation. We used these data to calculate a Shannon diversity index; Shannon diversity was 1.18 for combined sampling periods, which is considered low diversity by some sources in other fields of study (e.g., Clausen and Biggs 1997, Kearns and Oliveras 2009), but may be typical for some vertebrates (e.g., Price 2004). Shannon diversity varied substantially across the different sampling periods (SDµ = 2.04 ± 2.07 SD). These values have little real meaning without reference to ecosystem type and consensus on how pollinator diversity indicates condition, though agreement on such standards would allow managers to tackle the problem of pollinator decline more aggressively.

In the future, surveys of bees and other pollinators, in addition to repeated sampling of butterflies, would provide a more thorough measure of overall pollinator diversity. Condition was *Not Available.*

Confidence

Few data existed for invertebrate pollinators at Badlands NP, 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

Some butterfly abundance data were available for Badlands NP (Marrone 2014), with sampling conducted at nine locations throughout the park. These data were thorough enough to allow us to calculate diversity (see above), but were limited to butterflies. In the future, surveys of bees and other pollinators, in addition to repeated sampling of butterflies, would provide a more thorough measure of overall pollinator abundance. Condition was *Not Available.*

Confidence

Few data existed for invertebrate pollinators at Badlands NP, and were collected for only one type of invertebrate pollinator. Confidence was *Low*.

Trend

Trend was *Not Available.*

Vulnerable Species

🟡

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

Condition

Regal fritillary (*Speyeria idalia*) was identified as present at Badlands NP, was a species of conservation concern on the Xerces Society Red List (Xerces Society 2016b), and was being considered for ESA listing (USFWS 2016). Other butterflies in South Dakota are species of concern and under consideration for ESA listing, but not confirmed as present within the park. The two listed butterflies in South Dakota, the threatened Dakota skipper (*Hesperia dacotae*) and endangered Poweshiek skipperling (*Oarisma poweshiek*) (USFWS 2016), can occur in eastern and northeastern parts of the state but are unlikely to occur in Badlands NP.

Western bumble bees (*Bombus occidentalis*) and yellow-banded bumble bees (*Bombus terricola*) are likely to be present at Badlands NP (Xerces Society 2016a), but had not been confirmed as present; this species was under petition for ESA listing. Rusty patched bumble bees (*Bombus affinis*) and yellow-banded bumble bees (*Bombus terricola*), species also being considered for ESA listing, could possibly be present but were more likely to be present in eastern South Dakota (Xerces Society 2016a).

One pollinator of conservation concern was identified as present within Badlands NP 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 Badlands NP, and were collected for only one type of invertebrate pollinator. Confidence was *Low*.

Trend

Trend was *Not Available.*

Invertebrate Pollinators Overall Condition

Table 4.19.2. Invertebrate pollinators overall condition.

Indicators	Measures	Condition
Diversity	- Shannon index	○
Abundance	- Mean visitation rate - Mean density in traps	○
Vulnerable species	- Level of conservation concern	🟡
Overall condition for all indicators and species		🟡

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 Badlands NP, and were collected for only one type of invertebrate pollinator. Confidence was *Low.*

Trend

Trend was *Not Available.*

4.19.5. 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 South Dakota, 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. Badlands NP 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.

4.19.6. Data Gaps

Butterfly data collected over 10 years prior to this assessment (Marrone 2004) formed the basis of our assessment. A comprehensive survey of all potential pollinators would be an important step to understanding condition of pollinators in Badlands NP, 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 section 4.5.3. Indicator: Dissolved Oxygen, for Water Quality methods). 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) of natural resource conditions, potential threats and stressors to those resources, scientific needs and data gaps, and management issues for Badlands National Park. 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 Badlands NP 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.

Yellow Mounds by Carl Johnson, Artist in Residence, NPS (2009).

Table 5.1. Summary of natural resources conditions, confidence, trends, and rationale for resource condition.

Priority resource	Condition, confidence, and trend	Summary of overall condition
Viewshed	🟢	Viewshed condition depended on two indicators: scenic quality of view and land cover content within viewshed. Three measures of scenic quality (landscape character integrity, vividness, and visual harmony) indicated good condition, as did a 98.5% natural land cover and 1.41% developed land cover. The ongoing concern with this resources in Badlands NP is that development around the park could negatively affect viewshed.

Table 5.1 (continued). Summary of natural resources conditions, confidence, trends, and rationale for resource condition.

Priority resource	Condition, confidence, and trend	Summary of overall condition
Night sky	🟢	NPS Natural Sounds and Night Skies Division collected night sky data in the park in 2006 and 2011. We used these data to assess night sky condition using two indicators: night sky quality and natural light environment. Three measures of night sky quality (Bortle dark sky index, synthetic sky quality meter, and sky quality index) indicated good condition, as did a low anthropogenic light ratio—the measure of natural light environment. Some light from the town of Interior, SD, could affect the light environment some.
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. The indicator identified by NSNSD, anthropogenic impact, indicated that soundscape was in good condition. Managers expressed concern that the modeled data did not capture the high noise levels present in the park during parts of the summer, particularly associated with motorcycle rallies and helicopter tours. Condition was of moderate concern.
Air quality	🟡	Badlands NP is a Class I airshed and held to the highest 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. Oil and gas development to the west of the park may be affecting air quality to some extent.
Surface water quality	🟡	We assessed water quality using the most recent data available for core water quality indicators (acidity, dissolved oxygen, temperature, specific conductivity) and biological indicators (invertebrate assemblage, fecal indicator bacteria). Core indicators were in good condition, while biological indicators, generally reflective of more long term quality aspects, indicated significant concern; overall condition was moderate concern.
Geology	🟡	Badlands NP is characterized by naturally high weathering and erosion rates, and the badlands formations within the park are specifically due to these processes. Recent erosion and weathering rates were within the range of normal variation, but extensive trampling by visitors has affected erosion on the buttes. Additionally, erosion patterns have changed and accelerated near the road where culverts have been abandoned. Condition was of moderate concern.

Table 5.1 (continued). Summary of natural resources conditions, confidence, trends, and rationale for resource condition.

Priority resource	Condition, confidence, and trend	Summary of overall condition
Paleontological resources	🔴	Paleontological resource condition at the park depended on the potential for fossil loss. High weathering and erosion rates mean that fossils are frequently uncovered, but the potential damage to the fossils in this situation indicated significant concern. Theft and vandalism are also major concerns, and mitigation requires collecting fossils quickly as they are exposed and documenting those fossil locations.
Vegetation	🟡 ⇔	A complete vegetation assessment was completed for Badlands NP in the course of this NRCA and we based our assessment entirely on those results. Several measures of upland plant community and exotic plant detection 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 population rates by the 1960s, but their numbers increased again following some federal protections. Prairie dogs in South Dakota reached a population high in 2008, then declined following a plague outbreak. Plague was a management issue for the park at the time of this survey and likely will be in the future.
Black-footed ferrets	🔴 ⇔	Once thought extinct, black-footed ferrets were reintroduced into Badlands NP beginning in 1994. The most recent data available at the time of this survey revealed that 32 adult ferrets were present. We used federal status of this endangered species to identify a condition of significant concern.
Bison	🟡	Bison are a heavily managed resource in the park, and many factors figure into the health of this herd. We used a peer-reviewed approach to assessing bison health, taking into account herd size and composition, landscape size and use, ecological interactions, geography, and health and genetics. Using these factors as indicators, we identified an overall condition of moderate concern.
Swift Fox	🔴	Swift foxes are a species of concern in South Dakota, considered threatened by the state and sensitive by the Bureau of Land Management. A population has grown from a reintroduction to Badlands NP in 1987. To assess swift fox condition from 2003–2009, the time period for which we had data, we used the recovery criteria of a self-sustaining population. Growth rate was negative, indicating significant concern.

Table 5.1 (continued). Summary of natural resources conditions, confidence, trends, and rationale for resource condition.

Priority resource	Condition, confidence, and trend	Summary of overall condition
Bats	🟡	Many bats are at risk and sensitive across large portions of their range; we assessed bat condition at Badlands NP by looking at condition of 11 individual bat species and the presence of an infectious fungus. Overall bat condition was of moderate concern, though some species are doing well and others at a higher level of concern.
Bighorn Sheep	🟢⇧	We assessed condition of bighorn sheep based on population growth rate and population size. While population counts had occurred recently (in 2015), these counts included individuals that had been added to the herd by managers and, therefore, were not appropriate for calculating growth rate. Counts indicated moderate condition. Natural population growth rate data were most recently collected from 1987–1997, and indicated a good condition. Overall condition was good.
Bobcat	🟢⇧	Bobcat are hunted as a furbearer species in South Dakota, but recent population trends in the western part of the state indicate an increase in population sizes. Data were unavailable within Badlands NP, where hunting is not allowed, but population data from a nearby study area were extrapolated to western South Dakota and indicated an increase in bobcat numbers. Bobcat are protected in Badlands NP and, though hunting pressure could affect individuals near the park boundaries, the population in the park is likely to be doing as well as that in greater western South Dakota. Condition was good.
Mule Deer	🟢	Mule deer condition depended on population growth rate and population size. Statewide, mule deer have been declining, with some evidence for increases from 2014–2016. Mule deer survival monitoring began in Badlands NP in 2015, and the few data available indicated a positive growth rate. Condition was good, but confidence was low.
Herpetofauna	🟡	Twelve reptiles and eight amphibians occur or are suspected to occur in Badlands NP. We assessed herpetofauna condition at Badlands NP by looking at condition of individual reptile and amphibian species and the presence of an infectious disease. Overall herpetofauna condition was of moderate concern, though more quantitative data would allow a more complete assessment. Reptiles and amphibians are imperiled internationally, and their condition is of concern to conservationists internationally.
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 Badlands NP are central to the enabling legislation of the park and its purpose. One reason the park exists is to protect and preserve flora, fauna, and natural processes, particularly in the prairie grasslands (NPS 2008). Working within this purpose, managers at Badlands NP further the NPS Mission of preserving natural and cultural resources for future generations (NPS 2016) and help to protect 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 Badlands NP 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. Communicating effectively with neighbors is key to protecting these resources.

Managers at Badlands NP emphasized that collecting updated inventory data for a variety of natural resources and maintaining a consistent monitoring program for natural resources was a priority. One general need identified during this discussion that is of high importance is the consistency of monitoring for all key natural resources.

In this vein, coordinating data collection and monitoring with other agencies and NGO partners will be productive to creating a high quality data set for natural resources in the future. In particular, coordination with the Oglala Sioux Tribe (OST) is vital to the management of The South Unit and Palmer Creek Area of Badlands NP. The South Unit sits on lands owned by the OST. At the time of this assessment the NPS and OST co-managed the South Unit; the NPS was responsible for daily management and overall administration of the South Unit, the OST and NPS managed cultural and natural resources; both entities also shared the responsibilities of operating the White River Visitor Center (NPS and OSPRA 2012). The NPS and Oglala Sioux Parks and Recreation Authority (OSPRA) prepared a general management plan to explore options of transferring management responsibility fully to the OST, wherein the preferred option for all parties was to pursue the establishment of the first tribal national park (NPS and OSPRA 2012). At the time of this assessment, the preferred option to create a tribal national park had been put on hold (R. Benton, personal communication, 20 November, 2016).

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 Badlands NP, 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 of this NRCA.

5.4.1. Viewshed

At Badlands NP, rich fossil deposits, a long human history of Native Americans and homesteaders, the largest undisturbed mixed grass prairie in the U.S., and striking visual displays of deposition and erosion in the Badlands formations, are important aspects of the visitor experience (National Park

Service 2016a). These park features combine to create a unique visual setting in a remote, natural environment.

The long history of conservation in the Badlands of South Dakota and the largely undisturbed and undeveloped landscape surrounding the park has ensured that the area continues to offer visitors an outstanding visual experience. Native Americans and early settlers would have been likely to encounter a similar environment to that existing in the Badlands today.

Viewshed Condition Summary

Viewshed condition depended on two indicators: scenic quality of view and land cover content within viewshed. Three measures of scenic quality (landscape character integrity, vividness, and visual harmony) indicated good condition, as did a 98.5% natural land cover and 1.41% developed land cover. Viewshed condition was *Resource in Good Condition*, confidence in condition was *High*, and trend was *Not Available* (Table 5.1).

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. The Air Resource Division needs to work with the park to conduct an inventory with volunteers, seasonal staff, and natural resource managers. Part of this inventory involves taking photographs for future monitoring, in the event that full inventories cannot be completed as frequently as necessary for the park. Following this initial inventory, the park can develop a monitoring approach.

Park managers agreed that viewshed was in good condition at the time of this assessment, but expressed concern about proposed construction projects just outside the park. In particular, windmills and cell towers could be developed within the park viewshed. Monitoring of viewshed is a priority (M. Pflaum and E. Childers, personal communication, 29 September 2016) and communicating with constituents in the counties adjacent to the park is an important component of staying up to day on development plans and proposal in the region.

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. For now, however, some of the darkest skies in the lower 48 states surround Badlands NP.

Clear, dark night skies are a valuable natural resource at Badlands National Park. An astronomy program has been conducted during the summer months at Badlands NP since 2006. These programs begin after the evening ranger programs and offer visitors the opportunity to view night sky objects through telescopes. Rangers leading the program help to locate constellations, stars, planets, and other objects. In early July, 2016, the park successfully completed its 5th Annual Astronomy Festival. The 2016 three-day festival included telescope viewing of the sky each night, planetarium shoes, model rocket building and launching workshops, and guest speakers. The annual festival and the nightly sky events have been very successful (C. Schroll, personal communication, 31 July 2016).

Night Sky Condition Summary

NPS Natural Sounds and Night Skies Division collected night sky data in the park in 2006 and 2011. We used these data to assess night sky condition using two indicators: night sky quality and natural light environment. Three measures of night sky quality (Bortle dark sky index, synthetic sky quality meter, and sky quality index) indicated good condition, as did a low anthropogenic light ratio—the measure of natural light environment. Some light from the town of Interior, SD, could affect the light environment some. Night sky condition was *Resource in Good Condition*, confidence in condition was *High*, and trend was *Not Available* (Table 5.1).

Night Sky Gaps and Management Issues

Badlands NP night sky experts identified that light from the small nearby town of Interior SD, two miles away, could be a source of light pollution in the park (C. Schroll, personal communication, 31 July 2016). There may be an opportunity here for a partnership with Interior to limit light pollution by redirecting lights. Continued diligence to limit light pollution within the park, especially within the Cedar Pass campground is a priority. Park management will continue to work with concessioners to make sure their lighting is in compliance.

5.4.3. Soundscape

Badlands NP is surrounded by vast areas of prairie and badlands formation, with some agricultural development bordering the park unit. Primary sources of non-natural sounds within the park include automobile traffic, visitor conversations and associated acoustics, maintenance operations, and air traffic passing overhead. Industrial activities and noise from business and heavily populated residential areas are unlikely to affect the acoustic environment in Badlands NP. The closest town with population > 10,000 is Rapid City, SD (population ~70,900), about 60 kilometers (37 miles) to the northwest. Despite the park's distance from heavily populated areas, noise can be a problem in the park. In the summer, motorcycle traffic to and from rallies create serious noise issues in the park. Additionally, helicopter tours create noise pollution.

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 was in good condition. Managers highlighted that noise levels increase dramatically during the summer from motorcycle rallies and helicopter tours. This noise is probably not captured by the soundscape model, in which the average predicted sound level washes out the decibels spikes that may occur with motorcycle traffic. Based on feedback from park managers, soundscape condition was *Warrants Moderate Concern*, confidence in condition was *Medium*, and trend was *Not Available* (Table 5.1).

Soundscape Gaps and Management Issues

The disparity between the modeled soundscape data and expert opinion of soundscape condition highlight the need for baseline acoustic ambient data collection. These data 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.

Motorcycle and helicopter noise remain a challenge for the park. Working with neighbors to resolve the issue of helicopter noise has not resolved the problem, though efforts continue. Management strategies to reduce motorcycle noise in the park are unresolved but of interest to the park.

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

Air Quality Condition Summary

Badlands NP is a Class I airshed and is held to the highest air quality standards. Air quality indicators of visibility, ozone, particulate matter, 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).

Air Quality Gaps and Management Issues

Some site-specific data were available, 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 Badlands NP.

Oil and gas development to the west of the park may be affecting air quality to some extent, as might a coal burning power plant in western Nebraska.

5.4.5. Water Quality

Badlands National Park is located in the Bad, Middle Cheyenne-Elk, Middle Cheyenne-Spring, Upper White, and Middle White River drainage basins. Each of these rivers flow east into the Missouri River, though only the White River runs through the park. Other water resources within the park are limited, consisting primarily of intermittent streams—Battle, Cedar, Palmer, and Sage Creeks, ephemeral water bodies, and constructed. The top water quality priority at the Badlands NP is the Civilian Conservation Corps (CCC) Springs, an artificial stock pond, and Sage Creek has also received monitoring.

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) and biological indicators (invertebrate assemblage, fecal indicator bacteria). Core indicators were in good condition, while biological indicators, generally reflective of more long term quality aspects, indicated significant concern. Overall water quality condition was *Warrants Moderate Concern*, confidence in condition was *Medium*, and trend was *Not Available* (Table 5.1).

Water Quality Gaps and Management Issues

Water quality data for core indicators at Badlands NP were limited to samples collected once in Sage Creek and the stock ponds in the last 10 years, and frequent sampling is required for any more detailed analysis of trend. In particular, park managers were concerned about surface and ground water contamination by atrazine from neighbors just west of the park. Recent data from CCC springs did not indicate atrazine was present, but sampling both ground water and surface water in the future for this chemical and others would be prudent. At the time of this assessment, sampling was set to occur every six years; priorities were sampling the CCC spring (Wilson et al. 2014) and work completed by Tronstad et al. (2015) to monitor sage creek and the stock dams (K. Paintner, personal communication, 2 December 2016). Heavy use of available water resources by livestock and agriculture upstream and bison within the park are the most likely causes of water quality impairment. Changes to upstream land use or management practices could have unanticipated consequences.

5.4.6. Geology

The rugged geology of Badlands National Park is a primary draw to the park for visitors. The weathering and erosion that create the striking geologic features in that park are important resource issues within the park. While these processes naturally occur at high rates in Badlands NP, they can be exacerbated by human activities such as hiking, construction of roads or trails, and lapsed infrastructure maintenance.

Geology Condition Summary

Badlands NP is characterized by naturally high weathering and erosion rates, and the badlands formations within the park are specifically due to these processes. Recent erosion and weathering rates were within the range of natural variation, but extensive trampling by visitors has affected erosion on the buttes. Additionally, erosion patterns have changed and accelerated near the road where culverts have been abandoned. Geologic resource condition was *Warrants Moderate Concern*, confidence in condition was *Medium,* and trend was *Not Available* (Table 5.1).

Geology Gaps and Management Issues

Park management identified the need to measure erosion rates within the park in 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, geologic impacts are associated with the most heavily used areas. In particular, abandoned culverts accelerate erosion.

5.4.7. Paleontological Resources

Badlands National Park was established in large part to protect fossil resources. Abundant and diverse flora and fauna are well known from the White River Badlands, and these fossils have played a large role in our understanding of the evolution and adaptation of plants and animals to climate change. Numerous vertebrate taxa as well as scarce plant fossils, petrified wood, and invertebrates have been described from these strata. While the mammalian fossils are the most well studied, fossils of bony fish, amphibians, turtles, squamates, crocodiles and alligators, and birds are also known from the Badlands.

Paleontological Resource Condition Summary

Paleontological resource condition at the park depended on the potential for fossil loss. High weathering and erosion rates mean that fossils are frequently uncovered, but the potential damage to the fossils in this situation indicated significant concern. Theft and vandalism are major concerns, and mitigation requires collecting fossils quickly as they are exposed and documenting those fossil locations. Overall paleontological resource condition was *Warrants Significant Concern*, confidence in condition was *High*, and trend was *Not Available* (Table 5.1).

Paleontological Resource Gaps and Management Issues

Fossils are important natural resources at Badlands NP, and increasing the number of paleontological surveys would be a productive step towards protecting paleontological resources in the park. Vandalism and theft are major issues for the park. If park paleontologists can get out and document resources, they can collect fossils before they are stolen or vandalized. Collecting, cataloguing, and preparing specimens for display are priorities of park managers (R. Benton, personal communication, 29 September 2016). A strategic, long term, and consistent program of paleontological monitoring to document and collect fossil before weathering and theft destroy them would facilitate this goal.

5.4.8. Vegetation

Resource overview from the vegetation report written by Isabel W. Ashton and Christopher J. Davis (2016):

Badlands National Park is a mosaic of sparsely vegetated badlands, native mixed-grass prairie, woody draws, and exotic grasslands. Vegetation monitoring began at BADL in 1998 by the Northern Great Plains Fire Ecology Program. The Northern Great Plains Inventory & Monitoring Program (NGPN) began vegetation monitoring at BADL in 2011. Vegetation monitoring protocols and plot locations were chosen to represent the entire park and to coordinate efforts with the Northern Great Plains Fire Ecology Program (FireEP). A total of 127 plots were established by NGPFire and NGPN in BADL and the combined sampling efforts began in 2011. 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 Badlands NP in the course of this NRCA, and we based our assessment entirely on those results. Several measures of upland plant community and exotic plant detection indicated moderate concern. Overall vegetation condition *Warrants Moderate Concern*, confidence in condition was *Medium*, and trend was *Unchanging* (Table 5.1).

Vegetation Gaps and Management Issues

Vegetation managers at Badlands NP struggle with exotic plants, constantly fighting an uphill battle to reduce exotic plant cover and improve habitat for existing native plants (E. Childers, personal communication, 29 September 2016). The park has been managing exotic cover through the fire management plan and also recognizes a need to deal with the expansion of sweet clover in the prairie dog towns. Other strategies of exotic invasive place control warrant exploration (B. Kenner, personal communication, 12 December 2016).

5.4.9. Birds

Badlands NP is located within the badlands and prairies bird conservation region. The badlands and prairies 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 Badlands NP.

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).

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

Maintaining healthy black-tailed prairie dog populations is fundamental to the character and ecological integrity of Badlands National Park. Prior to being affected by plague, Badlands NP accounted for about 59% of the acreage occupied by black-tailed prairie dogs on all NPS lands. Some prairie dog colonies, such as Roberts Prairie Dog Town in the northern part of the park, are important tourist attractions. Badlands NP is dedicated to protecting the species and participates in state and federal management protocols. The largest management issue facing prairie dogs in the park is sylvatic plague caused by *Yersinia pestis*, a lethal, generalist, non-native bacterium. Plague has greatly reduced the number of active prairie dog colonies within the park since 2008. Badlands NP has engaged in multi-agency efforts to curb plague within the park and surrounding grasslands.

Badlands NP has also served as a reintroduction site for endangered and threatened species, efforts that would not have been possible without an extensive population of prairie dogs. Badlands NP was the second reintroduction site for black-footed ferrets owing to the high quality of prairie dog habitat, and swift foxes were translocated to Badlands NP beginning in 2003.

Prairie Dog Condition Summary

Black-tailed prairie dogs were reduced to very low population rates by the 1960s, but their numbers increased again following some federal protections. Prairie dogs in South Dakota reached a population high in 2008, then declined following a plague outbreak. Plague was a management issue for the park at the time of this survey and likely will be in the future. Overall condition of prairie dogs was *Warrants Significant Concern*, confidence in condition was *High*, and trend was *Deteriorating* (Table 5.1).

Prairie Dog Gaps and Management Issues

Prairie dog monitoring occurred at least once every two years from 2000–2015, but monitoring approaches have not been systematic or consistent (E. Childers, personal communication, 29 September 2016). Improved monitoring efforts are a priority.

Current management needs are to continue dusting for the fleas that carry plague and administering the oral vaccine to prairie dog populations. Park managers highlighted the important of keeping prairie dog management objectives in mind for improving the condition of black footed ferrets and swift fox. Continued cooperation among federal agencies and non-governmental organizations, which has been the hallmark of ferret recover in the Conata Basin/Badlands area (B. Kenner, personal communication, 12 December 2016), is essential to preserving prairie dogs in the Conata Basin/Badlands area.

5.4.11. Black-footed Ferret

Since 1991, ferrets have been reintroduced to 26 sites in eight states (Wyoming, South Dakota, Montana, Arizona, Utah, Colorado, Kansas and New Mexico), one site in Mexico, and one site in Canada, Populations in Mexico and Canada are now extirpated. At present, populations are self-sustaining at only four locations: Conata Basin/Badlands and Cheyenne River in South Dakota, one in Arizona, and one in Wyoming. It is possible that even these “self-sustaining” sites may require additional ferret allocations in the near future. Even with ongoing and intensive management, wild black-footed ferret populations remain small and fragmented.

Black-footed Ferret Condition Summary

Once thought extinct, black-footed ferrets were reintroduced into Badlands NP beginning in 1994. The most recent data available at the time of this survey revealed that 32 adult ferrets were present. We used federal protection status to assess ferret condition. Overall condition of black-footed ferret was *Warrants Significant Concern*, confidence in condition was *High*, and trend was *Unchanging* (Table 5.1).

Black-footed Ferret Gaps and Management Issues

There are two potential sources of uncertainty in the current population estimation approach. The first is that survey effort is not randomized or stratified, so the area of inference differs somewhat from year to year. The survey area is focused on a small number of known black-footed ferret colonies and is therefore similar from year to year. The second potential source of uncertainty is that variance in population size is not estimated. The ability to detect ferrets during surveys may change over time according to a variety of factors, including weather, surveyor experience, detection method, etc.

The single largest threat to black-footed ferrets is plague. Plague affects ferrets both indirectly through reduced prairie dog numbers and directly through mortalities. While extensive dusting of burrows and vaccination of ferrets have prevented extirpation of black-footed ferrets in Conata Basin/Badlands, the population has been drastically reduced since plague first moved into the area. Management strategies include dusting with insecticides to remove fleas, but some fleas have become resistant. Experimental approaches with dust and vaccines are ongoing.

Preservation of an endangered species at the verge of extinction is an intensive and expensive endeavor. Because of the ongoing challenge of plague, support for the ferret program must come from the highest levels of the three involved federal agencies. Fate of the ferret cannot be left to efforts of people at the ground level working with limited staff and funding (B. Kenner, personal communication, 12 December 2016).

5.4.12. Bison

By the end of the 1800s, bison had been reduced to approximately 1,000 animals living within Yellowstone National Park, zoos, and private ranches. Today, conservation efforts have restored bison populations to over 500,000 animals, although only 5% of these bison exist in publicly owned, or conservation, herds. These “conservation herds” are managed in the public interest by governments and environmental organizations. The number of bison in conservation herds has remained stable since the 1930s. It should also be noted that the number of bison thought to be free of cattle genes number significantly fewer than these estimates. Bison currently occupy less than 1% of their historical range.

Bison Condition Summary

Bison are a heavily managed resource in the park, and many factors figure into the health of this herd. We used a peer-reviewed approach to assessing bison health, taking into account herd size and composition, landscape size and use, ecological interactions, geography, and health and genetics. Overall condition of bison was *Warrants Moderate Concern*, confidence in condition was *High*, and trend was *Not Available* (Table 5.1).

Bison Gaps and Management Issues

Information on how bison use the landscape at Badlands NP is generally lacking. USGS scientists are in the initial stages of a research project using collared bison to fill this data gap. They are studying the density and distribution of bison within the park, and seeing how these are related to forage availability, composition, and utilization.

Current bison management efforts at Badland NP include a plan to increase the grazing area by 8903 hectares (22,000 acres) and to improve access to water, the most limiting resource for bison in the park. Badlands NP is involved in bison management and research efforts across parks, namely Wind Cave National Park.

5.4.13. Swift Fox

While swift foxes may have been common at one time, populations were reduced in the early 1900’s due to conversion of native prairie to agriculture, incidental take from predator control aimed primarily at coyotes and wolves, and unregulated hunting and trapping. Their historic range coincided with that of black-tailed prairie dogs (*Cynomys ludovicianus*), whose reduced range may also have contributed to declines in swift foxes because of reduced prey availability and changes to habitat quality.

There were no reports of swift foxes in South Dakota from 1914–1966, and there were only occasional reports from 1966–1975. Swift foxes were first confirmed again in South Dakota in the 1970s on the Pine Ridge Reservation. The western half of South Dakota may contain suitable swift fox habitat. The best available information on current swift fox distribution indicates that they are found in only a small portion of suitable habitat in the state.

Swift Fox Condition Summary

Swift foxes are a species of concern in South Dakota, considered threatened by the state and sensitive by the Bureau of Land Management. A population has grown from a reintroduction to Badlands NP in 1987. To assess swift fox condition from 2003–2009, the time period for which we had data, we used the recovery criteria of a self-sustaining population. Growth rate was negative, giving a condition of *Warrants Significant Concern*, confidence in condition was *High*, and trend was *Not Available* (Table 5.1).

Swift Fox Ferret Gaps and Management Issues

Any rigorous data on population parameters, preferably with estimates of associated error, such as abundance, density, occupancy, reproduction, survival, mortality, population growth, or distribution from in and around the park would be informative. Most if not all of these population measures are being studied as part of ongoing research being conducted by the NPS and South Dakota State University.

Swift foxes are often associated with prairie dog colonies, and populations of swift foxes may decline with declines in prairie dogs. Prairie dogs constitute a large proportion of the swift fox diet in South Dakota. Prairie dog colonies attract more species of small mammals and higher densities of prey species. Changes in vegetation structure (i.e., reduced vegetation height) on colonies may also attract swift foxes. Swift fox prefer to den on or near prairie dog colonies. For all of these reasons, prairie dog colonies are important for swift foxes.

In the areas that have a high number of coyotes, swift fox are more likely to den near roads, as coyotes avoid roads. Also, they like grazed areas where they have better visibility from their dens (B. Kenner, personal communication, 12 December 2016).

5.4.14. Bats

Thirteen bat species, of which eight species are fully resident and three are resident in the summer, are known to occur throughout South. Eleven bat species are found in Badlands NP and three of these species are of particular concern to the state, receiving a listing as high priority Species of Greatest Conservation Need in the South Dakota State Wildlife Action Plan. Additional bat species have a Special Species Status for the state, Sensitive Species designation for the region, and/or a federal listing under the Endangered Species Act. At the time of this assessment, two species (little brown myotis and tri-colored bat) were being petitioned for listing under ESA.

Bat Condition Summary

Many bats are at risk and sensitive across large portions of their range; we assessed bat condition at Badlands NP by looking at condition of 11 individual bat species and the presence of an infectious fungus. Overall bat condition was *Warrants Moderate Concern*, though some species are doing well and others at a higher level of concern. Confidence in condition was *Medium*, and trend was *Not Available* (Table 5.1).

Bat Gaps and Management Issues

To detect a change in local bat populations, the most practical approach would be to derive an abundance index from acoustic monitoring (I. Abernethy, personal communication, 26 August 2016). For example, a bat abundance index could be the number of recordings from a species per unit time; repeated annually, this approach could reveal relative changes in bat numbers.

White-nose syndrome (WNS) is one of the greatest threats to bats. Though the disease has not yet appeared in South Dakota, or within 250 miles of the state border, it may appear in the next few years. Managers at Badlands NP have submitted a proposal to conduct environmental tests as well as direct testing of bats for WNS. Additionally, a proposal has been submitted to monitor, now that baseline inventory has been completed. Other key threats to South Dakota bats are insect control programs, mine closures that neglect to mitigate for potential use by bats, and vandalism to roosting sites and hibernacula. Additional threats may be some recreational activities such as rock climbing (and spelunking where caves are present), and wind energy development.

5.4.15. Rocky Mountain Bighorn Sheep

At the time of this assessment, there were four main herds of bighorn sheep in South Dakota, including the herd at Badlands NP, which accounted for roughly a quarter of the total bighorn population in the state. The US Forest Service (USFS) designated Rocky Mountain bighorn sheep a sensitive species for Region 2, which includes Badlands NP. Sensitive species status means that bighorn sheep are emphasized in USFS planning and management activities to ensure their conservation.

There is a limited quota for hunting bighorn sheep in South Dakota, and residents currently harvest 2–5 rams annually from the Black Hills population. The state instituted a cooperative program with landowners in the Black Hills to install fencing meant to reduce disease transmission from domestic to wild sheep.

Rocky Mountain Bighorn Sheep Condition Summary

We assessed condition of bighorn sheep based on population growth rate and population size. While population counts had occurred recently (in 2015), these counts included individuals that had been added to the herd by managers and, therefore, were not appropriate for calculating growth rate. Counts indicated moderate condition. Natural population growth rate data were most recently collected from 1987–1997, and indicated a good condition. Overall condition was *Resource in Good Condition*, confidence in condition was *Low,* and trend was *Improving* (Table 5.1).

Rocky Mountain Bighorn Sheep Gaps and Management Issues

Any rigorous data on population parameters, preferably with estimates of associated error, such as abundance, density, occupancy, reproduction, survival, mortality, population growth, or distribution from in and around the park would be informative. Ongoing studies of collared animals in and around Badlands NP can begin to fill these gaps in population data.

Although the Badlands bighorn herd is currently considered free of disease NPS has funded a bighorn disease study starting in 2016. The goals of the project are to gather baseline data on potential disease exposure, identify disease pathogens that could be in the resident population, and collect demographic data to assess population viability. Biologists also plan to examine survival and reproduction, movements, and the presence of livestock around the park.

5.4.16. Bobcat

In the 1960s, some data indicated that bobcat populations were declining in the western United States, but more recent evidence suggests that bobcat have been increasing throughout their native range. National Park Service lands are important reference and monitoring sites for animal populations, and the NPS is dedicated to protecting bobcat and their habitat.

Bobcat Condition Summary

Bobcat are hunted as a furbearer species in South Dakota, but recent population trends in the western part of the state indicate an increase in population sizes. Data were unavailable within Badlands NP, where hunting is not allowed, but population data from a nearby study area were extrapolated to western South Dakota and indicated an increase in bobcat numbers. Bobcat are protected in Badlands NP and, though hunting pressure could affect individuals near the park boundaries, the population in the park is likely to be doing as well as that in greater western South Dakota. Condition was *Resource in Good Condition*, confidence in condition was *Low*, and trend was *Improving* (Table 5.1).

Bobcat Gaps and Management Issues

Any rigorous data on population parameters, preferably with estimates of associated error, such as abundance, density, occupancy, reproduction, survival, mortality, population growth, or distribution from in and around the park would be informative. Ongoing studies of collared animals in and around Badlands NP can begin to fill these gaps in population data.

Bobcat are a furbearer species that are hunted in South Dakota, and pelts are financially valuable. Harvest pressure around the edge of the park could affect the population in Badlands NP. Bobcat diet is typically dominated by lagomorphs but bobcat will take other small mammals, and prairie dogs may be an important component of winter diet in Badlands NP. Plague has caused declines in prairie dogs, which may reduce prey availability. Additionally, bobcat are susceptible to plague and may be affected directly.

5.4.17. Mule Deer

The Great Plains ecoregion is the easternmost portion of mule deer range, comprising shrub steppe and mixed- or shortgrass prairie. Deer populations nearly went extinct within the region by the 1900s, following heavy consumption during exploration in the 1800s, but are now common in the Great Plains. South Dakota deer populations were high in the mid-2000s, but at the time of this assessment population numbers were below management goals for most herd units.

Mule Deer Condition Summary

Mule deer condition depended on population growth rate and population size. Statewide, mule deer have been declining, with some evidence for increases from 2014–2016. Mule deer survival monitoring began in Badlands NP in 2015, and only very few data were available at the time of this assessment. Growth rate was positive so condition was *Resource in Good Condition*, but data were sparse so confidence in condition was *Low*, and trend was *Not Available* (Table 5.1).

Mule Deer Gaps and Management Issues

Any rigorous data on population parameters, preferably with estimates of associated error, such as abundance, density, occupancy, reproduction, survival, mortality, population growth, or distribution from in and around the park would be informative. Ongoing studies of collared animals in and around Badlands NP can begin to fill these gaps in population data. While chronic wasting disease has not officially been detected within any of the herds found within Badlands NP, but it has been detected in Pennington County, within which the majority of the north unit of Badlands NP is situated.

5.4.18. Herpetofauna

Thirty reptile species and 15 amphibian species are known to occur throughout South Dakota, of which eight amphibians and 12 reptiles were suspected or confirmed to occur in Badlands NP. At the time of this assessment, two of these species were of particular concern to the state, receiving a listing as high priority Species of Greatest Conservation Need in the South Dakota State Wildlife Action Plan. Additional species had special conservation status from USDI Bureau of Land Management, at the state level, and within the Rocky Mountain Region (Region 2) of the USDA Forest Service.

Herpetofauna Condition Summary

Twelve reptiles and eight amphibians occur or are suspected to occur in Badlands NP. We assessed herpetofauna condition at Badlands NP by looking at condition of individual reptile and amphibian species and the presence of an infectious disease. Overall herpetofauna condition was of moderate concern, though more quantitative data would allow a more complete assessment. Reptiles and amphibians are imperiled internationally, and their condition is of concern to conservationists internationally. Overall condition was *Warrants Moderate Concern*, confidence in condition was *Low*, and trend was *Not Available* (Table 5.1).

Herpetofauna Gaps and Management Issues

An updated comprehensive survey of all herpetofauna present in the park would be an important step to understanding condition of herpetofauna in Badlands NP. Additionally, repeated monitoring is critical to understanding if populations are changing within the park. Sampling for chytrid fungus within the park would elucidate how prevalent the disease really is in park populations.

5.4.19. Pollinators

Invertebrate pollinators in South Dakota include native insects and honey bees, all of which have varying food and habitat needs. Badlands NP is home to a total of 69 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 butterflies also present were two-tailed swallowtails (*Papilio multicaudata*) and Melissa blue butterflies (*Plebejus melissa*). While bumble bees (*Bombus* sp.) and other invertebrate pollinators are likely present in Badlands NP, 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).

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 Badlands NP. 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 Badlands NP 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. Damage to pollinators likely has negative consequences for bird populations in the park.

5.5. Literature Cited

National Park Service and Oglala Sioux Tribe Parks and Recreation Authority (NPS and OSPRA). 2012. South Unit, Badlands National Park, final general management plan and environmental impact statement. US Department of the Interior and Oglala Sioux Tribe.

Tronstad, L. 2015. Aquatic invertebrate monitoring at Agate Fossil Beds National Monument: 2014 annual report. Department of the Interior, National Park Service, Fort Collins, Colorado, USA.

Wilson, M. H., B. L. Rowe, R. A. Gitzen, S. K. Wilson, and K. J. Painter-Green. 2014. Water Quality Monitoring Protocol for Wadeable Streams and Rivers in the Northern Great Plains Network. Page 122. Natural Resources Report, National Park Service.

Appendix A. Viewshed details and figures for each vantage point included in the assessment.

Table A1. Digital viewshed analyses were completed for each of the 15 following vantage points, but modified Visual Resource Inventories were only completed for the points designated with asterisks (*).

Vantage Point	Location	Figure
*BADL Vantage 1 (Big Badlands Overlook)	43.785674, -101.901185	A1
*BADL Vantage 2 (Cliff Shelf Trail)	43.750795, -101.931493	A2
BADL Vantage 3	43.760954, -101.973505	A3
BADL Vantage 4	43.789013, -102.033218	A4
BADL Vantage 5	43.795493, -102.060665	A5
BADL Vantage 6	43.821861, -102.175787	A6
BADL Vantage 7 (Ancient Hunters Overlook)	43.865909, -102.226993	A7
BADL Vantage 8	43.869238, -102.234355	A8
BADL Vantage 9	43.884283, -102.238825	A9
BADL Vantage 10	43.875541, -102.256019	A10
BADL Vantage 11	43.905179, -102.307032	A11
BADL Vantage 12	43.803663, -102.136654	A12
BADL Vantage 13	43.511441, -102.496475	A13
BADL Vantage 14	43.701805, -102.580399	A14
BADL Vantage 15	43.559287, -102.886428	A15

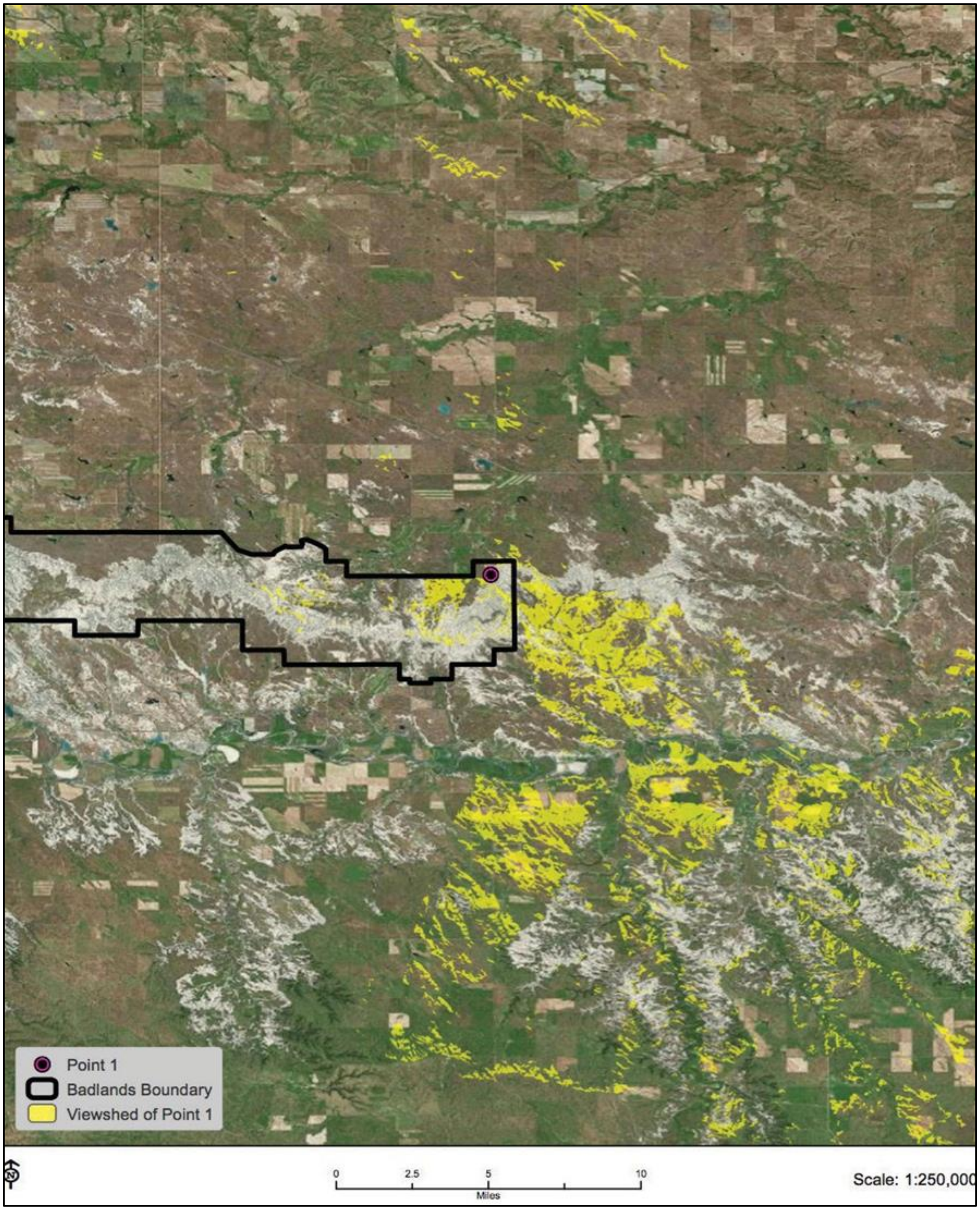

Figure A1. Viewshed for vantage point 1 in Badlands National Park.

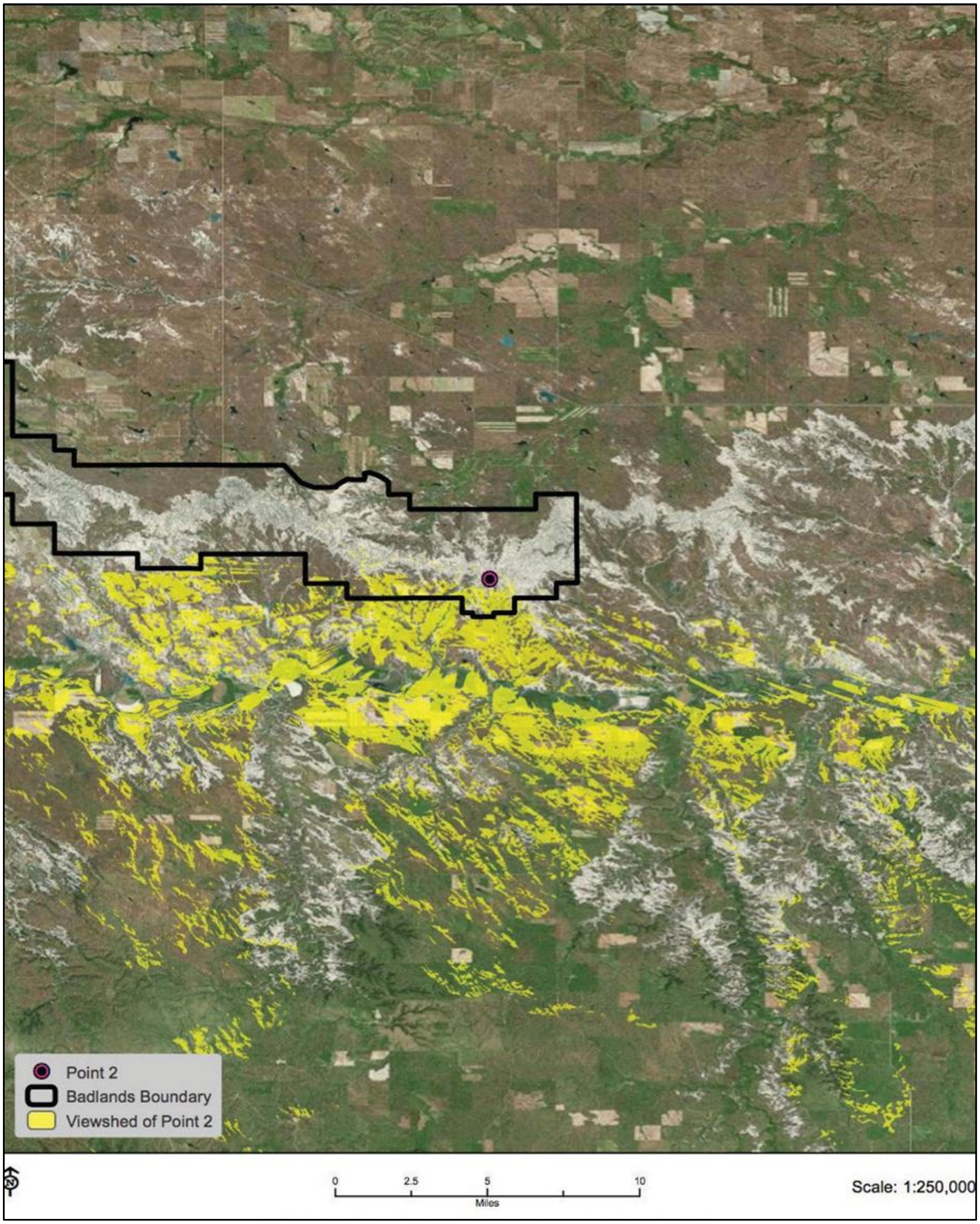

Figure A2. Viewshed for vantage point 2 in Badlands National Park.

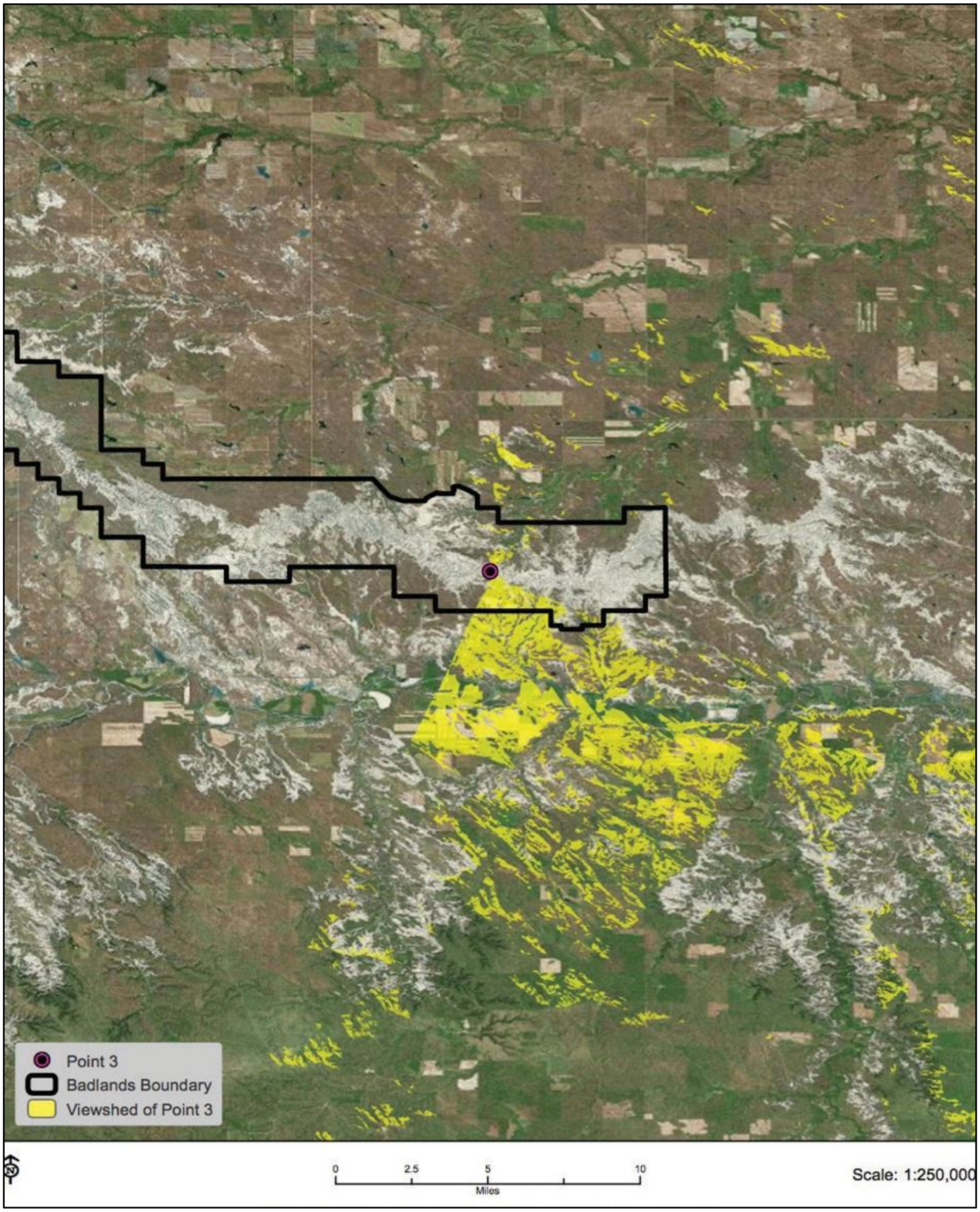

Figure A3. Viewshed for vantage point 3 in Badlands National Park.

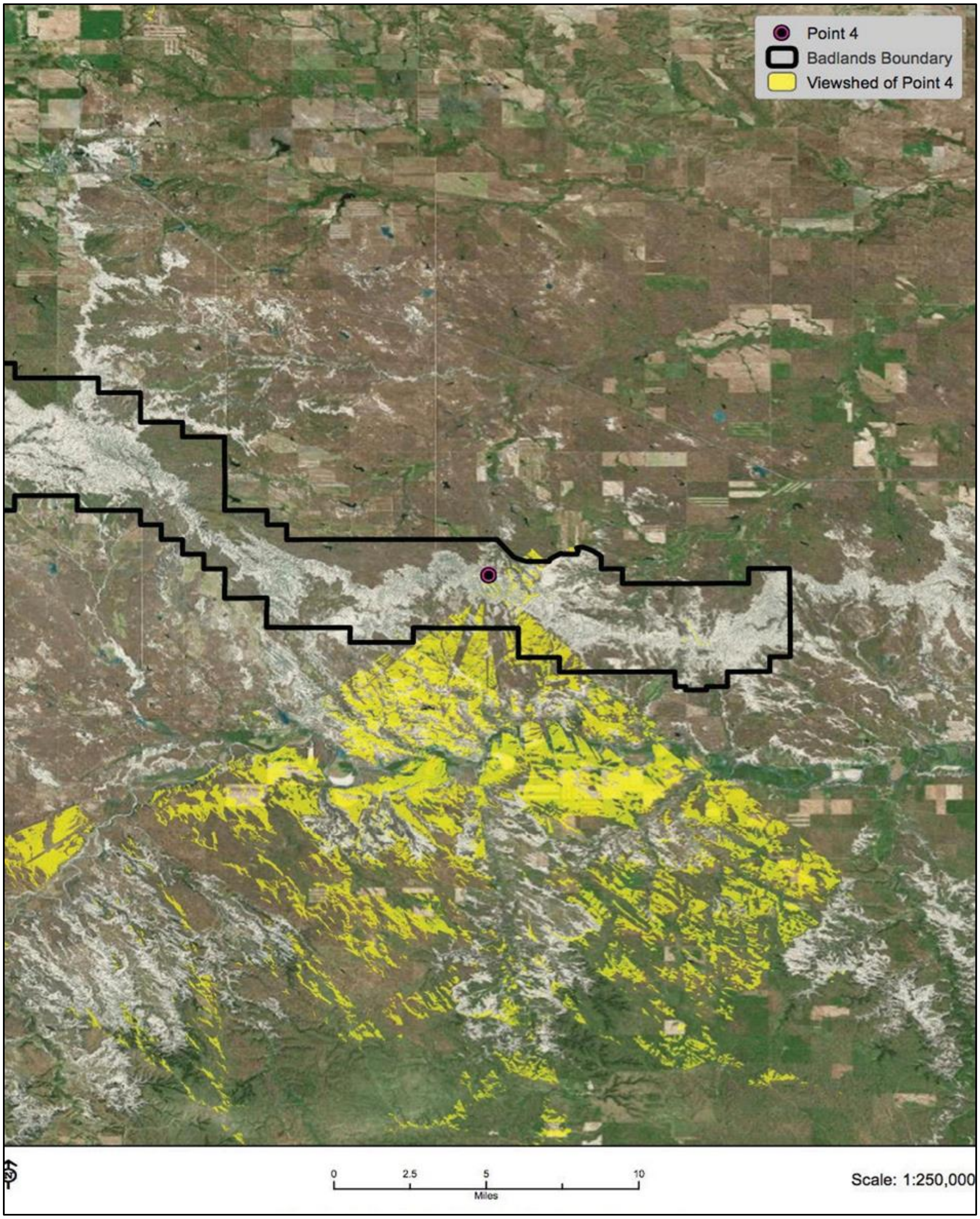

Figure A4. Viewshed for vantage point 4 in Scotts Bluff NM.

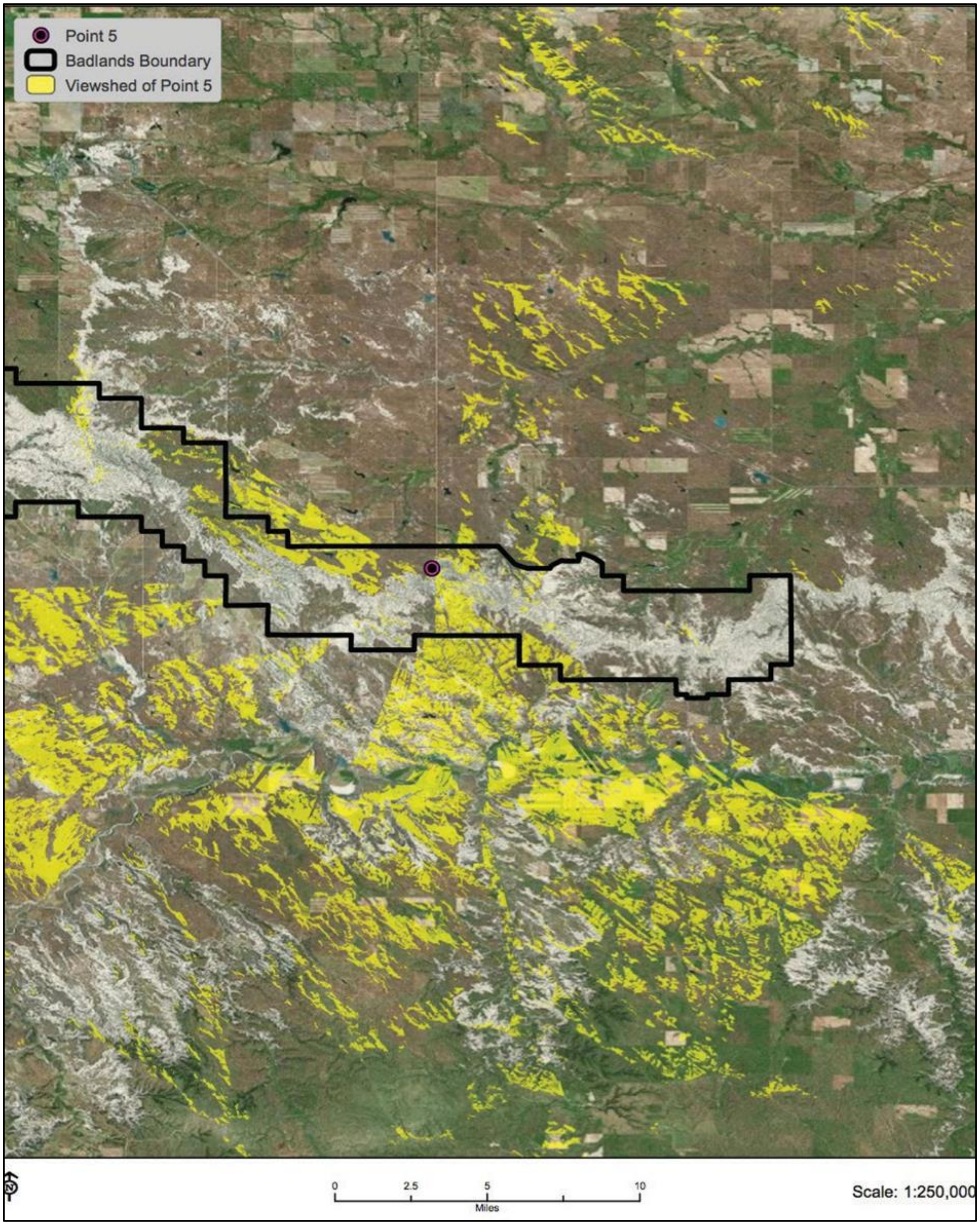

Figure A5. Viewshed for vantage point 5 in Badlands National Park.

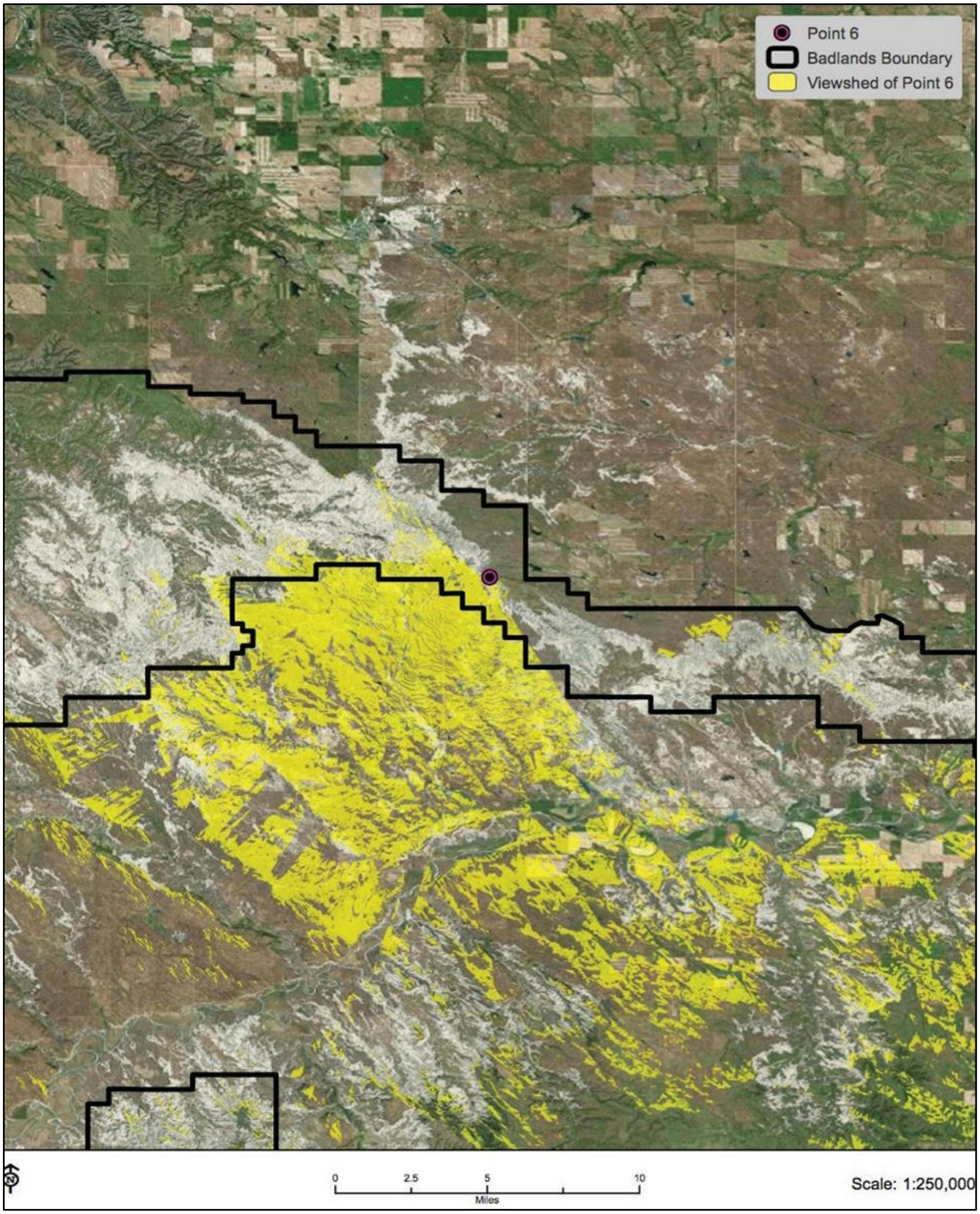

Figure A6. Viewshed for vantage point 6 in Badlands National Park.

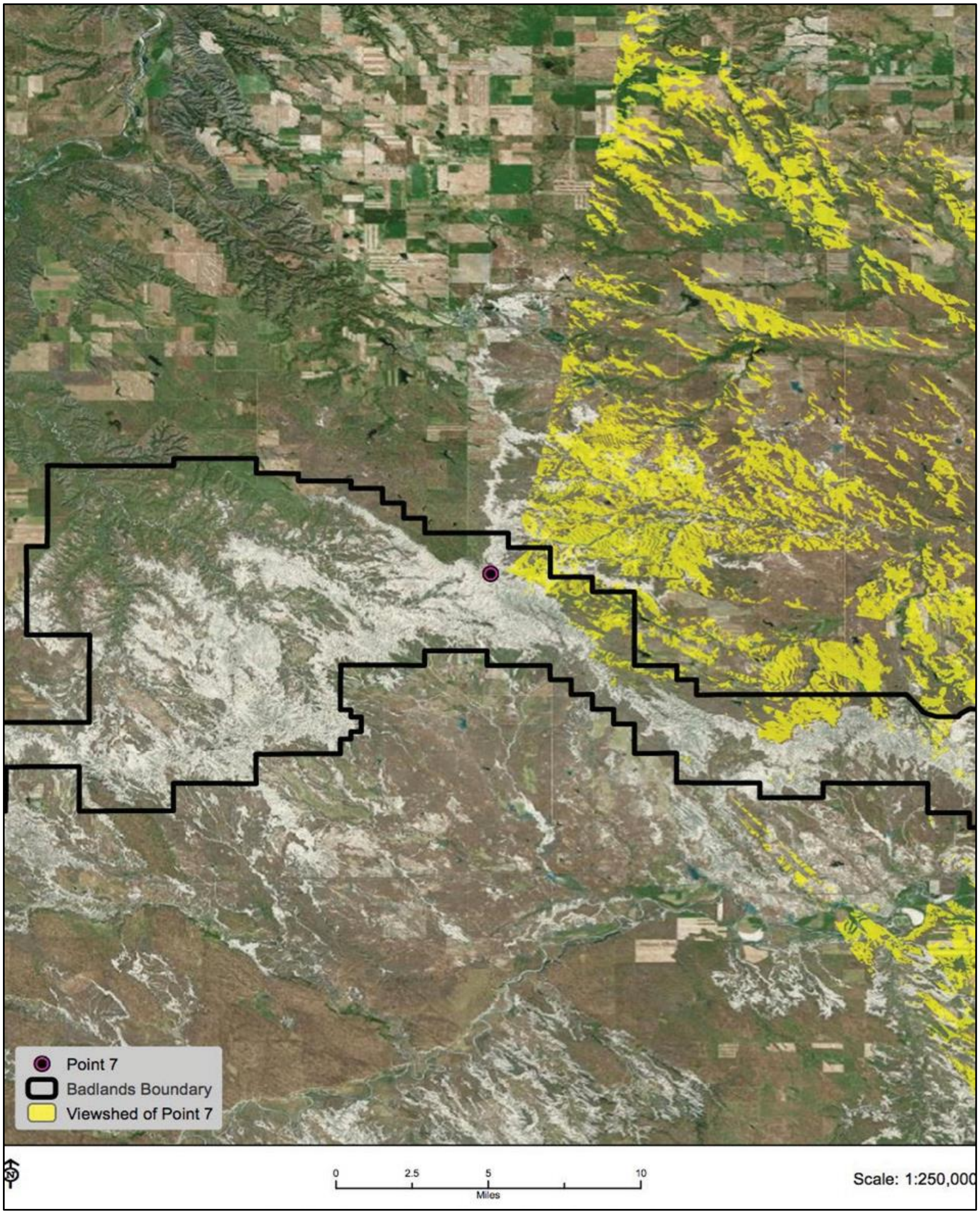

Figure A7. Viewshed for vantage point 7 in Badlands National Park.

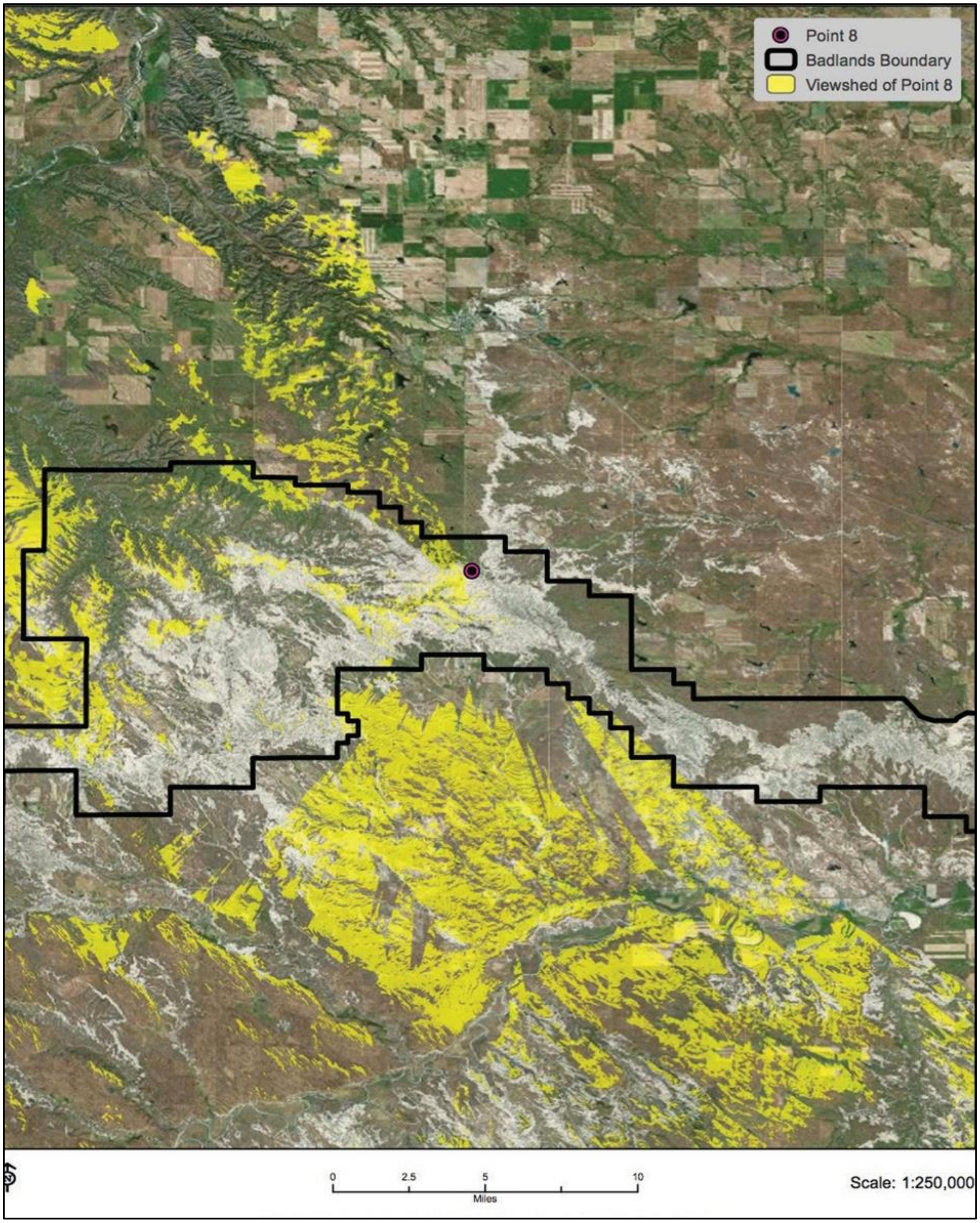

Figure A8. Viewshed for vantage point 8 in Badlands National Park.

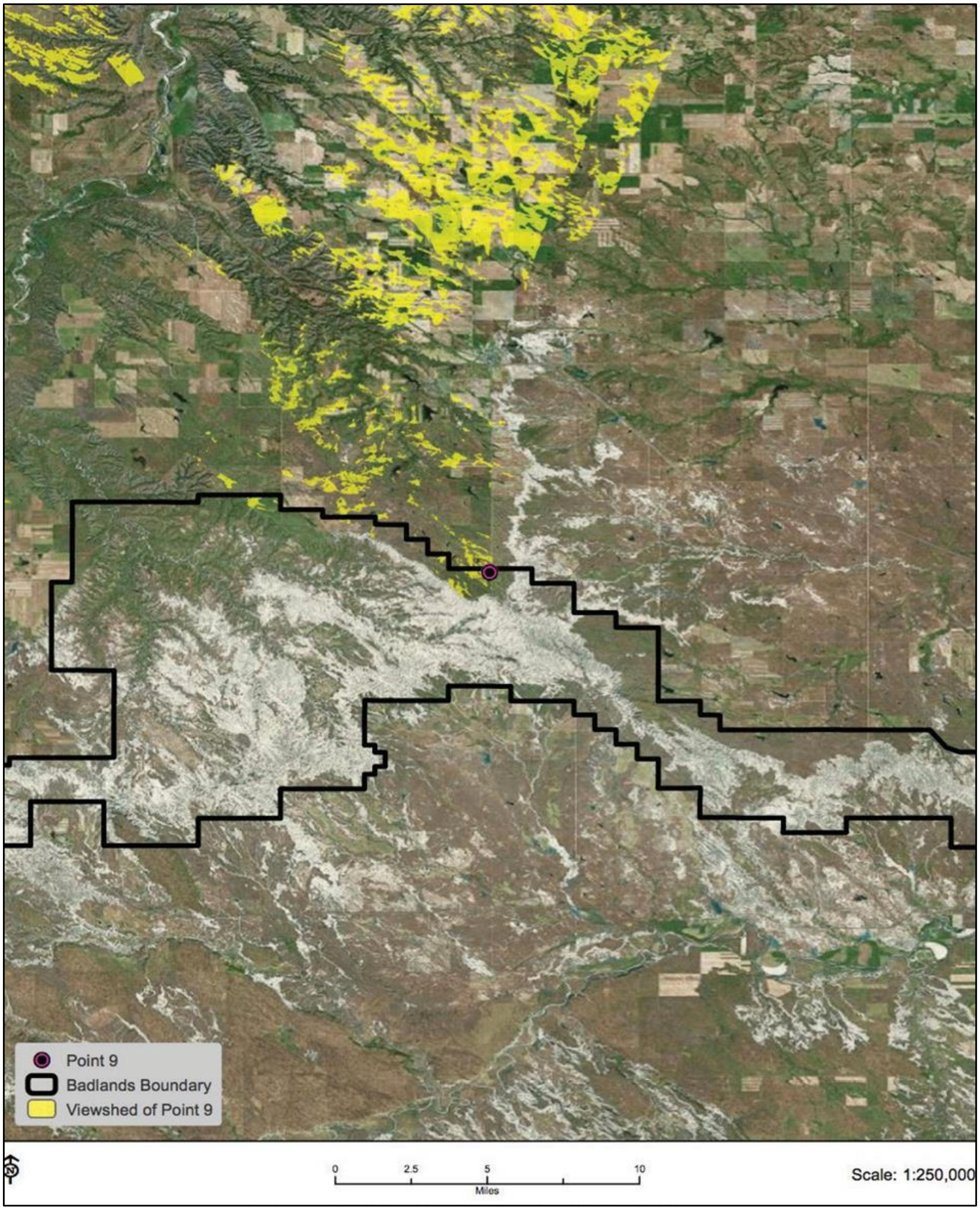

Figure A9. Viewshed for vantage point 9 in Badlands National Park.

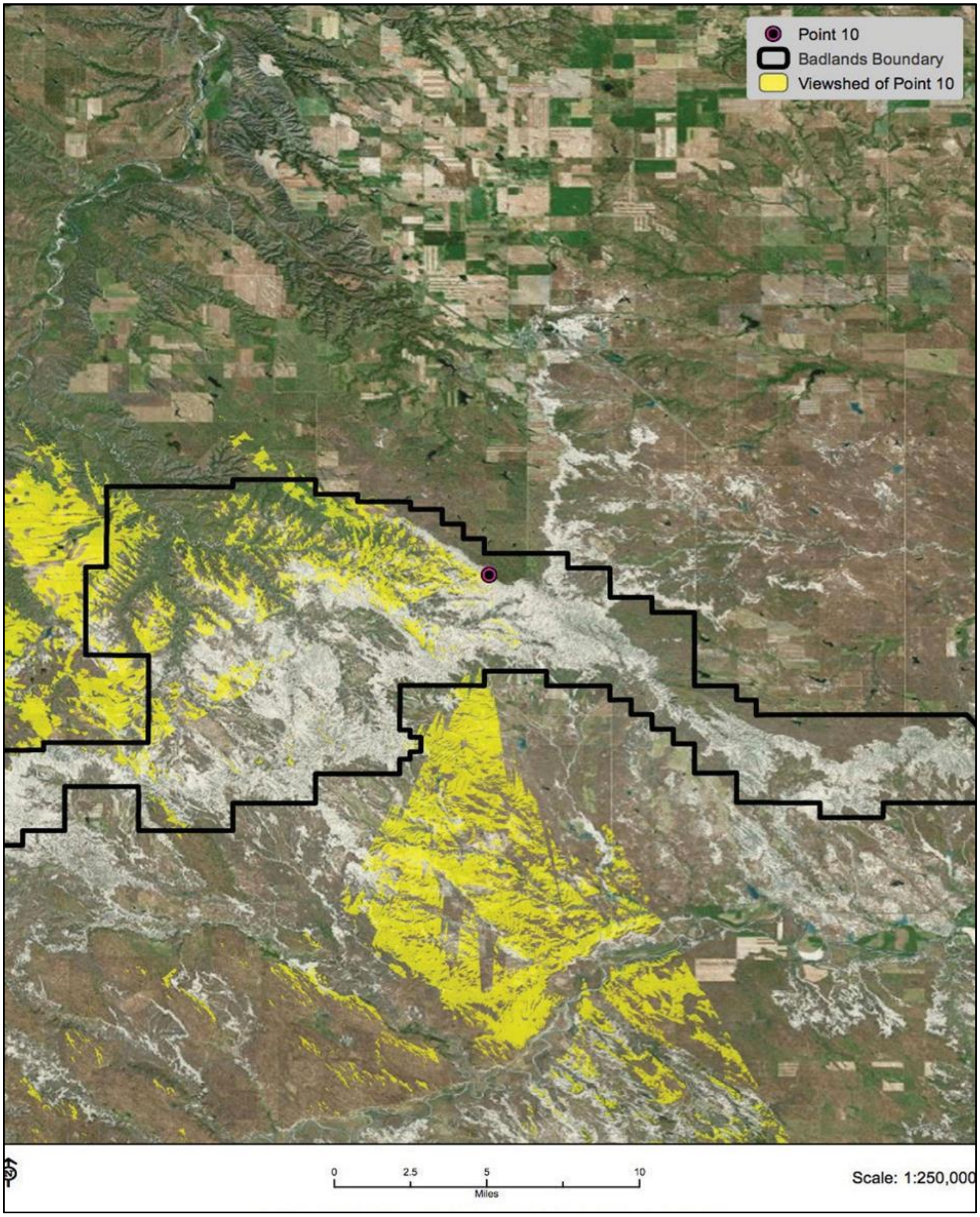

Figure A10. Viewshed for vantage point 10 in Badlands National Park.

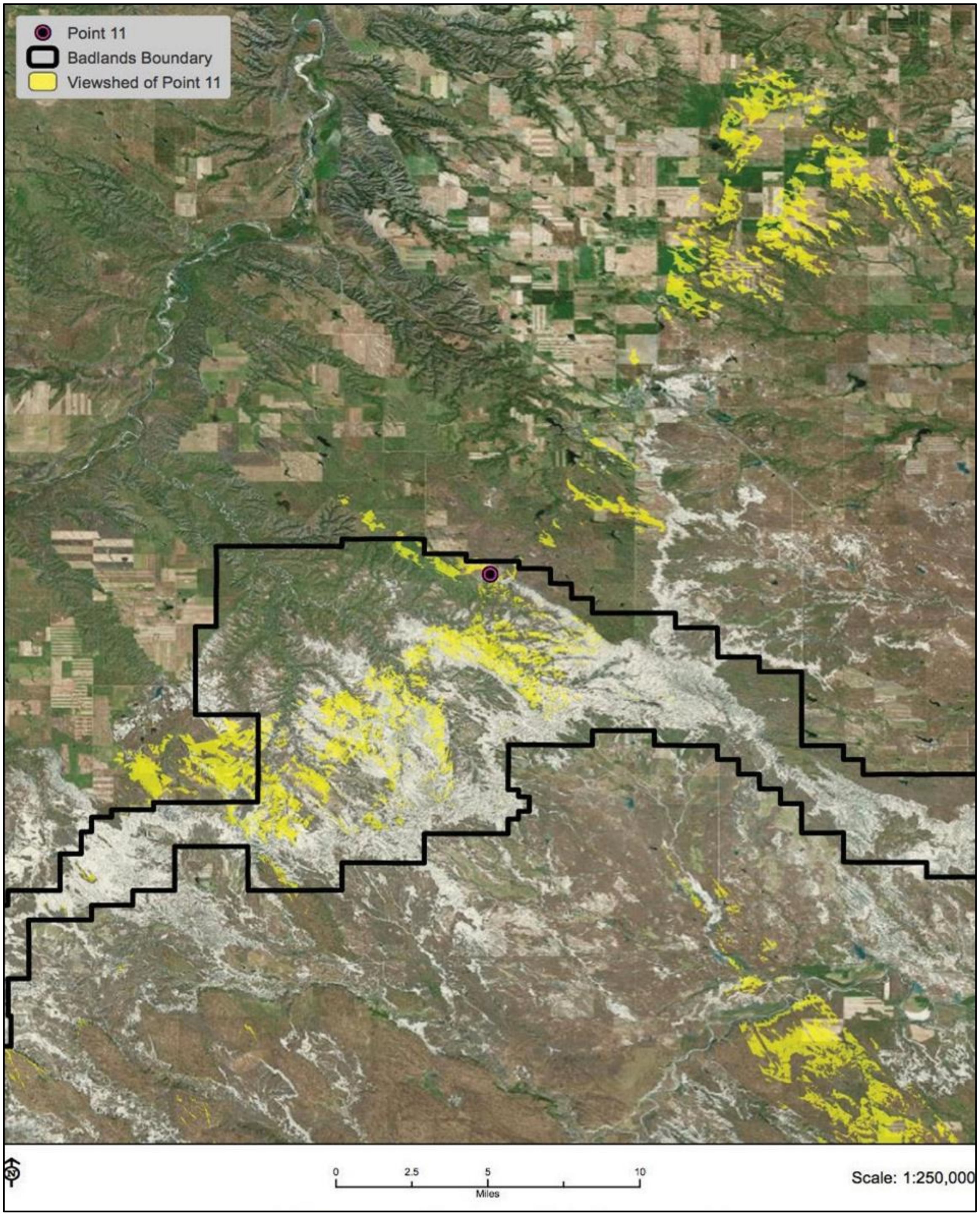

Figure A11. Viewshed for vantage point 11 in Badlands National Park.

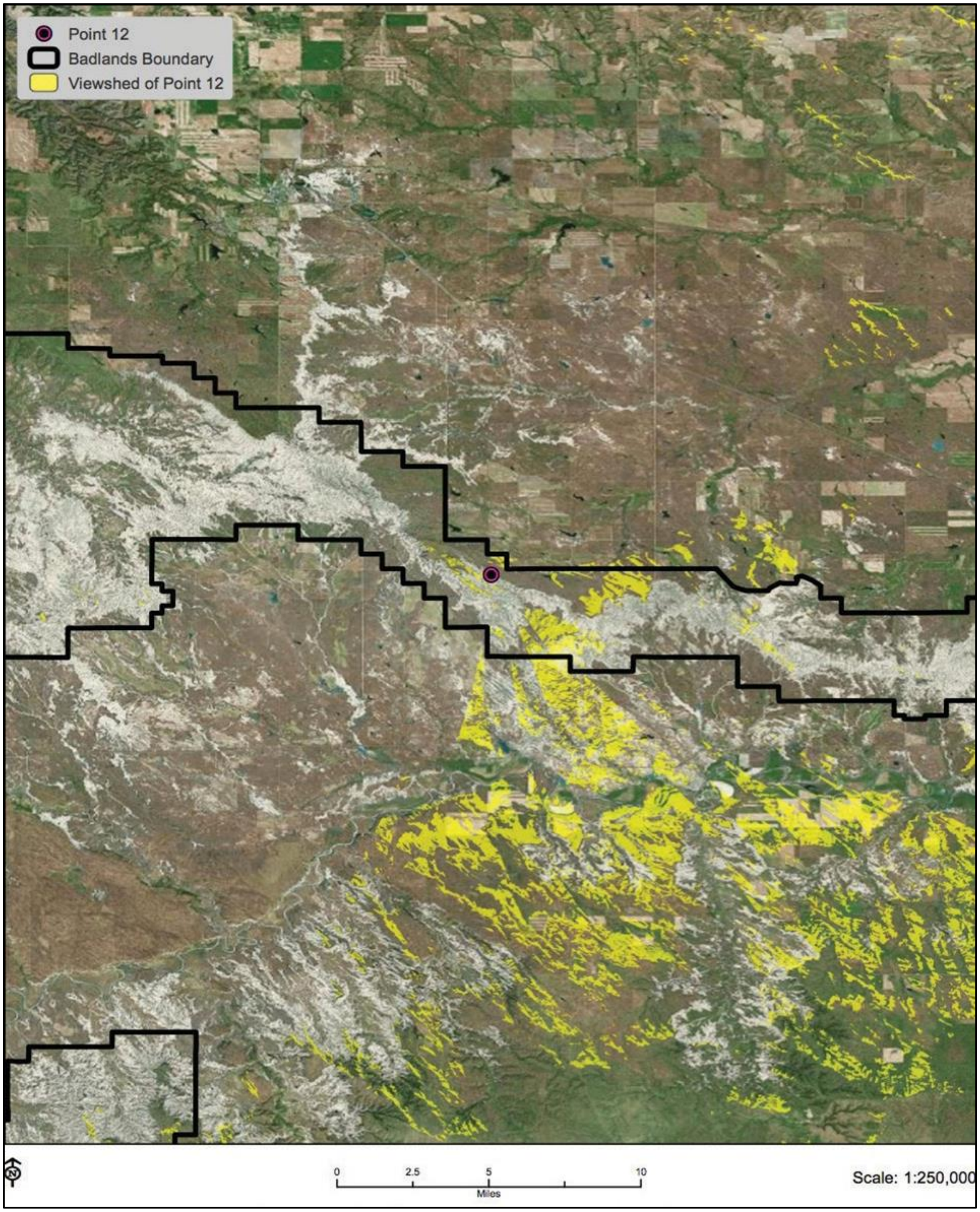

Figure A12. Viewshed for vantage point 12 in Badlands National Park.

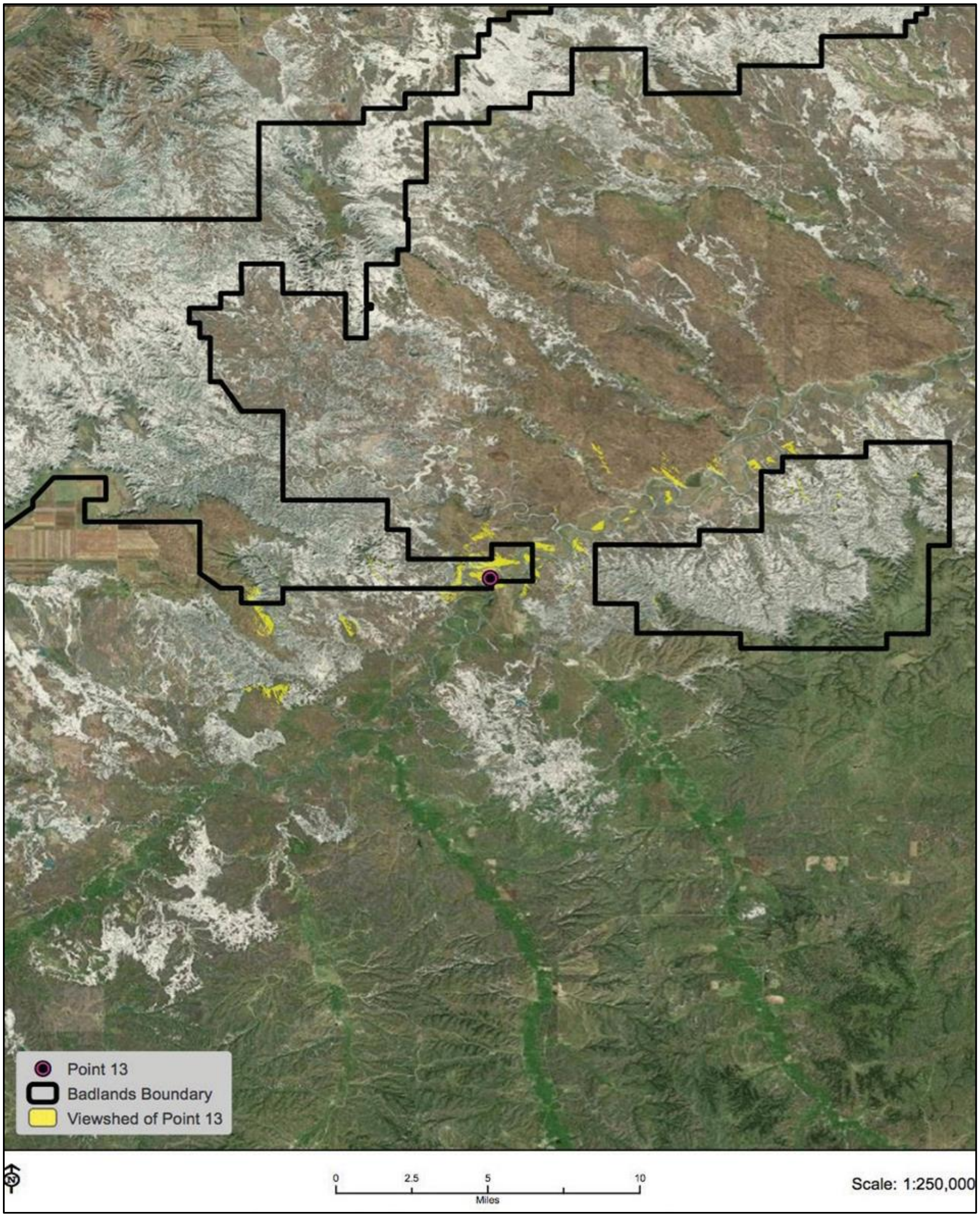

Figure A13. Viewshed for vantage point 13 in Badlands National Park.

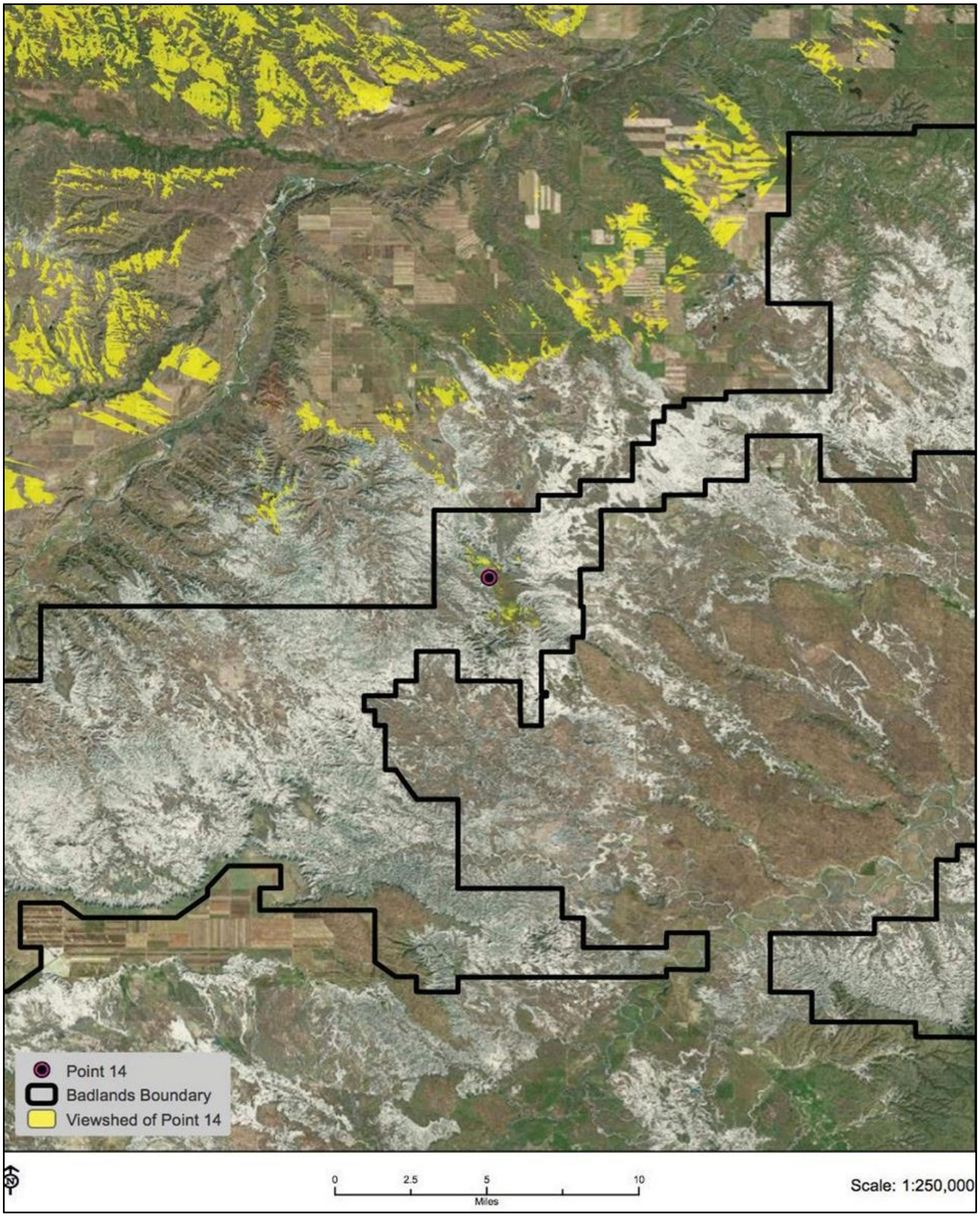

Figure A14. Viewshed for vantage point 14 in Badlands National Park.

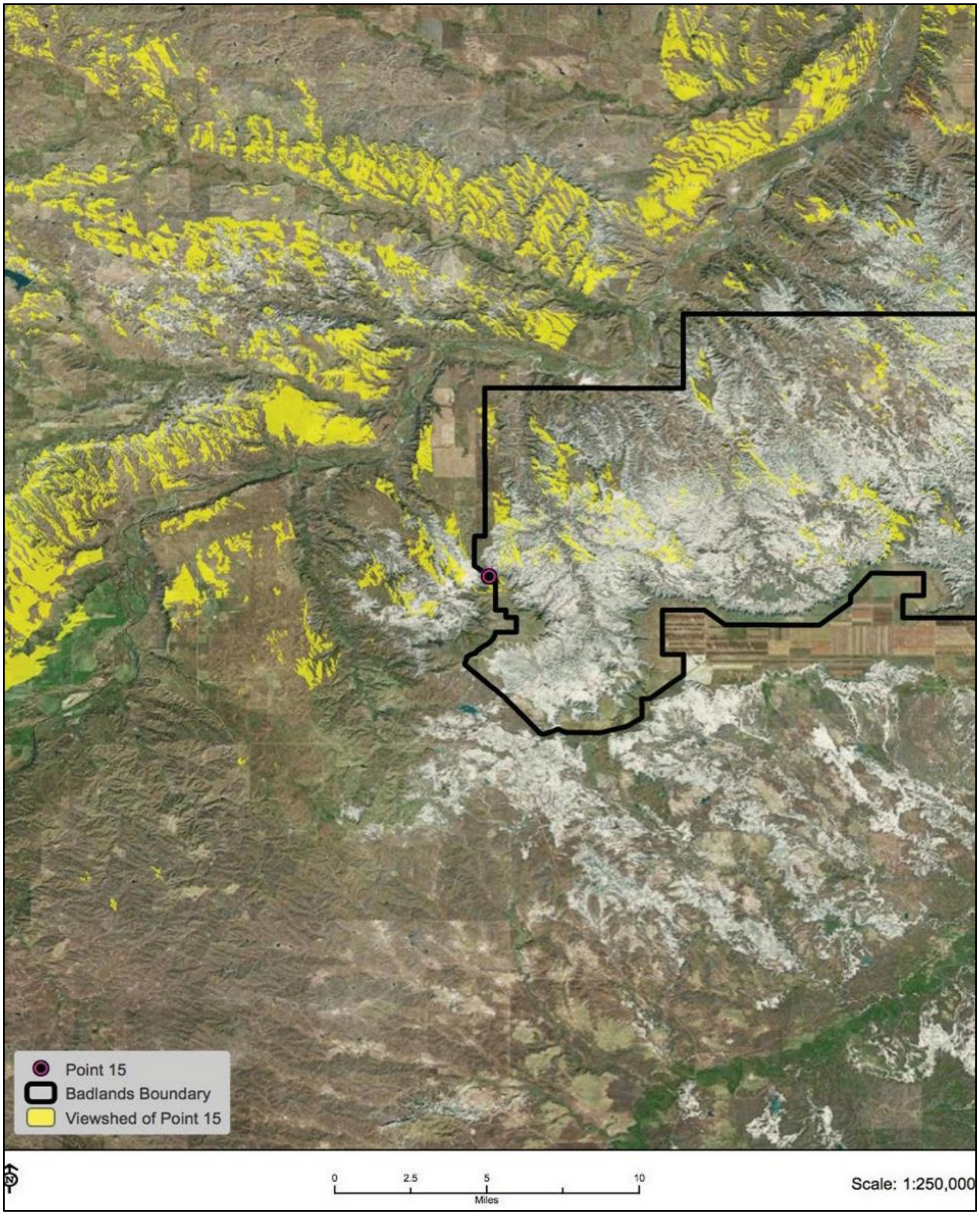

Figure A15. Viewshed for vantage point 15 in Badlands National Park.

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 meter 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 land-cover 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. Determine percentage of viewshed area that overlaps given landcover class at predefined distances from vantage points.

Determining the Percentage of Viewshed Area that Overlaps Given Landcover Class at Predefined Distances from Vantage Points

1. Create buffer zones of 0-0.5 miles, 0.5-3 miles 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 land-cover 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 BADL.

Family	Code	Scientific Name	Common Name	Exotic	Rare
Agavaceae	YUGL	*Yucca glauca*	soapweed yucca	No	No
Alismataceae	SALA2	*Sagittaria latifolia*	broadleaf arrowhead	No	No
Amaranthaceae	AMAL	*Amaranthus albus*	prostrate pigweed	Yes	No
	AMBL	*Amaranthus blitoides*	mat amaranth	Yes	No
	AMRE	*Amaranthus retroflexus*	redroot pigweed	No	No
Anacardiaceae	RHAR4	*Rhus aromatic*	fragrant sumac	No	No
	RHTR	*Rhus trilobata*	skunkbush sumac	No	No
	TORA2	*Toxicodendron radicans*	eastern poison ivy	No	No
	TORY	*Toxicodendron rydbergii*	western poison ivy	No	No
Apiaceae	LOFO	*Lomatium foeniculaceum*	desert biscuitroot	No	No
	LOMA3	*Lomatium macrocarpum*	bigseed biscuitroot	No	No
	LOMAT	*Lomatium* spp.	biscuitroot	No	No
	MUSIN	*Musineon* spp.	wildparsley	No	No
	MUDI	*Musineon divaricatum*	leafy wildparsley	No	No
	OSLO	*Osmorhiza longistylis*	longstyle sweetroot	No	No
Asclepiadaceae	ASPU	*Asclepias pumila*	plains milkweed	No	No
	ASSP	*Asclepias speciosa*	showy milkweed	No	No
	ASVE	*Asclepias verticillata*	whorled milkweed	No	No
	ASVI	*Asclepias viridiflora*	green comet milkweed	No	No
Asteraceae	ACMI2	*Achillea millefolium*	common yarrow	No	No
	AGGL	*Agoseris glauca*	pale agoseris	No	No
	AMAR2	*Ambrosia artemisiifolia*	common ragweed	No	No
	AMBRO	*Ambrosia* spp.	ragweed	Yes	No
	AMPS	*Ambrosia psilostachya*	cuman ragweed	No	No
	AMTR	*Ambrosia trifida*	great ragweed	No	No
	ANMI3	*Antennaria microphylla*	littleleaf pussytoes	No	No
	ANPA4	*Antennaria parvifolia*	small-leaf pussytoes	No	No
	ARCA12	*Artemisia campestris*	field sagewort	No	No
	ARCA13	*Artemisia cana*	silver sagebrush	No	No
	ARDR4	*Artemisia dracunculus*	tarragon	No	No
	ARFR4	*Artemisia frigida*	fringed sagewort	No	No
	ARLO7	*Artemisia longifolia*	longleaf sagebrush	No	No
	ARLU	*Artemisia ludoviciana*	white sagebrush	No	No
	ASTER	*Aster* spp.	aster	No	No
	BREU	*Brickellia eupatorioides*	false boneset	No	No
	CANU4	*Carduus nutans*	Nodding thistle	Yes	No

Family	Code	Scientific Name	Common Name	Exotic	Rare
	CIAR4	*Cirsium arvense*	Canada thistle	Yes	No
	CICA11	*Cirsium canescens*	prairie thistle	Yes	No
	CIFL	*Cirsium flodmanii*	Flodman's thistle		No
	CIRSI	*Cirsium* spp.	thistle	Yes	No
	CIUN	*Cirsium undulatum*	wavyleaf thistle	No	No
	COCA5	*Conyza canadensis*	horseweed	No	No
	CORA4	*Conyza ramosissima*	dwarf horseweed	No	No
	CROC	*Crepis occidentalis*	largeflower hawksbeard	No	No
	DIPR2	*Diaperia prolifera*	bighead pygmycudweed	No	No
	DYPA	*Dyssodia papposa*	fetid marigold	No	No
	ECAN2	*Echinacea angustifolia*	blacksamson echinacea	No	No
	ERCA4	*Erigeron canus*	hoary fleabane	No	No
	ERIGE2	*Erigeron* spp.	fleabane	No	No
	ERNA10	*Ericameria nauseosa*	rubber rabbitbrush	No	No
	ERPU2	*Erigeron pumilus*	shaggy fleabane	No	No
	ERST3	*Erigeron strigosus*	prairie fleabane	No	No
	ERSU2	*Erigeron subtrinervis*	threenerve fleabane	No	No
	GRSQ	*Grindelia squarrosa*	curlycup gumweed	No	No
	GUSA2	*Gutierrezia sarothrae*	broom snakeweed	No	No
	HEAN3	*Helianthus annuus*	common sunflower	No	No
	HELIA3	*Helianthus* spp.	sunflower	Yes	No
	HEMA2	*Helianthus maximiliani*	Maximilian sunflower	No	No
	HEPA19	*Helianthus pauciflorus*	stiff sunflower	No	No
	HEPE	*Helianthus petiolaris*	prairie sunflower	No	No
	HEVI4	*Heterotheca villosa*	hairy false goldenaster	No	No
	IVAX	*Iva axillaris*	povertyweed	No	No
	LASE	*Lactuca serriola*	prickly lettuce	Yes	No
	LIPU	*Liatris punctata*	dotted blazing star	No	No
	LOAR5	*Logfia arvensis*	field cottonrose	No	No
	LYJU	*Lygodesmia juncea*	rush skeletonplant	No	No
	MUOB99	*Mulgedium oblongifolium*	blue lettuce	No	No
	NOCU	*Nothocalais cuspidata*	prairie false dandelion	No	No
	OLRI	*Oligoneuron rigidum*	stiff goldenrod	No	No
	PACA15	*Packera cana*	woolly groundsel	No	No
	PAPL12	*Packera plattensis*	prairie groundsel	No	No
	RACO3	*Ratibida columnifera*	upright prairie coneflower	No	No
	SEIN2	*Senecio integerrimus*	lambstongue ragwort	No	No
	SOLID	*Solidago* spp.	Goldenrod	No	No

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	SOMI2	*Solidago missouriensis*	Missouri goldenrod	No	No
	SOMO	*Solidago mollis*	velvety goldenrod	No	No
	SONE	*Solidago nemoralis*	gray goldenrod	No	No
	SYER	*Symphyotrichum ericoides*	white heath aster	No	No
	SYFA	*Symphyotrichum falcatum*	white prairie aster	No	No
	SYLA3	*Symphyotrichum laeve*	smooth blue aster	No	No
	SYMPH4	*Symphyotrichum*	Aster	No	No
	SYOB	*Symphyotrichum oblongifolium*	aromatic aster	No	No
	TAOF	*Taraxacum officinale*	common dandelion	Yes	No
	TEAC	*Tetraneuris acaulis*	stemless four-nerve daisy	No	No
	TRDU	*Tragopogon dubius*	yellow salsify	Yes	No
	XASP99	*Xanthisma spinulosum*	lacy tansyaster	No	No
	XAST	*Xanthium strumarium*	cocklebur	No	No
	SORI2	*Solidago rigida*	stiff goldenrod	No	No
Boraginaceae	CRCE	*Cryptantha celosioides*	buttecandle	No	No
	CRMI5	*Cryptantha minima*	little cryptantha	No	No
	CRTH	*Cryptantha thyrsiflora*	calcareous cryptantha	No	No
	LACE	*Lappula cenchrusoides*	Great Plains stickseed	No	No
	LAOC3	*Lappula occidentalis*	flatspine stickseed	No	No
	LAPPU	*Lappula* spp.	stickseed	Yes	No
	LASQ	*Lappula squarrosa*	European stickseed	Yes	No
	LIIN2	*Lithospermum incisum*	narrowleaf stoneseed	No	No
	MELA3	*Mertensia lanceolata*	prairie bluebells	No	No
Brassicaceae	ALDE	*Alyssum desertorum*	desert madwort	Yes	No
	ALSI8	*Alyssum simplex*	alyssum	Yes	No
	ARABI	*Arabidopsis* spp.	rockcress	Yes	No
	ARABI2	*Arabis* spp.	rockcress	No	No
	ARGL	*Arabis glabra*	tower rockcress	No	No
	ARHI	*Arabis hirsuta*	hairy rockcress	No	No
	ALPA7	*Alyssum parviflorum*	alyssum	Yes	No
	BOHO99	*Boechera holboellii*	Holboell's rockcress	No	No
	CABU2	*Capsella bursa-pastoris*	shepherd's purse	Yes	No
	CAMI2	*Camelina microcarpa*	littlepod false flax	Yes	No
	CHTE2	*Chorispora tenella*	blue mustard	Yes	No
	COOR	*Conringia orientalis*	hare's ear mustard	Yes	No
	DEPI	*Descurainia pinnata*	western tansymustard	No	No
	DESO2	*Descurainia sophia*	herb sophia	Yes	No
	DRNE	*Draba nemorosa*	woodland draba	No	No

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	DRRE2	*Draba reptans*	Carolina draba	No	No
	ERCA14	*Erysimum capitatum*	sanddune wallflower	No	No
	ERCH9	*Erysimum cheiranthoides*	wormseed wallflower	No	No
	ERIN7	*Erysimum inconspicuum*	shy wallflower	No	No
	ERRE4	*Erysimum repandum*	spreading wallflower	Yes	No
	ERAS2	*Erysimum asperum*	western wallflower	No	No
	LEDE	*Lepidium densiflorum*	common pepperweed	No	No
	LEPID	*Lepidium* spp.	pepperweed	Yes	No
	PHLU99	*Physaria ludoviciana*	foothill bladderpod	No	No
	SIAL2	*Sisymbrium altissimum*	tall tumblemustard	Yes	No
	STAF99	*Strigosella africana*	African mustard	Yes	No
	TUGL	*Turritis glabra*	tower rockcress	Yes	No
	THAR5	*Thlaspi arvense*	field pennycress	Yes	No
Cactaceae	ESMI3	*Escobaria missouriensis*	Missouri foxtail cactus	No	No
	ESMI3	*Escobaria missouriensis*	Missouri foxtail cactus	No	No
	OPFR	*Opuntia fragilis*	brittle pricklypear	No	No
	OPHU	*Opuntia humifusa*	devil's-tongue	No	No
	OPMA2	*Opuntia macrorhiza*	twistspine pricklypear	No	No
	OPPO	*Opuntia polyacantha*	plains pricklypear	No	No
	OPUNT	*Opuntia* spp.	pricklypear	No	No
Campanulaceae	TRLE3	*Triodanis leptocarpa*	slimpod Venus' looking-glass	No	No
	TRPE4	*Triodanis perfoliata*	clasping Venus' looking- glass	No	No
Caprifoliaceae	SYOC	*Symphoricarpos occidentalis*	western snowberry	No	No
Caryophyllaceae	CEAR4	*Cerastium arvense*	field chickweed	No	No
	CEFO2	*Cerastium fontanum*	common mouse-ear chickweed	Yes	No
	PASE	*Paronychia sessiliflora*	creeping nailwort	No	No
	SIAN2	*Silene antirrhina*	sleepy silene	No	No
	SILEN	*Silene* spp.	catchfly	Yes	No
Chenopodiaceae	ATAR2	*Atriplex argentea*	silverscale saltbush	No	No
	ATCA2	*Atriplex canescens*	fourwing saltbush	No	No
	ATSU	*Atriplex suckleyi*	Suckley's endolepis	No	No
	CHAL7	*Chenopodium album*	lambsquarters	Yes	No
	CHDE	*Chenopodium desiccatum*	aridland goosefoot	No	No
	CHENO	*Chenopodium* spp.	goosefoot	Yes	No
	CHFR3	*Chenopodium fremontii*	Fremont's goosefoot	No	No
	CHPR5	*Chenopodium pratericola*	desert goosefoot	No	No

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	CHSI2	*Chenopodium simplex*	mapleleaf goosefoot	No	No
	HAGL	*Halogeton glomeratus*	saltlover	Yes	No
	KOSC	*Kochia scoparia*	burningbush, kochia	Yes	No
	KRLA2	*Krascheninnikovia lanata*	winterfat	No	No
	MONU	*Monolepis nuttalliana*	Nuttall's povertyweed	No	No
	SACO8	*Salsola collina*	slender Russian thistle	Yes	No
	SAKA	*Salsola kali*	Russian thistle	Yes	No
	SALSO	*Salsola* spp.	Russian thistle	Yes	No
	SATR12	*Salsola tragus*	prickly Russian thistle	Yes	No
Commelinaceae	TRADE	*Tradescantia spp.*	spiderwort	No	No
	TRBR	*Tradescantia bracteata*	longbract spiderwort	No	No
	TROC	*Tradescantia occidentalis*	prairie spiderwort	No	No
Convolvulaceae	COAR4	*Convolvulus arvensis*	field bindweed	Yes	No
Cupressaceae	JUSC2	*Juniperus scopulorum*	Rocky Mountain juniper	No	No
Cyperaceae	CABR10	*Carex brevior*	shortbeak sedge	No	No
	CADU6	*Carex duriuscula*	needleleaf sedge	No	No
	CAFI	*Carex filifolia*	threadleaf sedge	No	No
	CAIN9	*Carex inops*	sun sedge	No	No
	CAPR5	*Carex praegracilis*	clustered field sedge	No	No
	CAREX	*Carex* spp.	sedge	No	No
	CASA9	*Carex saximontana*	Rocky Mountain sedge	No	No
	CYAC2	*Cyperus acuminatus*	tapertip flatsedge	No	No
	ELAC	*Eleocharis acicularis*	needle spikerush	No	No
	ELCO2	*Eleocharis compressa*	flatstem spikerush	No	No
	ELEOC	*Eleocharis* spp.	spikerush	No	No
	ELPA3	*Eleocharis palustris*	common spikerush	No	No
Euphorbiaceae	CHAMA15	*Chamaesyce* spp.	sandmat	Yes	No
	EUBR	*Euphorbia brachycera*	horned spurge	No	No
	EUGL3	*Euphorbia glyptosperma*	ribseed sandmat	No	No
	EUMA7	*Euphorbia maculata*	spotted sandmat	No	No
	EUMA8	*Euphorbia marginata*	snow on the mountain	No	No
	EUMI5	*Euphorbia missurica*	prairie sandmat	No	No
	EUPHO	*Euphorbia* spp.	spurge, sandmat	Yes	No
	EUSE4	*Euphorbia serpens*	matted sandmat	No	No
	EUSE5	*Euphorbia serpyllifolia*	thymeleaf sandmat	No	No
	EUSP	*Euphorbia spathulata*	warty spurge	No	No
	EUST4	*Euphorbia stictospora*	slimseed sandmat	No	No
Fabaceae	ACAM99	*Acmispon americanus*	American bird's-foot trefoil	No	No
	AMCA6	*Amorpha canescens*	leadplant	No	No

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	AMNA	*Amorpha nana*	dwarf false indigo	No	No
	ASAG2	*Astragalus agrestis*	purple milkvetch	No	No
	ASBA	*Astragalus barrii*	Barr's milkvetch	No	S3/G3
	ASBI2	*Astragalus bisulcatus*	twogrooved milkvetch	No	No
	ASCR2	*Astragalus crassicarpus*	groundplum milkvetch	No	No
	ASFL2	*Astragalus flexuosus*	flexile milkvetch	No	No
	ASGI5	*Astragalus gilviflorus*	plains milkvetch	No	No
	ASGR3	*Astragalus gracilis*	slender milkvetch	No	No
	ASLA27	*Astragalus laxmannii*	Laxmann's milkvetch	No	No
	ASLO4	*Astragalus lotiflorus*	lotus milkvetch	No	No
	ASMI10	*Astragalus missouriensis*	Missouri milkvetch	No	No
	ASMO7	*Astragalus mollissimus*	woolly locoweed	No	No
	ASMU99	*Astragalus multiflorus*	looseflower milkvetch	No	No
	ASPL2	*Astragalus plattensis*	Platte River milkvetch	No	No
	ASRA2	*Astragalus racemosus*	cream milkvetch	No	No
	ASTRA	*Astragalus* spp.	milkvetch	No	No
	DAAU	*Dalea aurea*	golden prairie clover	No	No
	DACA7	*Dalea candida*	white prairie clover	No	No
	DAPU5	*Dalea purpurea*	purple prairie clover	No	No
	GLLE3	*Glycyrrhiza lepidota*	American licorice	No	No
	HEAL	*Hedysarum alpinum*	alpine sweetvetch	Yes	No
	LAPO2	*Lathyrus polymorphus*	manystem pea	No	No
	LUPU	*Lupinus pusillus*	rusty lupine	No	No
	MELU	*Medicago lupulina*	black medick	Yes	No
	MEOF	*Melilotus officinalis*	yellow sweetclover	Yes	No
	MESA	*Medicago sativa*	alfalfa	Yes	No
	OXLA3	*Oxytropis lambertii*	purple locoweed	No	No
	OXSE	*Oxytropis sericea*	white locoweed	No	No
	PEAR6	*Pediomelum argophyllum*	silverleaf Indian breadroot	No	No
	PECU3	*Pediomelum cuspidatum*	largebract Indian breadroot	No	No
	PEDI9	*Pediomelum digitatum*	palmleaf Indian breadroot	No	No
	PEES	*Pediomelum esculentum*	large Indian breadroot	No	No
	PSLA3	*Psoralidium lanceolatum*	lemon scurfpea	Yes	No
	PSTE5	*Psoralidium tenuiflorum*	slimflower scurfpea	No	No
	THRH	*Thermopsis rhombifolia*	golden pea	No	No
	VIAM	*Vicia americana*	American vetch	No	No
Fumariaceae	COMI2	*Corydalis micrantha*	smallflower fumewort	No	No

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Geraniaceae	GECA5	*Geranium carolinianum*	Carolina geranium	No	No
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Geraniaceae	GERAN	*Geranium* spp.	geranium	No	No
Grossulariaceae	RIAM2	*Ribes americanum*	American black currant	No	No
	RIAU	*Ribes aureum*	golden currant	No	No
	RIBES	*Ribes* spp.	currant	No	No
	RICE	*Ribes cereum*	wax currant	No	No
	RIMI	*Ribes missouriense*	Missouri gooseberry	No	No
Hydrophyllaceae	ELNY	*Ellisia nyctelea*	Aunt Lucy	No	No
Iridaceae	SIAN3	*Sisyrinchium angustifolium*	narrowleaf blue-eyed grass	No	No
Iridaceae	SIMO2	*Sisyrinchium montanum*	strict blue-eyed grass	No	No
Juncaceae	JUBA	*Juncus balticus*	Baltic rush	No	No
	JUIN2	*Juncus interior*	inland rush	No	No
Lamiaceae	HEDR	*Hedeoma drummondii*	Drummond's false pennyroyal	No	No
	HEHI	*Hedeoma hispida*	rough false pennyroyal	No	No
	NECA2	*Nepeta cataria*	catnip	Yes	No
	SARE3	*Salvia reflexa*	lanceleaf sage	No	No
Liliaceae	ALTE	*Allium textile*	textile onion	No	No
	CAGU	*Calochortus gunnisonii*	Gunnison's mariposa lily	No	No
	CANU3	*Calochortus nuttallii*	sego lily	No	No
	LEMO4	*Leucocrinum montanum*	common starlily	No	No
	MARA7	*Maianthemum racemosum*	feathery false lily of the valley	No	No
	MAST4	*Maianthemum stellatum*	starry false lily of the valley	No	No
	LIRI	*Linum rigidum*	stiffstem flax	No	No
Malvaceae	SPCO	*Sphaeralcea coccinea*	scarlet globemallow	No	No
Melanthiaceae	TOVE2	*Toxicoscordion venenosum*	meadow deathcamas	No	No
Nyctaginaceae	MIHI	*Mirabilis hirsuta*	hairy four o'clock	No	No
	MILI3	*Mirabilis linearis*	narrowleaf four o'clock	No	No
Oleaceae	FRPE	*Fraxinus pennsylvanica*	green ash	No	No
Onagraceae	OEBI	*Oenothera biennis*	common evening primrose	No	No
	OECE2	*Oenothera cespitosa*	tufted evening primrose	No	No
	OECU99	*Oenothera curtiflora*	velvetweed	No	No
	OENOT	*Oenothera* spp.	evening-primrose	No	No
	OESU99	*Oenothera suffrutescens*	scarlet beeblossom	No	No

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Oxalidaceae	OXDI2	*Oxalis dillenii*	slender yellow woodsorrel	No	No
	OXST	*Oxalis stricta*	common yellow woodsorrel	No	No
Plantaginaceae	PLEL	*Plantago elongata*	prairie plantain	No	No
	PLMA2	*Plantago major*	common plantain	Yes	No
	PLPA2	*Plantago patagonica*	woolly plantain	No	No
Poaceae	ACHY	*Achnatherum hymenoides*	Indian ricegrass	No	No
	AGCR	*Agropyron cristatum*	crested wheatgrass	Yes	No
	AGST2	*Agrostis stolonifera*	creeping bentgrass	No	No
	ALPR3	*Alopecurus pratensis*	meadow foxtail	Yes	No
	ANGE	*Andropogon gerardii*	big bluestem	No	No
	ARIST	*Aristida* spp.	threeawn	No	No
	ARPU9	*Aristida purpurea*	purple threeawn	No	No
	BOCU	*Bouteloua curtipendula*	sideoats grama	No	No
	BODA2	*Bouteloua dactyloides*	buffalograss	No	No
	BOGR2	*Bouteloua gracilis*	blue grama	No	No
	BOHI2	*Bouteloua hirsuta*	hairy grama	No	No
	BRCI2	*Bromus ciliatus*	fringed brome	No	No
	BRIN2	*Bromus inermis*	smooth brome	Yes	No
	BRJA	*Bromus japonicus*	Japanese brome	Yes	No
	BROMU	*Bromus* spp.	brome	Yes	No
	BRSQ2	*Bromus squarrosus*	corn brome	Yes	No
	BRTE	*Bromus tectorum*	cheatgrass	Yes	No
	BUDA	*Buchloe dactyloides*	buffalograss	No	No
	CALO	*Calamovilfa longifolia*	prairie sandreed	No	No
	DASP2	*Danthonia spicata*	poverty oatgrass	No	No
	DIOL	*Dichanthelium oligosanthes*	Heller's rosette grass	No	No
	DISP	*Distichlis spicata*	saltgrass	No	No
	ELCA11	*Elymus caninus*	bearded wheatgrass	No	No
	ELCA4	*Elymus canadensis*	Canada wildrye	No	No
	ELEL5	*Elymus elymoides*	squirreltail	No	No
	ELLA3	*Elymus lanceolatus*	thickspike wheatgrass	No	No
	ELRE4	*Elymus repens*	quackgrass	Yes	No
	ELTR7	*Elymus trachycaulus*	slender wheatgrass	No	No
	ELVI3	*Elymus virginicus*	Virginia wildrye	No	No
	ELYMU	*Elymus* spp.	wildrye	Yes	No
	FEOC	*Festuca occidentalis*	western fescue	No	No
	FEOV	*Festuca ovina*	sheep fescue	No	No
	HECO26	*Hesperostipa comata*	needle and thread	No	No

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	HOJU	*Hordeum jubatum*	foxtail barley	No	No
	HOPU	*Hordeum pusillum*	little barley	No	No
	KOMA	*Koeleria macrantha*	prairie Junegrass	No	No
	MUCU3	*Muhlenbergia cuspidata*	plains muhly	No	No
	MUPA99	*Muhlenbergia paniculata*	tumblegrass	No	No
	MURA	*Muhlenbergia racemosa*	marsh muhly	No	No
	NAVI4	*Nassella viridula*	green needlegrass	No	No
	PACA6	*Panicum capillare*	witchgrass	No	No
	PANIC	*Panicum* spp.	panicgrass	No	No
	PASM	*Pascopyrum smithii*	western wheatgrass	No	No
	PAVI2	*Panicum virgatum*	switchgrass	No	No
	PHPR3	*Phleum pratense*	timothy	Yes	No
	POA	*Poa* spp.	bluegrass	Yes	No
	POAL2	*Poa alpina*	alpine bluegrass	No	No
	POCO	*Poa compressa*	Canada bluegrass	Yes	No
	POPA2	*Poa palustris*	fowl bluegrass	No	No
	POPR	*Poa pratensis*	Kentucky bluegrass	Yes	No
	POSE	*Poa secunda*	Sandberg bluegrass	No	No
	PSJU3	*Psathyrostachys juncea*	Russian wildrye	Yes	No
	PSSP6	*Pseudoroegneria spicata*	bluebunch wheatgrass	No	No
	SCSC	*Schizachyrium scoparium*	little bluestem	No	No
	SPAS	*Sporobolus asper*	composite dropseed	Yes	No
	SEVI4	*Setaria viridis*	green foxtail	Yes	No
	SPAI	*Sporobolus airoides*	alkali sacaton	No	No
	SPCO16	*Sporobolus compositus*	composite dropseed	No	No
	SPCR	*Sporobolus cryptandrus*	sand dropseed	No	No
	SPHE	*Sporobolus heterolepis*	prairie dropseed	No	No
	SPORO	*Sporobolus* spp.	dropseed	No	No
	SPPE	*Spartina pectinata*	prairie cordgrass	No	No
	VUOC	*Vulpia octoflora*	sixweeks fescue	No	No
Polemoniaceae	COLI2	*Collomia linearis*	tiny trumpet	No	No
	IPCO5	*Ipomopsis congesta*	ballhead ipomopsis	No	No
	MIGR	*Microsteris gracilis*	slender phlox	No	No
	PHGR16	*Phlox gracilis*	slender phlox	No	No
	PHAN4	*Phlox andicola*	prairie phlox	No	No
	PHHO	*Phlox hoodii*	spiny phlox	No	No
	PHLOX	*Phlox* spp.	phlox	No	No
Polygalaceae	POAL4	*Polygala alba*	white milkwort	No	No
	POVE	*Polygala verticillata*	whorled milkwort	No	No

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Polygonaceae	ERFL4	*Eriogonum flavum*	alpine golden buckwheat	No	No
	ERPA9	*Eriogonum pauciflorum*	fewflower buckwheat	No	No
	FACO	*Fallopia convolvulus*	black bindweed	Yes	No
	POAV	*Polygonum aviculare*	prostrate knotweed	Yes	No
	PORA3	*Polygonum ramosissimum*	bushy knotweed	Yes	No
	RUAL4	*Rumex altissimus*	pale dock	No	No
	RUCR	*Rumex crispus*	curly dock	Yes	No
	RUMEX	*Rumex* spp.	dock	Yes	No
	RUST4	*Rumex stenophyllus*	narrowleaf dock	Yes	No
Primulaceae	ANOC2	*Androsace occidentalis*	western rockjasmine	No	No
Ranunculaceae	ANCA9	*Anemone caroliniana*	Carolina anemone	No	No
	ANCY	*Anemone cylindrica*	candle anemone	No	No
	ANEMO	*Anemone* spp.	anemone	Yes	No
	ANPA	*Anemone parviflora*	smallflowered anemone	No	No
	DECA3	*Delphinium carolinianum*	Carolina larkspur	No	No
	MYMI2	*Myosurus minimus*	tiny mousetail	No	No
	RAMA2	*Ranunculus macounii*	Macoun's buttercup	No	No
	RANUN	*Ranunculus* spp.	buttercup	Yes	No
Rosaceae	POPE8	*Potentilla pensylvanica*	Pennsylvania cinquefoil	No	No
	POTEN	*Potentilla* spp.	cinquefoil	No	No
	PRAM	*Prunus americana*	American plum	No	No
	PRPU3	*Prunus pumila*	sandcherry	No	No
	PRVI	*Prunus virginiana*	chokecherry	No	No
	ROAR3	*Rosa arkansana*	prairie rose	No	No
	ROBL	*Rosa blanda*	smooth rose	No	No
	ROWO	*Rosa woodsii*	Woods' rose	No	No
Family	Code	Scientific Name	Common Name	Exotic	Rare
Rubiaceae	GAAP2	*Galium aparine*	stickywilly	No	No
	GABO2	*Galium boreale*	northern bedstraw	No	No
	GALIU	*Galium* spp.	bedstraw	No	No
Salicaceae	SAEX	*Salix exigua*	narrowleaf willow	No	No
Santalaceae	COUM	*Comandra umbellata*	bastard toadflax	No	No
Scrophulariaceae	COPA3	*Collinsia parviflora*	maiden blue eyed Mary	No	No
	ORLU2	*Orthocarpus luteus*	yellow owl's-clover	No	No
	PEAL2	*Penstemon albidus*	white penstemon	No	No
	PEER	*Penstemon eriantherus*	fuzzytongue penstemon	No	No
	PEGL3	*Penstemon glaber*	sawsepal penstemon	No	No
	PEGR5	*Penstemon gracilis*	lilac penstemon	No	No
	PENST	*Penstemon* spp.	beardtongue	No	No

Family	**Code**	**Scientific Name**	**Common Name**	**Exotic**	**Rare**
	SYWY99	*Synthyris wyomingensis*	Wyoming kittentails	No	No
	VEAR	*Veronica arvensis*	corn speedwell	Yes	No
	VEPE2	*Veronica peregrina*	neckweed	No	No
	VETH	*Verbascum thapsus*	common mullein	Yes	No
Smilacaceae	SMILA2	*Smilax* spp.	greenbrier	No	No
Solanaceae	PHHE5	*Physalis heterophylla*	clammy groundcherry	No	No
	PHLO4	*Physalis longifolia*	longleaf groundcherry	No	No
	PHVI5	*Physalis virginiana*	Virginia groundcherry	No	No
	SORO	*Solanum rostratum*	buffalobur nightshade	No	No
	SOTR	*Solanum triflorum*	cutleaf nightshade	No	No
Ulmaceae	CEOC	*Celtis occidentalis*	common hackberry	No	No
	ULAM	*Ulmus americana*	American elm	No	No
Urticaceae	PAPE5	*Parietaria pensylvanica*	Pennsylvania pellitory	No	No
Verbenaceae	VEBR	*Verbena bracteata*	bigbract verbena	No	No
	VEST	*Verbena stricta*	hoary verbena	No	No
Violaceae	VINU2	*Viola nuttallii*	Nuttall's violet,	No	No
	VIOLA	*Viola* spp.	violet	Yes	No
Vitaceae	PAVI5	*Parthenocissus vitacea*	woodbine	No	No
	VIRI	*Vitis riparia*	riverbank grape	No	No

Appendix D. Maps of Relative Exotic Species Cover at Badlands National Park.

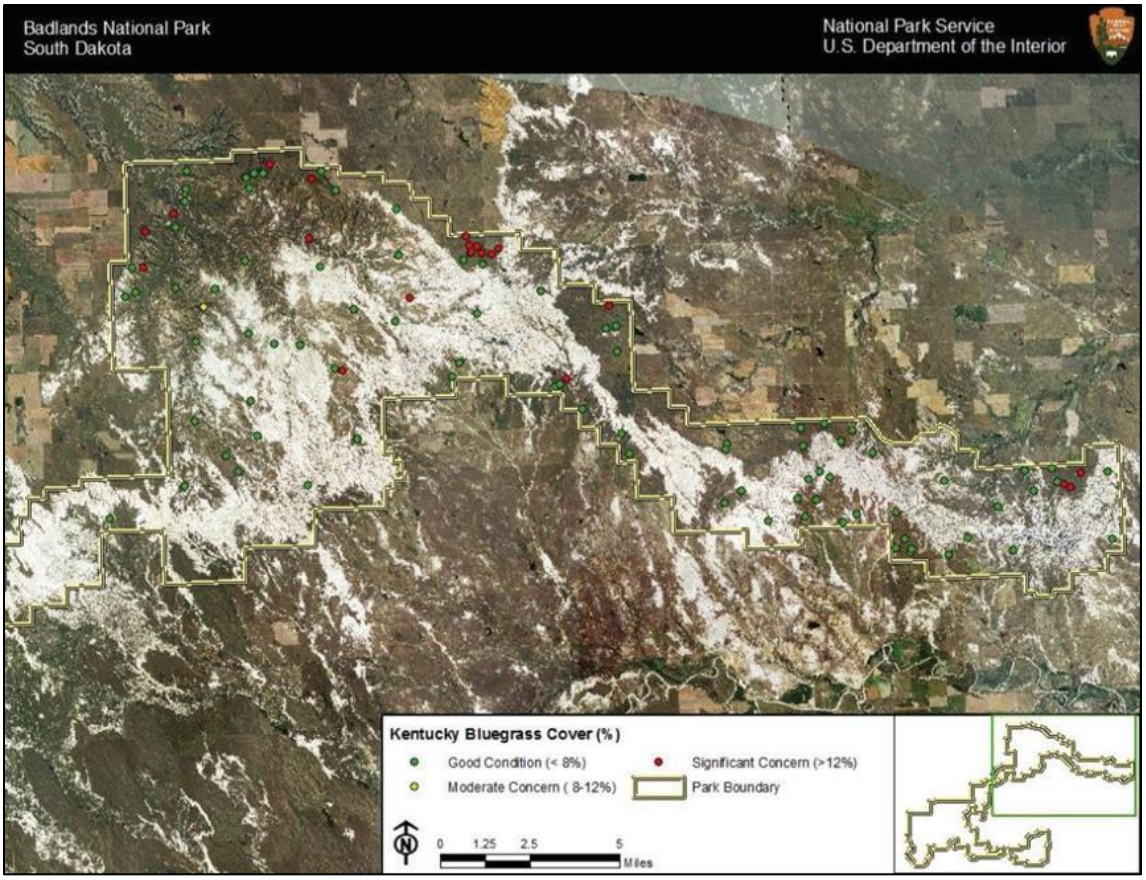

Figure D.1. Kentucky Bluegrass relative cover in BADL.

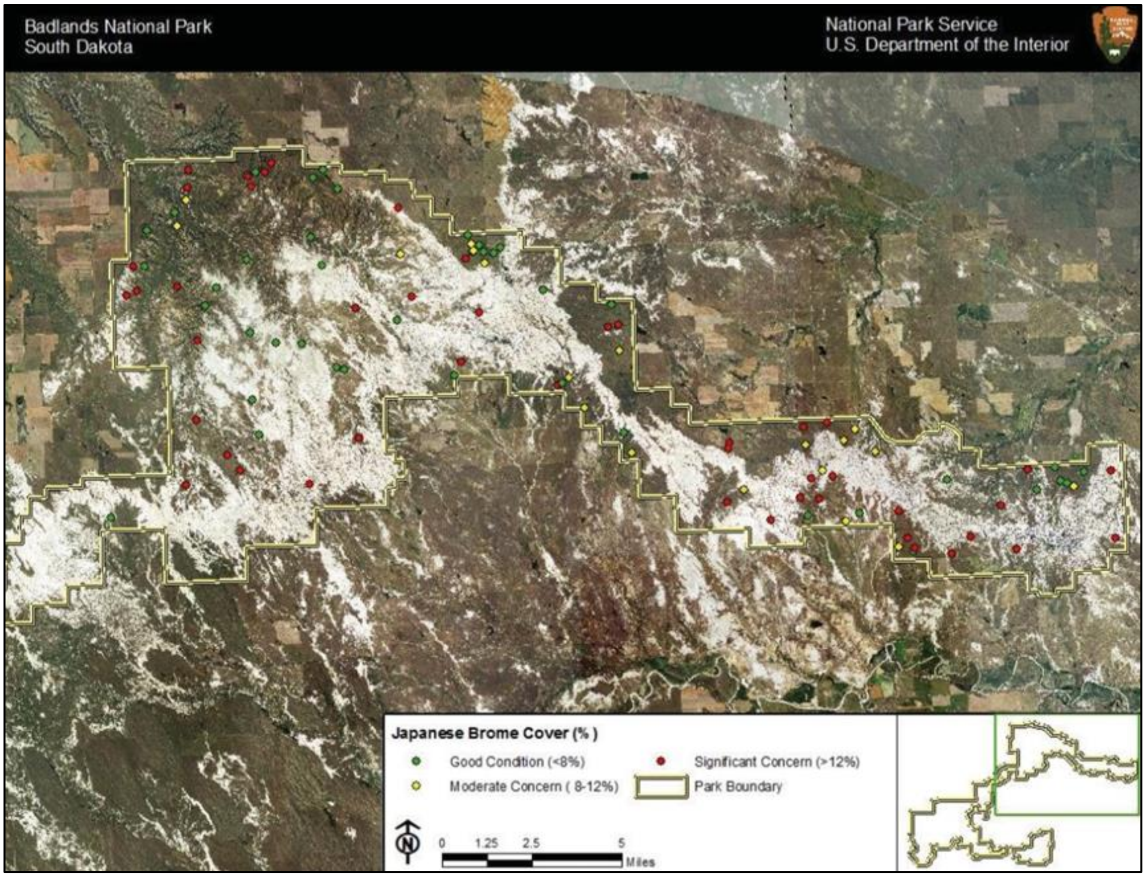

Figure D.2. Japanese Brome relative cover in BADL.

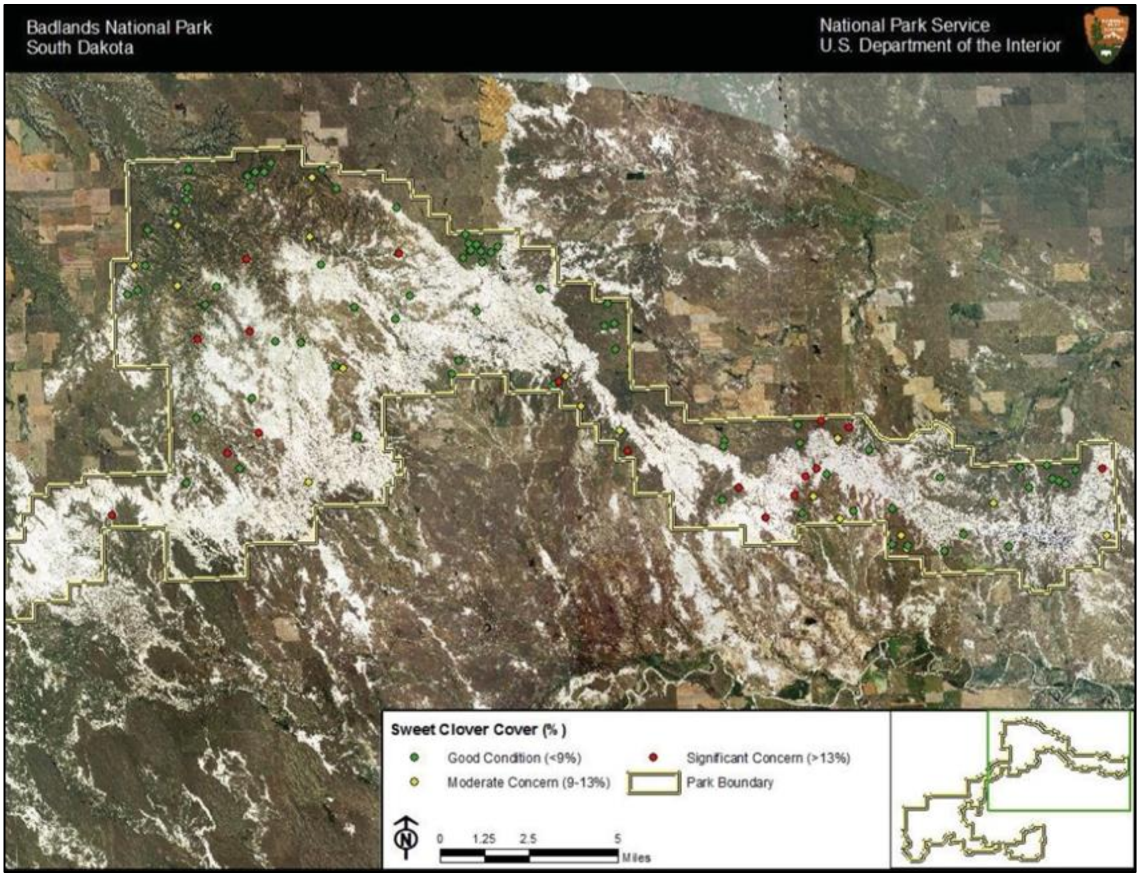

Figure D.3. Sweet clover relative cover in BADL.

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National Park Service
U.S. Department of the Interior

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